Expanding Industrial Thinking by formalizing the Industrial Engineering identity for the knowledge era

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Doctor of Philosophy… Healing through thinking… It's a strange concept I must admit, but one most worthy of attainment. Here is to those who helped me attain and be changed by this great honor. Although this section may only ever be read by the people being acknowledged, they are truly the ones who made this study possible and not giving them the proper respect and gratefulness they deserve would detract from the quality of this study. The story of how I decided to complete my PhD dates back to 2007 at a Cornell University graduation ceremony. I was in the stadium seating waiting for a family friend to receive his degree. I recall making several jokes about how graduates looked like ants from the place we were sitting; my father jokingly responded with: "if so then it's better I become a red ant" (hinting at achieving my PhD). Up until that point in my life, I had never considered a career as an academic. However, learning that the nature of the ideals of academia lie in uncovering knowledge for nothing other than benefiting humanity and refining their understanding changed my worldview forever.

The years passed, and I finished my first degree in Industrial Engineering. My mother and father were truly the ones who deserve all the gratitude for their support while I set the first step in the world of academia. Instead of going straight into the work world, my family supported my ambition to take a second step in the field of academia by completing two master's degrees. My supportive and wonderful father had also decided to complete a master's degree. My mother, being the kind heart of the home, provided us with the best a mother could give: tasty food, care and the beautiful emotions. My sister deserves special thanks for her continuous help in proofreading my work and debating it with me. Unsurprisingly, her understanding of the world and command of communication is leading her to a similar path of continuing in academia. My brothers, one being in a different field and one being too young to understand the complexities of research, provided me with the necessary breaks from my work that allowed me to reflect on its practicality and for that I am thankful. During the second year of my masters I also met my wife who, with her time and pure heart, gave me the emotional support necessary to complete my studies at the time. The support from all mentioned above only grew when I decided to continue with my PhD. Documenting every instance is simply not possible when you are surrounded by such supportive people. Thus, in addition to my gratitude I can offer my confidence that every good thing that comes out of my work and every truth uncovered as part of the research is in part due to them and shared with them.

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Acronyms

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ADR-in-EE – Action Design Research in Enterprise Engineering.....26
SSM – Soft System Methodology.....28
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ECSA – Engineering Council of South Africa 50
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Abstract

This PhD study provides a multi-perspective view of Industrial Thinking and the Industrial Engineering profession. The aim is to formalize the Industrial Engineering identity and expand its associated thinking style to deal with the challenges of the knowledge era. To date, however, the identity of the industrial engineer remains vague. Due to the broad knowledge base and application areas made available to industrial engineers, pinning down the commonality has proven difficult. This problem is further magnified by global forces shaping the knowledge era. Various works touch on some elements that can help in forming an identity, but they have not been combined into a common identity. Doing so is a critical development for the sake of communal advancement in the Industrial Engineering field. Defining this identity can significantly improve awareness within society about the field itself. This PhD argues that a modern understanding of the role of the industrial engineer can be established by formalizing the identity as a profession that is connected to all fields of knowledge and is a master of some.

Industrial Thinking, on the other hand, is poorly defined in literature. Often, it is merely used as a term to describe the shift in the cognitive thinking style of pre-industrial to industrial society. This description may have been sufficient for many. However, for the Industrial Engineering profession, this thinking style forms the root of its core value proposition and is the generator of the field's asymmetrical knowledge. This thinking style is naturally available in others but is leveraged most by the industrial engineer. However, given that industrial engineering is interdisciplinary in nature, it has always been difficult to explain this cognitive style with a single methodology, approach or process. This study tackles the specific problem of expanding this thinking style by defining and giving a fuller account of Industrial Thinking as well as discussing areas of concern that need to be addressed. Ultimately, the results are presented in an Industrial Thinking Systemigram which helps guide and expand the thinking process in a methodological way to meet the challenges of the knowledge era.

To achieve this modern outlook, a system context is drawn to identify key areas of concern (themes) surrounding the field of Industrial Engineering and its associated thinking style. As part of the methodology the overarching goal is separated from sub objectives (using suitable action research and soft system methodology). The sub objectives are explored in 5 individual articles addressing each area of concern/theme. They form the systemic stream of the document. These articles address the relationship of Industrial Engineering with issues on the individual, professional, economic, societal and environmental levels. The cultural stream is addressed in the overarching objective by defining industrial thinking and expanding it for the knowledge era. The findings are verified using semi-structured interviews with experts.

Keywords: Engineering Development; Engineering Management; Industrial Engineering; Industrial Thinking; Professional Identity; Systemigram; Systems Thinking,

Preface

I would like to convey my sincere thanks for choosing to read this study. There is a certain approach in conducting this study that I trust you will find to be both interesting and innovative. Although there are some empirical elements, the study is overwhelmingly a qualitative one that follows the principles of action research. At the start of the journey, I had the option of choosing between a PhD in Industrial Engineering (IE) and a PhD in Development and Management Engineering. With all my respect to the field of Industrial Engineering, I ended up choosing the Development and Management option because I believe that what I am doing with this PhD could be replicated for other engineering and non-engineering fields. In short, what I had hoped to show is how, even with a field as resilient and responsive as IE, taking a step back can help reveal internal flaws which need to be managed by IE professionals, and external areas where IE can be developed. This, naturally, is a continuous journey but this study has made significant contributions to the lifelong drive. The ultimate deliverable is ***expanding industrial thinking,*** which means giving a fuller account of by defining industrial thinking and making a more extensive by developing an Industrial Thinking Systemigram based on the formalized industrial engineering identity tackling the many forces of the knowledge era.

This PhD was completed using the PhD by article publication method. With that being said, a substantial literature review, visualized framework, methodology, and areas of concern (FMA) are unique to this PhD thesis and generate a golden thread that connects the outputs and insights [Chapters 1-5]. Five articles discussing various aspects connected to the overarching purpose of expanding industrial thinking make up an important part of this PhD [Chapters 6-10]. Each article is a standalone chapter, but links to the overall PhD. To help clarify this link, key findings were summarized in the page preceding the manuscript. The article's manuscripts, however, serve as additional reading describing an action taken by the researcher to address a real-world area of concern (different page colors were used for these sub-sections). Separate references and numbering are also kept for each article for the sake of neatness. This makes Chapter 11 a potential continuation point [after reading Chapters 1-5], since it recaps the important insights of the entire study. Furthermore, the combined findings are synergized into the Industrial Thinking Systemigram, which is internally verified against requirements and externally validated using semi-structured interviews. A summary is then provided, discussing the conclusions of this study and the way forward [Chapter 12].

This PhD document underwent 3 major iterations of 10 revisions each to reach this final state. Each revision restructured certain elements and sections of the PhD to ensure logical flow and build-up of thoughts. Utmost care was given to best explain the researcher's cognitive process. With that being said, the selected approach may leave certain questions which I can guarantee are answered as the chapters progress. Yet, in order to highlight the golden thread, visualized

depictions of the system context, framework, methodology and areas of concern are provided in their respective chapters (also available in Appendix A for ease of navigation). The articles are the sole work of the researcher. Shared authorship was made with the esteemed supervisor and promoter of this study, Prof van Dyk, for selected articles. Below is a breakdown of the published works:

Article 1 [Chapter 6]: Journal Article - The Industrial Engineering Identity from Historic Skills to Modern Values, Duties, and Roles

Published in the special edition of the South African Journal of Industrial Engineering (SAJIE), which is a double-blind peer reviewed journal. The journal is open access and published under a Creative Commons Attribution License. The article is available on SCOPUS. The author retains copyright but grants the journal right of the first publication. This article is co-authored with Prof van Dyk (the promoter).

Article 2 [Chapter 7]: Conference Paper - Gamifying the Industrial Engineering Profession

Published in the proceedings of the 7th annual conference for Industrial Engineering and Operations Management (IEOM) after a double-blind peer review. The paper was submitted as part of the special track for Global Engineering Education and won best paper. The article is available on IEOM repository. The publications are open access. The author retains copyright. This article is solely authored by Mr Hasan Darwish (the researcher).

Article 3 [Chapter 8]: Conference Paper – Impact of Major Environmental, Social and Economic Forces on the Field of Industrial Engineering

Published in the proceedings of the 27th annual conference for the South African Institute for Industrial Engineers (SAIIE) after a double-blind peer review. The paper won best poster presentation at the conference. The proceeds follow the same process as the SAJIE journal. The article is available on NWU repository. The publications are open access. The author retains copyright. This article is solely authored by Mr Hasan Darwish (the researcher).

Article 4 [Chapter 9]: Journal Article – Bottom of Pyramid 4.0: Modularising and Assimilating Industrial Revolution Cognition into a 4-Tiered Social Entrepreneurship Upliftment Model for Previously Disconnected Communities

This article was accepted by the Journal of Industrial Integration and Management: Innovation and Entrepreneurship (JIIM) on the 27th of April 2018 and will be published online in the following weeks.

Article 5 [Chapter 10]: Journal Article – Analysing the Environmental and Social Awareness of Industrial Engineering Using Corpus Analysis of the Industrial Engineering Handbook

This article was submitted to the European Journal of Industrial Engineering (EJIE) on the 28th of January 2018 and will undergo a double-blind peer review. Author received feedback to review publication and resubmit in April 2018.

1. Research Overview

1.1. Introduction to Context

> *The professional, by definition, has knowledge that others do not have—asymmetrical knowledge. How knowledge is attained, maintained, passed down and certified is an important part of professionalism. How it is put into practice is even more important—in other words, how professionals use their knowledge has a great deal to do with real professionalism and its proliferation (Beaton, 2010:9).*

It may come as a surprise to some that many of the professions we have come to know today have not always existed throughout history. Historically, "the classic 'learned' professions were divinity, law and medicine—the trinity of the professions" (Beaton, 2010:3). Fields like engineering, pharmacology and others in their current forms are only a few decades old. pharmacology, for example, both as a term and a profession, was only formally defined in the early 1900's (Scheindlin, 2017). Interestingly, the practical chemical knowledge and skills of the modern pharmacologists have existed before the coining of the term. For example, for a large part of the 16th-19th century, the job of a medicinal chemist in Syria was merged with that of a male hairdresser, and these individuals were called attars (عطار). In much of Europe, pharmacology was handled by perfume makers or chemists. Over time, however, the field developed an identity of its own. Scheindlin (2017) explains "the medicinal chemist may create the candidate compound, but the pharmacologist is the one who tests it for physiologic activity [because] there is a distinction between what a drug does and how it acts… Pharmacology asks How?". This may, at face value, seem like a minute difference, but the evolution of knowledge surrounding the field uncovered the need for a specialist knowledge area. Adding to this was society's genuine need for the intermediary professional between the medicinal chemist and society who can better explain the impact of the wealth of chemicals on their health and lives (Scheindlin, 2017).

Whilst engineering as an occupation has generally been acknowledged historically (with some dating the term back to the 11th century), it seems to have faced a similar situation as pharmacology when considering the modern understanding of the Engineering profession and its sub-disciplines. The term engineering is often attributed to the Latin *ingeniator* which meant someone "in possession of *ingenium* [ingenious behavior]" (Auyang, 2009:14). There is no doubt that ingenuity in using scientific findings for human benefit has existed long before the 11th century. This is proven by hundreds of ingenious devices and structures appearing worldwide concerned primarily with solving everyday problems in agriculture, housing and animal husbandry (Garrison, 1998:4-14). Yet, history shows how various empires and cultures in various geographical locations developed their own understanding of the role of engineering

in society (Garrison, 1998:4-14; Hill, 2013:4-6). These cultures may not have directly demarcated these individuals as 'engineers', but definitely appreciated the tinkering and sheer resourcefulness of these individuals that led to their ingenuous conceptions (often through trial and error).

The appearance of the phenomenon of engineering as an occupation (sustained by growth in available scientific knowledge) that compelled engineering activity's formalization as a profession, is worth special consideration and thought (Auyang, 2009:9-18). This is mainly because an investigative view of a profession's development (alongside its knowledge area) uncovers the reasons that led to development of the many branches of engineering (overarching fields such as chemical, civil, mechanical, interdisciplinary and electrical), their subdisciplines (expert areas such as acoustic, agricultural, nuclear, micro-electronic, bio-medical) and the further classification based on the degree of practical or technical behavior expected in the day to day occupation (ranging from technician [very practical] to engineer [mix] to scientist/specialist [very scientific]) (ECSA, 2017c; WIE, 2017).

The intricacy is uncovered when one grasps the importance of each of these subtle yet vital differentiations. In many ways, these differentiations represent the evolution of economic opportunity prompted by a continuous strive to evolve and adapt to macro forces (environmental, social and economic) (Beaton, 2010:7). Each subdivision is often a sign of the formation of a new identity with its own professional bodies, degrees, councils, asymmetrical knowledge, and place in society. This is because "knowledge, by its nature, progresses, and progress is enabled by the circuitry of the profession's interface with society. This means that society has the power to act upon the profession, even as the profession acts upon society. As a profession encounters society while applying its services, it is inevitably changed by the experience, and new knowledge is gained" (Beaton, 2010:13).

Some identities find their roots in the network stretching back thousands of years while others appeared on the network of possibility only recently (often instigated by a remarkable pioneer or disruptive technology). Yet, one thing remains constant: as social beings, humanity's survival depends on an exchange of services (even though this is often unseen and underappreciated). Moreover, the advancement of the species depends on individuals and entities taking an authentic and dedicated lifelong search and mastery of a specialized area in the web of knowledge. In this lies a very important part of human development, namely the development of one's identity without which one would be undervalued by both themselves and society.

1.2. Background on Problem

The widespread appreciation for the value created through engineering activity has been on the rise since the early 1800's. Fields like mechanical, electrical, chemical and civil engineering became well-known and preferred disciplines of study within engineering. This is largely attributed to most customer-facing products having distinguishing features designed or attributed to the fields of knowledge mentioned above. Yet, unseen by the customer is the work of various subdisciplines and knowledge areas that were vital to the product development. Additionally, the immense amount of engineering design and integration that goes into services and system design often goes unnoticed. This dilemma is multi-faceted, but perhaps one of the most important aspects of it can be defined as the relationship that a profession processes with society. Ideally this relationship should allow society to develop an understanding and appreciate its unique value proposition. As Beaton (2010:13,15) explains "the professions do well to generate trust, because society's perception of them bears significantly upon the degree of success that they enjoy… [Because] professions enter into economic, social, political and licensing contracts with society; and, in turn, society influences the development of the professions. Society and the professions exist in dynamic, creative tension… [and] a profession that does not allow itself to be changed by its interface with society is a profession doomed to decline".

Arguably, this puts the ball in the field of the profession. Although society bears a responsibility towards professions, the complex dynamics shaping modern society are too complex to underpin. However, even if the dynamics are properly addressed, rapid changes in society due to macro forces of the knowledge era can result in research studies quickly becoming descriptive of the past rather than resilient in the face of the future. A more promising approach is to start with the profession itself and assist in better modernizing its interface with society, explaining its role in the technologies that improve the quality of life, formalizing its professional identity, better defining its specialty knowledge areas and ultimately marketing the profession to potential entrants and society.

The focus of this study will be the profession of industrial engineering (IE) and its associated thinking style. Although the profession is well-established in many industrialized countries, the profession remains underrepresented in many countries and under-recognized by society and secondary school students as a potential field of study. This holds true for South Africa, where despite the establishment of the field or profession, most IE graduates are employed by international companies with operations in that specific country or state-owned companies as opposed to local companies, the public sector or small, medium, and micro enterprises (SMMEs) (Lister & Donaldson, 2011:48). In fairness, this imbalance is reasonable at times because some of the types of problems solved by industrial engineers only appear at factory,

company or industry level. Yet, this remains a problem because globalization is forcing small and big companies, public and private organizations to compete alike for the development, offering and sustaining of value propositions. Thankfully, the development of technology and the flexible nature of the profession has allowed for countless examples in the past decade where IE knowledge has contributed direct value to the public sector and SMMEs. These successes can be attributed to society and policy-makers becoming more receptive to industrial and systems thinking. Yet, various gaps exist that can accelerate this inclusion which would benefit both society and the development of IE.

1.3. Examination of the Core Problem

Virtually every human being is bound to take part in economic activity. In the Medieval era, the available economic activity options were named trades or crafts (Beaton, 2010:3). This evolved over time to the modern-day professions. This development, although small, carries subtle behavioral changes and a distinguishable difference in attitude towards one's role in the economy. Notably, professions are becoming more centered on the character, thinking style, attributed skills, and aptitudes necessary to produce quality members of a profession. Recent developments also highlight the role of codes of conduct and ethics in determining the suitability of an individual to be allowed into a professional body. This emerges from an expectation by society and fellow peers of that profession to protect the reputation and identity they collectively develop and ultimately own (Beaton, 2010).

As described in Maynard and Zandin (2001:21) "Industrial engineers many times encounter people who do not understand or are unfamiliar with the term 'industrial engineer'. One of the most commonly asked question of an industrial engineer in the workplace or outside may be, "What do industrial Engineers really do?'". Answering this question allows for the "immediate recognition of the profession by the layperson" (Maynard & Zandin, 2001:96). Pieces of information surrounding the progression, thinking style and application areas of the IE profession and its associated knowledge areas exist in literature and on the web. However, the value-laden and disconnected nature of these resources and the lack of a common professional identity that can be conveyed in a concise and meaningful manner remains the one of the biggest causes of confusion regarding the field. More importantly, to keep up with the expectations and concerns of society (personal, social, environmental and other), a modern-day profession needs to understand how its members interact with society. This makes it vital to develop a receptive interface (with individuals and entities that make up society) that acknowledges the unique nature and value of the asymmetrical knowledge and thinking style possessed and applied by the profession. Another major challenge is recruitment from society, which needs to strike a balance between protecting the quality of the profession whilst ensuring its sustainability.

2. System Context

This thesis requires a concurrent effort to use well-researched system principles that unravel the complexity of the systems surrounding the problem whilst using sound research methods to deliver meaningful and valid conclusions. This chapter includes the relevant literature used in developing an appropriate system context of both the real world and the research problem.

The main challenge when developing a multi-perspective view is developing a process that can depict the complexity whilst being easy to communicate. After all "many phenomena relating to life are 'complex' in nature – i.e., that they are interwoven, self-organizing, emergent and processual" (Bastardas-Boada, 2015:3). When the area of concern is interdisciplinary by nature (since it might even be reflective of a more complex or wicked problem), the concerned system requires its own analysis before any research is done. Thus, the non-linear nature of the study requires a continuous 'sum-up' of the work done to perpetuate a golden thread running through the research (using system principles) whilst using traditional procedural research methodologies in order to address a certain area of concern (Checkland & Holwell, 1998). The reason for a separate chapter on this topic is the multifaceted nature of the study, which can result in some of the linking features becoming blurred.

2.1. Systems

The emergence of system analysis, modelling, and synthesis as a discipline with various tools, allows a researcher to simplify a given problem into entities, boundaries and relationships (SEBoK, 2017). In essence, a system model "represents aspects of a system and its environment" and has many different types of models built for a variety of purposes. There are many different types of models, as there is a variety of purposes for which they are built… "[Some] enable the understanding of system behavior, while others enable the understanding of system structure" (SEBoK, 2017). The overarching system analysis approach that best caters for the given research problem (being complex in nature with pluralistic methods or considerations), is interpretative systems. However, to provide a background a brief review of systems thinking, its principles, and the elements of system modelling is provided.

2.1.1. Principles of a System (Analysis)

Several types of systems exist, each with its own unique set of properties and objectives. Tezu (2017:1), as with many others, define a system as "an orderly grouping of interdependent components linked together according to a plan to achieve a specific objective". Such accepted definitions of a system include reference to several principles that are shared across all systems (which facilitate using system analysis tools to understand virtually any system). Various authors make mention of these fundamental principles, albeit differently, but they are typically centered around 4 fundamental principles: synergy, continuity, cause and structure.

Synergy [Also referred to as 1+1=3, Synthesis, Emergent Properties, Integration] (Du Plessis, 2014; Sparrius, 2014; Wujec, 2015; Tezu, 2017): The synergy principle states that properties and features of the whole are not merely the sum of its parts. Although there are minute differences between each of the definitions, the above terms highlight the same fundamental feature which is "the performance of a system is not equal to the sum of the performance of its elements. This inequality is created by synergy which is caused by interaction" (Sparrius, 2014:19).That is typically why they are referred to as emergent. They emerge from the interaction and synergy between parts and are typically non-linear.

Cause [Also referred to as Central Objective, Purpose, Aim, Goal]: (Du Plessis, 2014; Sparrius, 2014; Wujec, 2015; Tezu, 2017): Cause refers to the reason for the system's existence. The term "goal" might be sufficient to describe man-made systems with specific objectives. However, causes become more complex along with more complex systems such as society. More complex systems have multiple goals which often synergize into overarching causes. Additionally, the complexity is furthered when the cause of one system may cause other systems to behave or interact in certain ways.

Continuity [Also referred to as Loops, Iterations, Feedback] (Du Plessis, 2014; Sparrius, 2014; Wujec, 2015): The continuity principle states that systems exist throughout a timeline with the initial conditions the system was created (or commissioned) with, alongside the built-in methods (loops, iterations and feedback) it interacts with in its environments and the progression of time affecting its state at any given point in that timeline. Typically, this continuity is associated with an end of life in mind and the system may experience problems during its lifecycle. Typically, "problems experienced downstream are symptoms of neglect upstream. Upstream problems can only be solved upstream" and "the ability to influence a system's characteristics diminishes very rapidly as the system proceeds from one stage of its life cycle to the next" (Sparrius, 2014:1). Feedback loops provide positive and/or negative inputs that can be further analyzed by the system to determine its path. A system's iterations are similarly a collection of positive or negative inputs that lead to the redesign or creation of a new system for the next iteration (usually based on the original design) (Sparrius, 2014; Tezu, 2017).

Structure [Also referred to as Network, Hierarchy, Levels, System of Systems, Components & Systems] (Du Plessis, 2014; Sparrius, 2014; Wujec, 2015): The structure principle states that every system is a component of a larger system and is made up of smaller systems in its own right. Thus, the structure principle highlights interdependence and organization (Tezu, 2017). Sparrius (2014:19) specifies that "systems exist in a multi-layer hierarchy, each more complex than the one below. Each layer in this hierarchy, say layer [N], is a system. Entities from the next-lower layer (layer [N + 1]) are its constituent elements. Entities from the next-higher layer (layer [N-1]) form its environment".

2.1.2. Elements of a System (Modelling)

Although the principles of a system assist in the conceptualization and understanding of the bigger picture; it is with system modelling that one can truly delve into the details that outline the functioning of that given system. Various system modelling techniques exist, but similarly to the principles of a system, certain elements can be considered as 'standard' in any system. Tezu (2017:1) summarizes the elements of a system based on their behavior as:

Outputs and inputs: "A major objective of a system is to produce an output that has value to its user. To get a good output, inputs to system must be appropriate. It is important to point out here that determining the output is a first step in specifying the nature, amount and regularity of the input needed to operate a system" (Tezu, 2017:1).

Processors: "It is the element of a system that involves the actual transformation of input into output. It is the operational component of a system. Processors may modify the input totally or partially, depending on the specifications of the output. In some cases, input is also modified to enable the processor to handle the transformation" (Tezu, 2017:1).

Control: "The control elements guide the system. It is the decision-making subsystem that controls the pattern of activities governing input, processing, and output" (Tezu, 2017:1).

Feedback: "Feedback measures output against a standard in some form… that includes communication and control. Feedback may be positive or negative, routine or informational. Positive feedback reinforces the performance of the system. Negative feedback generally provides the controller with information for action" (Tezu, 2017:1).

Environment: "The environment is the 'supra-system' within which an organization operates. It is the source of external elements that impinge on the system. In fact, it often determines how a system must function" (Tezu, 2017:1).

Boundaries and interfaces: "A system should be defined by its boundaries – the limits that identify its components, processes, and interrelationships when it interfaces with another system" (Tezu, 2017:1).

System Considerations: Time, Accuracy, Type, Nature and State.

2.1.2.1. Concept Mapping

Many system modelling techniques exist in literature. Some are more suited for technical systems whilst others are suited for abstract systems. After reviewing the techniques, it was determined that since the specific problem of this PhD is non-technical, traditional technical system modelling techniques (such as functional flow block diagrams [FFBD] and business process modelling notation [BPMN]) are not appropriate. Additionally, since the focus is not on 'requirements' and 'functionality' ('requirements' and 'functionality' are typically important aspects of systems), a different angle needs to be taken when constructing the model.

Thus, the requirement for this research is a modelling technique that uses traditional system elements but provides or allows for the creation of meaningful conceptual system models. Various soft and abstract techniques were reviewed (such as context diagrams, stock and flow diagrams, system diagrams). Preliminary models were attempted using these techniques. However, due to the specific context or given data for which these tools were built, they were deemed unsuitable for this specific socio-technical problem. Yet, a technique which was previously considered too informal proved to be suitable after reviewing literature surrounding it, namely concept mapping.

Trochim and McLinden (2017:1) detail that "concept mapping was developed in the 1980s as a unique integration of qualitative and quantitative methods designed to enable a group of people to articulate and depict graphically a coherent conceptual framework or model of any topic or issue of interest". A key focus in concept mapping is the fact that it is a structured process focused on creating maps that are relevant outside the mind of the producer (Trochim & McLinden, 2017). It is, therefore, important to have transparency and some formal stepped procedure. Concept mapping has evolved since its origin in the 1980s. Back then, concept mapping involved 3 steps: "(1) The generation of the conceptual domain (2) the structuring of the conceptual domain [and] (3) the representation of the conceptual domain" (Trochim & McLinden, 2017:2). In its most recent iteration, concept mapping involves six steps, namely "preparation; generation; structuring; representation; interpretation; and Utilization" (Trochim & McLinden, 2017:2).

Unlike context diagrams or context DFDs, a concept map does not focus on the interactions of external systems with a central system. Rather, it focuses on mapping all relevant systems and useful elements (regardless of size). Similarly, instead of focusing on the feedback received from support systems, like traditional system diagrams, a concept map details all interactions between the systems and how they affect one another. Lastly, unlike stock and flow diagrams, concept maps can be constructed without focusing on the quantitative aspects such as flow and reservoir capacity. In summary, a concept map model provides a flexible way to decompose a system, relate it to its environment and understand how to improve it (CSL4D, 2013). After all, "the whole point of thinking in systems is to model real systems in such a way that they can be improved. The model itself is also a system" (CSL4D, 2013).

A meaningful example of concept mapping to this study can be found below in Figure 1. The diagram is a concept map analyzing a system based on the works of C. West Churchman (a pioneer in systems thinking) in describing the minimal system (CSL4D, 2013). The minimal system as describes by Churchman truly captures the essence of the key elements needed to form a system and thus presented a better way to analyze them (CSL4D, 2013). It also provided insights on how to improve systems from this analysis.

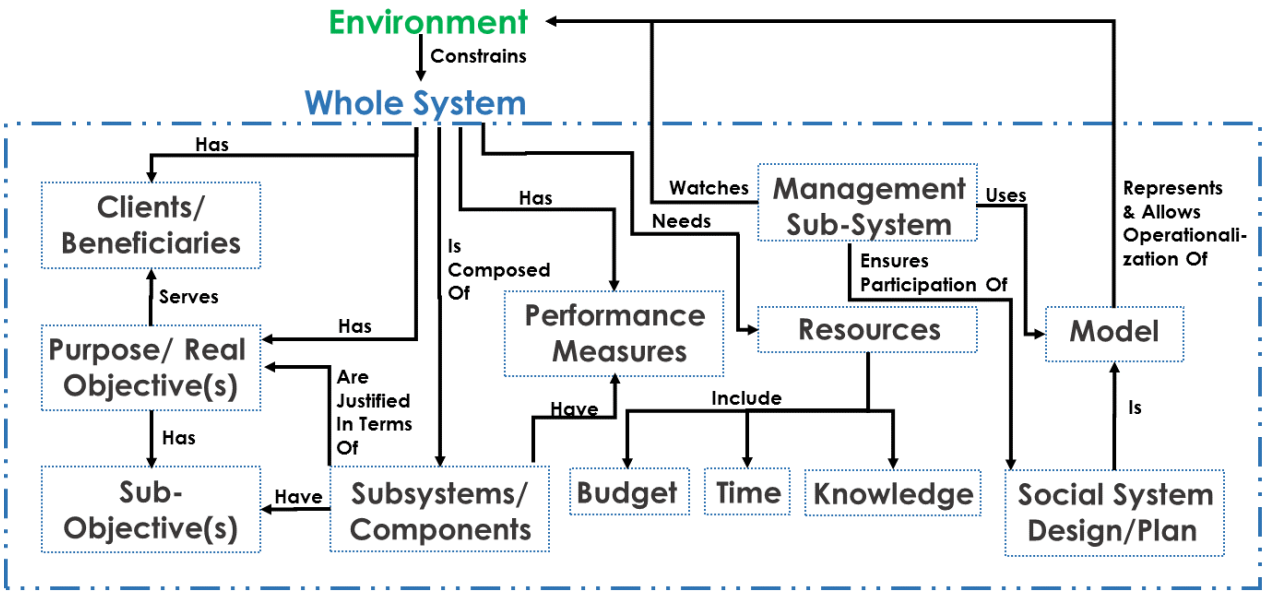


Figure 1: The Minimal System by Churchman (CSL4D, 2013)

Figure 1 shows the typical nature of interactions of virtually any system. Although some of the features of the diagram may not be relevant to some types of systems, failing to consider them in the first iteration of the context diagram development can result in illogical or missing features. Two key features to the models to be developed in this study using concept mapping that can be expanded on from Figure 1 above are:

1) **Relationship between system and environment:** It is crucial to understand the distinction between a system and the supra-system that encompasses it. This helps prevent systems of similar levels being modelled in a hierarchical relationship. A true supra-system should truly constrain all actions of the system it encompasses.
2) **The management subsystem:** It is important to notice that every whole system has some form of management subsystem responsible for positioning the system and initiates the necessary manoeuvres that utilize resources to strive towards certain performance measures (all guided by the model of that subsystem).

2.1.3. System Thinking (Synthesis)

The concept of systems thinking is worthy of discussion and review. Although gaining popularity, it can be said that this thinking style or approach remains underused due to a misevaluation that most problems are simple (when most are complicated or complex). Systems thinking can be defined in many ways but perhaps one of the best definitions is by Arnold and Wade (2015), who used systems thinking to collect the various available definitions and skills necessary for proper systems thinking and combined them into a single definition using systems analysis frameworks.

Arnold and Wade (2015:675) provide the objective definition that system thinking "is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them to produce desired effects. These skills work together as a system". Additionally, a clarification of each the terms is further provided by Arnold and Wade (2015:675):

> ***Systems:*** *Groups or combinations of interrelated, interdependent, or interacting elements forming collective entities* ***Synergistic:*** *Characteristic of synergy, which is the interaction of elements in a way that, when combined, produce a total effect that is greater than the sum of the individual elements.* ***Analytical skills:*** *Skills that provide the ability to visualize, articulate, and solve both complex and uncomplicated problems and concepts and make decisions that are sensible and based on available information. Such skills include demonstration of the ability to apply logical thinking to gathering and analyzing information, designing and testing solutions to problems, and formulating plans.* ***Identify:*** *To recognize as being a particular thing.* ***Understand:*** *To be thoroughly familiar with; apprehend clearly the character, nature, or subtleties of.* ***Predict:*** *To foretell as a deducible consequence.* ***Devise modifications:*** *To contrive, plan, or elaborate changes or adjustments.*

More important to this study, however, is the developed Systemigram (system-diagram) detailing the internal processes of system thinking. Since the main aim of the study is to expand Industrial Thinking and model it (using the IE Identity as a basis), one of the goals of this thesis is to devise a similar visualization. Arnold and Wade (2015:675) uses available literature to model system thinking using a Systemigram in Figure 2 below:

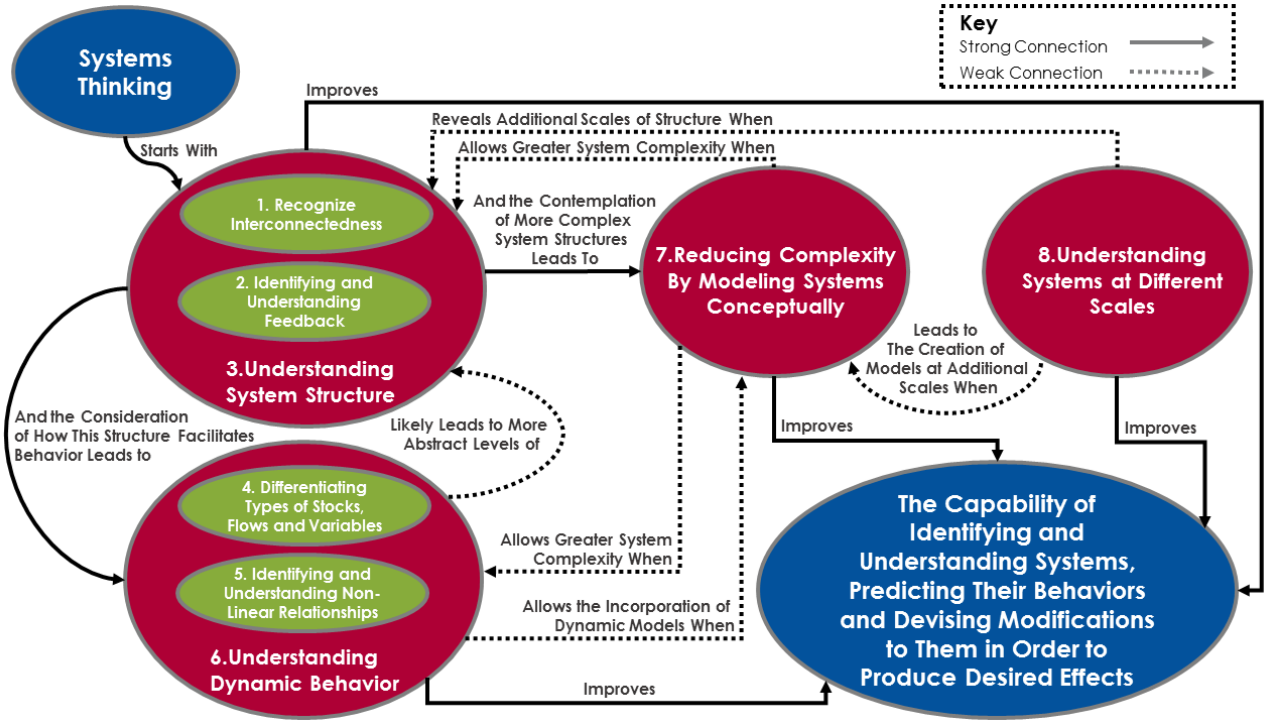


Figure 2: System Thinking Systemigram (Arnold & Wade, 2015:676)

2.2. Interpretative Systems Approach

For the specific problem of this thesis, it important to understand both the structure and behavior of the systems encompassing and affected by industrial thinking. While reviewing literature, it was found that it is necessary to follow a certain 'school of thought' or approach in the system analysis. An interpretive systems approach is found to be the most appropriate. Anon (2000:211-212,282) provides a summary that helps justify the selected approach:

> *An interpretive system methodology is a structured way of thinking with an attachment to the interpretive theoretical rationale that is focused on improving real-world problem situations…. [It] uses systems ideas as the basis for its intervention strategy and will frequently employ methods, models, tools and techniques which also draw upon system ideas… Each use of an interpretive system methodology should yield research findings as well as changing the real-world problem situation… An interpretive system approach is frequently referred to as 'soft system thinking'; because it gives pride of place to people rather than technology, structure or organization. In contract to functionalist approach, its primary area of concern is perceptions, values, beliefs and interests. It accepts that multiple perceptions of reality exist and sometimes come in conflict…. meaning can only be extracted by supplying appropriate 'contexts'… those who have wished to develop interpretive system methodologies, for intervening and changing systems, have had to search much harder to find appropriate theoretical support.*

David Alman (2014:4-6) provides a helpful visual interpretation of the type of systems by contrasting the hierarchy of causal relationships with the system thinking approach (displayed in Figure 3).

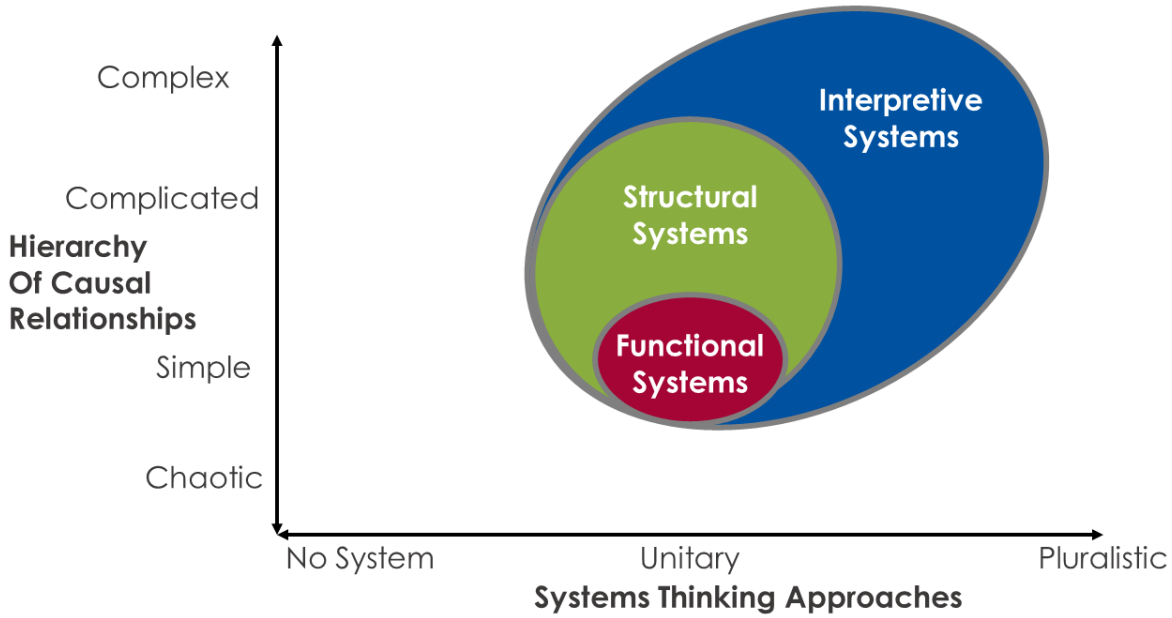


Figure 3: System Thinking Maturity Model (Alman, 2014:6)

Interpretive system "models are built from differing views of the system stakeholders… [they can] handle complex, or 'messy' problems or situations and look at both human designed systems and social systems. "Complex" in this context is defined as "unpredictable cause and effects, where causal relationships can only be seen retrospectively" Alman (2014:5). One of the methodologies mentioned in Alman (2014:4), the interactive planning methodology, was found to be helpful in understanding or handling 'messy' problems. Helpful insights were used in constructing the models in this PhD.

2.2.1. Interactive Planning

Ackoff (2001:3) describes the interactive planning methodology as being "directed at creating the future. It is based on the belief that an organization [profession in the case of this study since it is considered a form of organization] future depends at least as much on what it does between now and then, as what is done to it. Therefore, this type of planning consists of the design of a desirable present and the selection or invention of ways of approximating it as closely as possible. It creates its future by continuously closing the gap between where it is at any moment of time and where it would most like to be". Ackoff (2001:4-8) discusses two phases of interactive planning: idealization and realization.

Idealization can be described as the part that examines the entire spectrum to generate an idealized state that the organization should strive to. This is made of two steps: 1) formulating the mess, and 2) ends planning. Formulating the mess is the realization that "every organization is faced with a set of interacting threats and opportunities, a system of problems that we call a mess. The aim of this phase of planning is to determine how the organization would eventually destroy itself if it were to continue behaving as it is currently; that is, if it were to fail to adapt to a changing environment, even one that is perfectly predicted. Identification of this "Achilles' heel – the seeds of its self-destruction provides a focus for the planning that follows by identifying what must be avoided at all costs" (Ackoff, 2001:5). It typically involves a system analysis (how a system currently operates), obstruction analysis (identification of characteristics obstructing progress), reference projections (where organization will go if no change is implemented) and scenarios (a description of how and why the organization would destroy itself if assumptions were made true). Ends planning, on the other hand, involves "determining what the organization would ideally like to be now if it could be whatever it wanted, determining the gaps between this ideal and the organization projected in the reference scenario" (Ackoff, 2001:6). Naturally, this ideal state might never be achieved but striving towards it is a worthy goal.

Realization can be described as the steps taken to close the gap between the current and the ideal. It involves removing barriers and resolving issues by proactively using realistic

considerations. This comprises four steps: 1) means planning 2) resource planning 3) design of implementation, and 4) design of controls. Means planning is “determining what should be done to remove or reduce the gaps identified in ends planning; that is, selecting or inventing the courses of action, practices, projects, programs, and policies to be implemented in pursuing the organization's idealized redesign” (Ackoff, 2001:6). Resource planning determines the types of resources (facilities, equipment, people, etc.) available and how much of each is needed at desired times and places (as well as identified shortcomings) (Ackoff, 2001:6). Design for implementation determines “who does what, when and where” (Ackoff, 2001:6), whilst design of controls develops how to “monitor these assignments and implement planning decisions to determine whether they are producing expected results and, if not, determining what corrective action should be taken” (Ackoff, 2001:7).

In short, the methodology gives the chance for the designer to reinvent the organizational system given the current environment. “The design produced should be that of the best ideal-seeking system of which its designers can currently conceive… not an ideal organization; [because of] continuous improvement, it is neither perfect nor utopian” (Ackoff, 2001:8). For this study, the idealization of industrial thinking in order to assist in expanding its natural presence is a large part of the aim. The development of a series of interventions and artefacts stemming from formalized IE identity is the method used for realization.

2.3. Placing Research within System and Real-World Context

Vital to any piece of meaningful research is a framework of ideas (F), a methodology (M) and an area of concern (A) (Checkland & Holwell, 1998). Checkland and Holwell (1998) summarize this understanding of research in Figure 4 below. In many cases, some of those elements are available from literature and can be used in a new study addressing a new area of concern. However, in a PhD study, some development, refinement or reworking of standard frameworks and methodologies is necessary to deliver a unique piece of knowledge or perspective (especially when dealing with complex problems and the uncertainty of the knowledge era).

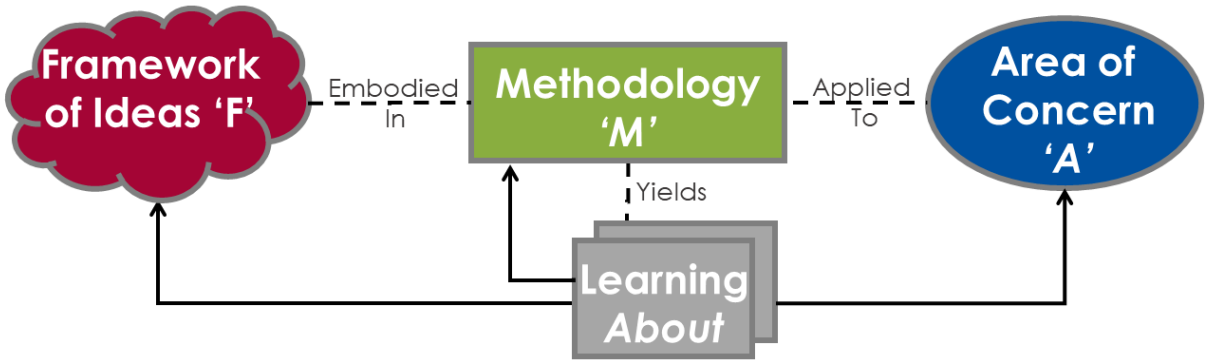


Figure 4: Relationship Between Elements of Research (Checkland & Holwell, 1998).

Thus, in reviewing the relevant knowledgebase of systems thinking, it became immediately apparent that, in order to give a true system view of the research, it is necessary to understand the context of the research within the real world. This means distilling the complexity of the real world by using an interpretive system lens and further focusing it (by using system principles, thinking and modelling) with a golden thread that runs through this PhD research. Once the research is concluded, this golden thread can be further detached and woven back into the fabric of the real world using the results (summarized in the Industrial Thinking Systemigram).

Research view: In using the works of Checkland and Holwell, it becomes clear that an appropriate framework, methodology and areas of concern need to be explicitly defined and visualized as part of the study. As discussed briefly above, the fact that this is a PhD allows for a certain amount of adaptation of traditional methodologies in order to assist in the new knowledge creation process, however, the process must still hold academic and scientific rigor. Chapter 3 formally defines a framework for the research. The methodology used in this thesis is developed in Chapter 4. Lastly, this methodology needs to be applied to selected areas of concern (themes), as reviewed in Chapter 5, in order to produce meaningful learning about. However, given the tangled nature of the areas of concern, it was decided to address each area of concern in a separate article and extract the transcendent findings that link to this overarching goal. Thus, each article represents a research area of concern, or theme, that is guided by the golden thread of the PhD. Naturally, no single article solves the identified cultural problem, yet, it does provide relevant insights. In order to maintain a golden thread through the research, it must adhere to the overall goal of *expanding industrial thinking,* embodied in the Industrial Thinking Systemigram. The approach is first internally verified. Additionally, the proposed generalizable findings are validated with external experts to ensure the correctness and effectiveness of the findings as a resolution to the input concerns.

Interpretive systems view: Using interactive planning, the IE profession is treated as an organization and its idealized state is defined and further focused using system principles, thinking and modelling into a golden thread. Once it emerges from the research, the findings are used to help realize this ideal state.

Real world view: Using system modelling and thinking, a concept map was developed of relevant real-world interactions surrounding the industrial engineer. Some interactions were simplified for purposes of this study, but the model aimed to present a full view of how an industrial engineer has an intrinsic effect on society and the environment through their designed solutions for industry. The important highlight from this visual representation is the indirect second order and third order impacts of how an industrial engineer is taught.

A view summarizing the research overview using the system approaches (discussed in this chapter) was developed in Figure 5 to place the research within an appropriate context.

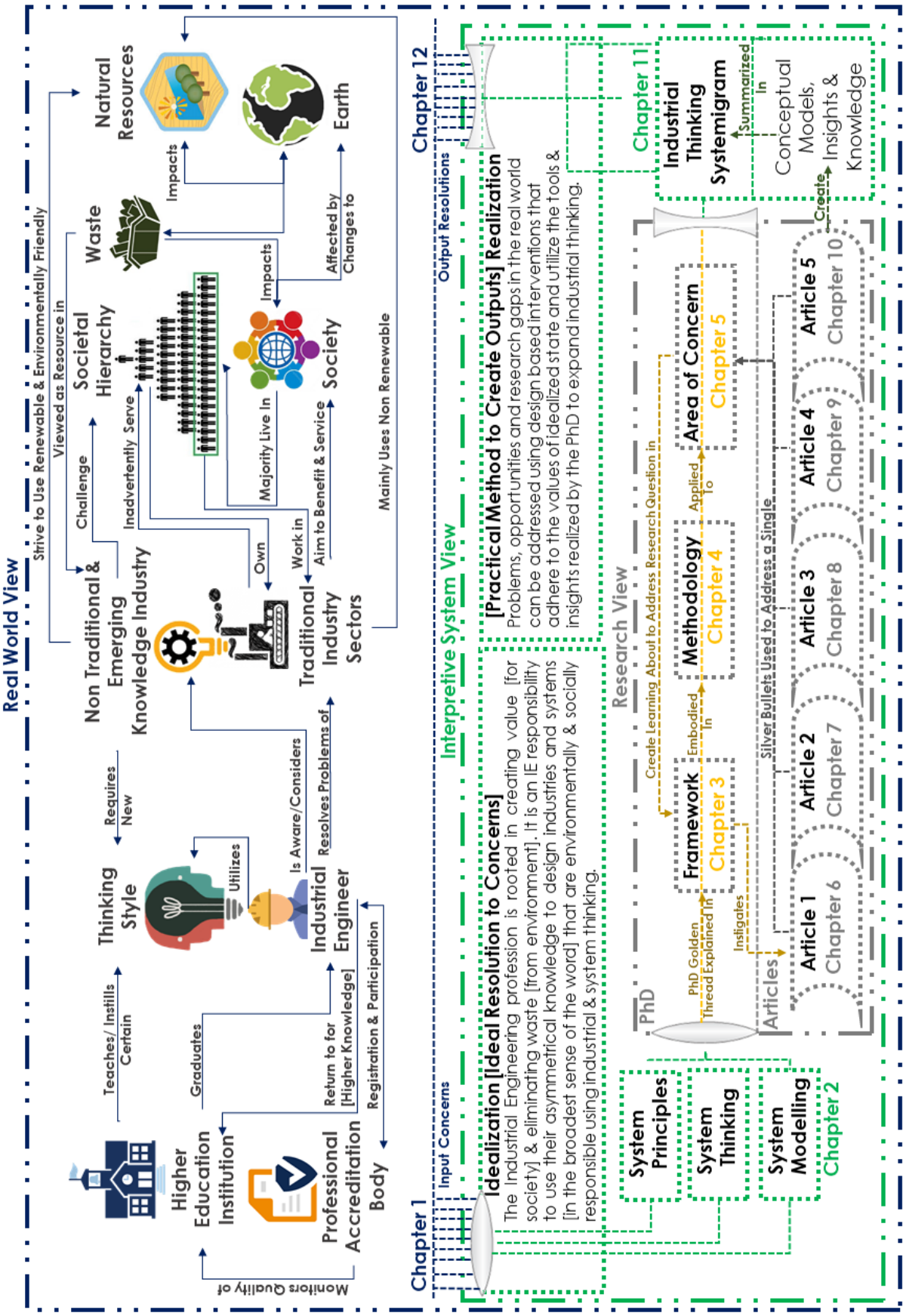


Figure 5: Visualized PhD System Context [Own Work]

3. Research Framework

3.1. Research Rationale

At first glance, it may appear that trying to study the phenomenon of Industrial Thinking would be an interesting but practically insignificant exercise (especially in an engineering context). Yet, if one approaches this study appreciating the 'profession' as an enterprise or system, it is almost instantaneously revealed that there is significant value to be added in development and management of the profession. A profession, much like an enterprise or system, has organizational structures, and interfaces with the economy and society. It comprises many elements (whether it be existing professionals, future professionals, accreditation bodies, IT systems and intangible knowledge) working towards the same goal. Additionally, it is invested in its continuity by training new professionals (in the form of students and young graduates) to replace dedicated professionals who have done their part in maintaining and growing the knowledge, networks and position of that profession. It also has an internal culture (both explicit and implicit, national and international). Yet, one of the key foreseen challenges to any profession is adapting to the disruptive forces of the knowledge era and developing a conscious awareness of the increased environmental concerns of society.

3.1.1. In Depth Description of Title

[What] does this study do? Expand Industrial Thinking. In this study, expanding takes many meanings. Expanding, according to the dictionary definition, means giving a fuller version or account, to make more extensive. Most important to this study, is expanding the areas of concern of industrial thinking. This implies expanding on its philosophies and definitions that underpin this thinking style. Furthermore, an added goal is to expand the users of industrial thinking, both within society (simplified definition) and the profession (using a procedural model). **[How] is this done?** By Formalizing the industrial engineering identity. This is shown, later in the study, to be a truly essential piece of literature that was missing and was uncovered as part of this study. What time frame is in mind **[When]?** For the Knowledge Era. This study takes a futuristic (rather than a retrospective) view since the technologies introduced in the knowledge era radically challenge traditional knowledge areas **[The Where]** which are now required to be progressively resilient and taught in the profession **[The Why].** The link between these aspects and questions is further elaborated in visual representations of the system context, research framework, methodology, and areas of concern.

3.1.2. The Problem Statement

A significant conceptual research gap exists that hinders the development of Industrial Thinking, within the IE profession, which would need to be closed in order for the thinking style to be sensitive towards and resolve social and environmental challenges of the knowledge era.

3.2. Research Scope

The suggested research topic is multi-faceted and requires a broad understanding of various topics (some of which cannot be addressed empirically) surrounding the expansion of a thinking style and its benefit. Although this study will attempt to comment on and discuss the maximum number of relevant aspects stemming from the objectives and questions, a special focus will be given to a specific list of aspects which can result in the most positive change (guided by the Pareto rule). The PhD will endeavor to make a unique and valuable contribution to the IE professional identity, IE continuous education, and the areas in which a gap is identified through developed interventions and steps taken by the researcher.

3.2.1. Research Method

It is apparent that this PhD differs from the traditional engineering thesis. Various elements point towards more developmental, cognitive or management themes. Furthermore, there is an undeniable entanglement with social sciences for the selected problem. This is to be expected in a doctoral thesis and part of the strength of the research comes from unravelling a complex problem. Yet, the biggest challenge remains finding an appropriate method or approach for dividing and achieving the objectives of this study. Following various consultations, courses, and research, it was determined that action research (AR) holds the most promise. Modified versions of this approach have been used successfully in numerous social science studies. Yet, due to its unstructured nature, few engineering theses have attempted using it. However, correctly combining action research with the soft system methodology can assist in guiding the research to achieve its objectives whilst maintaining a properly documented and stage-based methodology. This is done by splitting systemic issues from the overarching cultural one. The overarching cultural issue is embodied in the main research question and is addressed with the purpose of the PhD, whilst, each article tackles a specific sub-question and delivers a defined objective (addressing a systemic issue).

3.2.2. Research Questions

Main Research Question: How can the cognitive thinking style, industrial thinking, develop (internally) within the IE profession and expand (externally) within society to uphold and mature the unique value it brings to solving complex challenges of the knowledge era?

Sub-questions:

- What represents the essence of industrial thinking and how can this be extracted from the identity and conduct of the industrial engineer?
- What modern educational tools exist that can assimilate the asymmetric knowledge and resources surrounding the IE profession in a promotable, inclusive and accessible manner?
- How do the major forces of the knowledge era (economic, social and environmental) affect the profession of IE and its associated thinking style?

- Externally, which previously under-assessed socio-economic groups can benefit from industrial development (which has failed to consider & address their needs in past)?
- Internally, how can industrial thinking become more harmonious with modern environmental and ethical outlooks of society?

Combined, these questions will demystify some of critical nodes in the network which, if strengthened, will result in an overall improvement and expand industrial thinking. Additionally, they will shed light on how to best utilize resources to achieve this goal.

3.2.3. Research Purpose and Objectives

The purpose for this PhD thesis is the development of an Industrial Thinking Systemigram which accurately reflects the aspirations and asymmetrical knowledge unique to the profession. This is instrumental in ensuring beneficial proliferation of the thinking style necessary for progressive resilience in the face of macro challenges of the knowledge era.

The research undertakes to achieve one the following objectives in each published article:

- Formalize an IE identity that most accurately represents the duties, roles and values of the profession;
- Conceptualize a comprehensive professional platform that connects stakeholders in the profession with each other and society at large
- Classify and discuss the role of major Environmental, Social and Economic (ESE) factors on the field of IE (Namely the impact of knowledge era ESE technologies on IE subdisciplines)
- Develop a model that addresses imbalances in the benefactors of Industrial development
- Revitalize the importance of environmental and ethical considerations in Industrial philosophies & terminologies.

It is clear from the nature of the questions and objectives in this study that they need to be addressed separately. Thus, the selected method of PhD by article publication proves useful because it allows each article to follow a methodology suitable to the area of concern or theme whilst being able to generate usable insights for the overall study. This is similar to a multi campus university adjusting its academic offering to suit its location, social surroundings and other criteria whilst holding true to an overall brand and identity. Yet, identifying the golden thread and devising a methodology to keep track of progress requires special attention. The flexible nature of action research provides a mechanism for extracting relevant insights from the article components (systemic issues) which can serve as inputs to the overarching objective that is the development of the Industrial Thinking Systemigram. Moreover, selecting an appropriate verification and validation method is vital. Details are discussed in Chapter 4.

3.3. Research Outline

The first chapter of this study provided an overview on the context and problem. In order to further clarify the golden thread, a system context diagram was visualized [Chapter 2]. This highlighted the need for a clear research framework [Chapter 3], overarching research methodology [Chapter 4] and research investigation on the area of concern [Chapter 5]. Five articles [Chapter 6-10] discussing the various areas of concern (themes) of expanding Industrial Thinking are included as separate chapters. Each article explores a specific research question in further detail and delivers on an objective using the appropriate methodology. Thus, each article can be seen as a unique piece of generated knowledge. Together, the combined results and conclusions of the articles are used in developing an Industrial Thinking Systemigram (satisfying the overarching objective of the PhD), which is validated against internal requirements and verified externally using semi-structured interviews [Chapter 11]. Thereafter, the concluding remarks for this thesis are presented [Chapter 12].

3.3.1. Limitations and Assumptions

The study can be seen as a globally relevant study. Although it may make use of specific countries and examples for case studies, the goal is to provide a universally beneficial contribution for the field of IE with a special focus on assisting developing economies realize the value of the field. Widely respected academic works were used as a basis for developing many of the artefacts and models found in this PhD Study. Naturally, one of the requirements for this PhD thesis is that it must be unique and impactful in its contribution to academia and industry.

3.3.2. Importance of the Research

It is pleasant to see the number of industrial engineers leading global projects. Furthermore, global projects and initiatives are starting to shift into rural regions in an attempt to servitize low-income and rural communities (80% of the world's population). The unique understanding of the impact of changing technological forces and economic systems on society makes industrial engineers more likely to be part of the teams that undertake this responsibility. However, if this is not highlighted through a proactive role by IE departments to develop Industrial Thinking, stakeholders involved might be left thinking that the tools they learn can only be utilized in corporate environments (based on a preconceived idea of the meaning of industry) rather than for the benefit of all.

In short, industrial engineers solve problems of 'industry'. The understanding of what counts as an industry, and the importance of social harmony and environmental sustainability is becoming more apparent. Thus, it is of vital importance to expand Industrial Thinking to meet those challenges.

3.4. Visualized Research Framework

A visual comprehensive summary of the PhD study can be found in Figure 6 below:

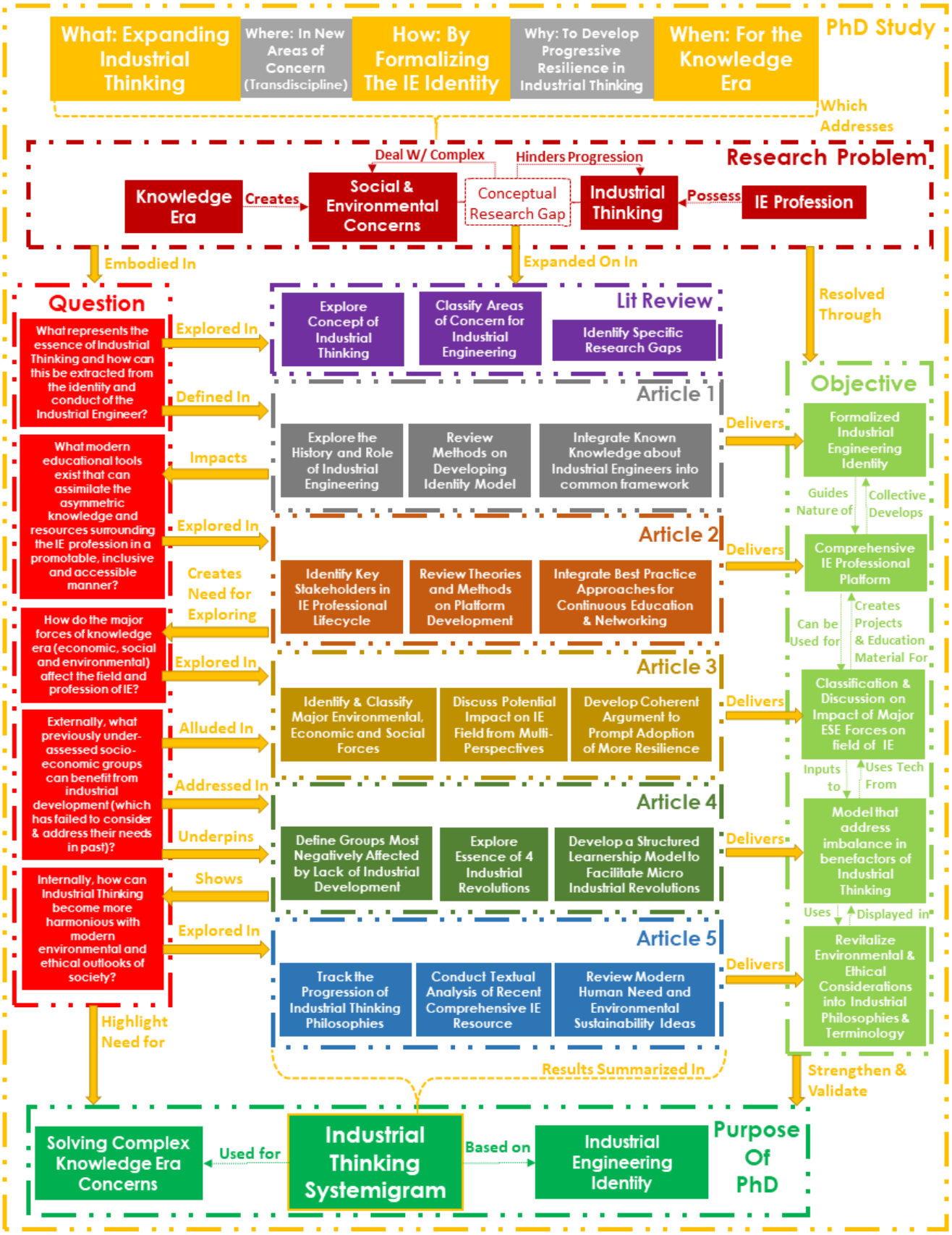


Figure 6: Visualized PhD Research Framework [Own Work]

4. Research Methodology

Much of today's research methods follow the principles of the scientific method. The scientific method is a form of organized inquiry into research problems used in the natural sciences. It typically generates knowledge by creating an inquiry and resolving it through systematic experimentation (using recorded measurements, observations and alterations) of the experiment parameters (Checkland & Holwell, 1998). It gained popularity in the modern era due the rigor of its results. The principles of the scientific method, which allow this rigor, are often described as reductionism (sufficient explanation of the complex can be made by decomposing complex phenomena to simpler elements), repeatability (ability to get the same results for an inquiry or experiment given the same approach is followed and thereby creating 'public knowledge'), and refutation (ability to reject a given process or piece of knowledge if a more scientifically grounded alternative is generated and it includes an assumption that every piece of knowledge is 'not yet refuted' but could be in future) (Checkland & Holwell, 1998).

The popularity of the scientific method as a means of research subdued other forms of less procedural and scientific research for a significant period of time. However, it became apparent that reductionism cannot answer everything. Checkland and Holwell (1998:1) elaborate that although "the process of knowledge acquisition which has the strongest truth claim is the research process of natural science… the application of this process to phenomena beyond those for which it is developed is problematic". This is especially true for more complex phenomena such as social ones. Since they are "mental abstractions at a meta-level to their manifestation, even thinking and arguing about them can change them… [since they are not] 'homogenous through time' hence the idea of taking part in change in organizations as a basis for research in the social world" (Checkland & Holwell, 1998:12).

This naturally leads researchers in other fields to seek other *foundations to base their research on. Many of these research approaches found solace in action research (AR). Various definitions exist depending on the environment it is applied to.* Carr and Kemmis (2003:162) define AR as "a form of self-reflective enquiry undertaken by participants in social situations to improve the rationality and justice of their own practices, their understanding of these practices, and the situations in which the practices are carried out". A notable portion of action research takes place in educational environments (which supports the main ideas discussed in the definition above). Another definition focusing on the resolution aspect defines AR as "a process of uncovering solutions through progressive problem-solving activities. The outcome is intended to improve practices and address issues. Often performed by a group of participants, the process involves investigation through activity rather than theoretical response" (BusinessDictionary, 2017a). This highlights an important aspect inherent to AR, which is its applied nature and implicit notion of balance between theory and application.

4.1. Action Research (AR)

The above can be considered a broader definition, but still holds true since the aim of action research is to "contribute both to the practical concerns of people in an immediate problematic situation and to further the goals of social science simultaneously. Thus, there is a dual commitment in action research to study a system and concurrently to collaborate with members of the system in changing it in what is together regarded as a desirable direction" (Gilmore *et al.*, 1986:161). In action research, the process of creating new knowledge is fundamentally different to that of the natural sciences. This main differentiation from natural sciences is that, in natural sciences, the process being researched is external to the reality the researcher is testing (through a hypothesis), whereas in AR the researcher cannot fully separate themselves from the real world problem and thus must actively participate in resolving it. Checkland and Holwell (1998:12,15) visually represent (shown in Figure 7 below) the difference between the natural science knowledge creation process and action research:

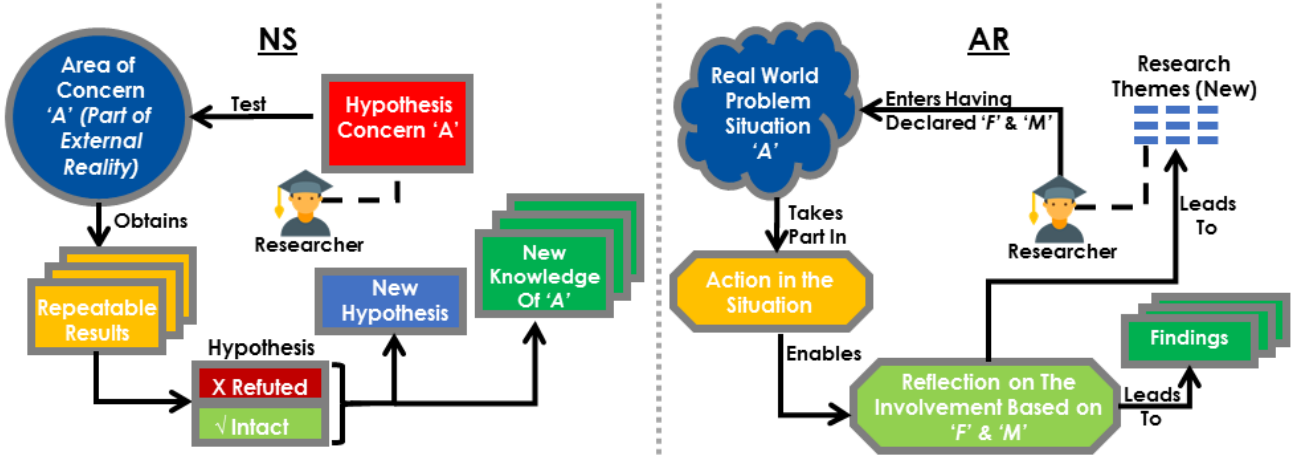


Figure 7: Natural Science Process [L] AR Process [R] (Checkland & Holwell, 1998:12,15)

It remains challenging to find a way to obtain a similar level of 'truth claim' in action research. This, in addition to the above, begs many questions like when does the AR process stop? And how can the findings be transferred? Checkland and Holwell (1998:16-20) elaborate that:

> *The AR process accepts that 'themes' have to replace hypothesis…. [where] the laboratory researcher can stop when replicable results show that a hypothesis has been refuted… [whereas AR has to] use the researcher's judgement that the chosen methodology and its framework of ideas (F) have yielded significant learning in interaction with the area of application. Attempting to 'write up' the results will often reveal whether or not a strong case can be made that this position has been reached. Since any organization situation at a particular time, with its particular participants having their own individual or shared histories, may be unique, it cannot be guaranteed that results can be made richly meaningful to people in other*

> *situations…. Our argument here is that the aim in AR should be to enact a process based on a declared-in-advance methodology in such a way the process is recoverable by anyone interested in subjecting the research to critical scrutiny… if findings are to be taken seriously, they must be supported by appropriate arguments and or evidence; there must be… an adequate 'warrant' in conjunction with a particular framework which supplies 'backing' for the warrant and ultimately the 'claims'…. This gives well organized AR a 'truth claim' much stronger than that of mere 'plausibility'… [lastly] since system ideas are a strong component of much methodology which is relevant to qualitative research methods such as AR, it seems appropriate that Systems Practice should extend its cover to include interventions aimed at both acquiring knowledge and helping to bring about organizational change*

Thus, the nature of this research is very much aligned with the objectives of AR (which can be used since engineering has a social science focus). In order for the process to be more systematic with the AR, the works of Checkland and Holwell (1998) on AR will be used extensively, especially in structuring of the FMA to ensure recoverability. Although the above extracts provide guidance for the overarching research, several more specific methodologies that would typically be classified under AR are reviewed further to develop a relevant and systematic methodology for this study. Yet, it is important to note some characteristics that can increase the plausibility and 'truth claim' of AR. For this PhD thesis, these can be used as an internal verification checklist. The helpful characteristics of AR extracted from Checkland and Holwell (1998:20) are:

i. *Researcher intends to change the organization*
ii. *There must be implications beyond the specific situation*
iii. *Research seeks theory as an explicit concern*
iv. *Any tools, techniques or models developed need to be linked to the research design*
v. *Emergent theory will emerge from both data and initial theory*
vi. *Theory building will be incremental and cyclical*
vii. *Presentation should acknowledge prescription and description*
viii. *There will be an orderliness in approach*
ix. *Exploration of data and theory building should be explainable to others*
x. *Later reporting is part of theory exploration and development*
xi. *i-x are necessary but not sufficient for valid AR*
xii. *It is used where other methods are not appropriate*
xiii. *Triangulation is used if possible*
xiv. *History and context are given due weight*
xv. *The dissemination of findings goes beyond those involved in a study*

Several potential methodologies (based on AR or that were developed using AR) will be reviewed before selecting one (or combining multiple) that suits this specific research study.

4.1.1. Action Design Research (ADR)

A central feature of any field of engineering is the concept of design. IE is no different to other disciplines in this area and much of what is taught and done in IE can be classified as a design (supply chain design, facility design…etc.). This, in itself, presents a challenge when applying standard AR thinking. Yet, Sein *et al.* (2011) overcame this challenge by combing the design research approach with action research approach. The result is known in literature as Action Design Research (ADR). Action design research proposes that artefacts are "shaped by the organizational context during development and use" (Sein *et al.*, 2011:37). This specific methodology integrates the idea of action, from action research, as a means of incorporating valuable interactions and contextual factors created during the design process (Sein *et al.*, 2011:38). Sein *et al.* (2011) discuss how both AR and DR are seen by many researchers as part of the same research process, but no attempts at cross-fertilizations were taken. By attempting to combine them, Sein *et al.* (2011) developed a combined research process with several stages that are guided by useful principles which hold true to the objectives of both research approaches. The process and explanation of the principles are found in Figure 8 and Table 1.

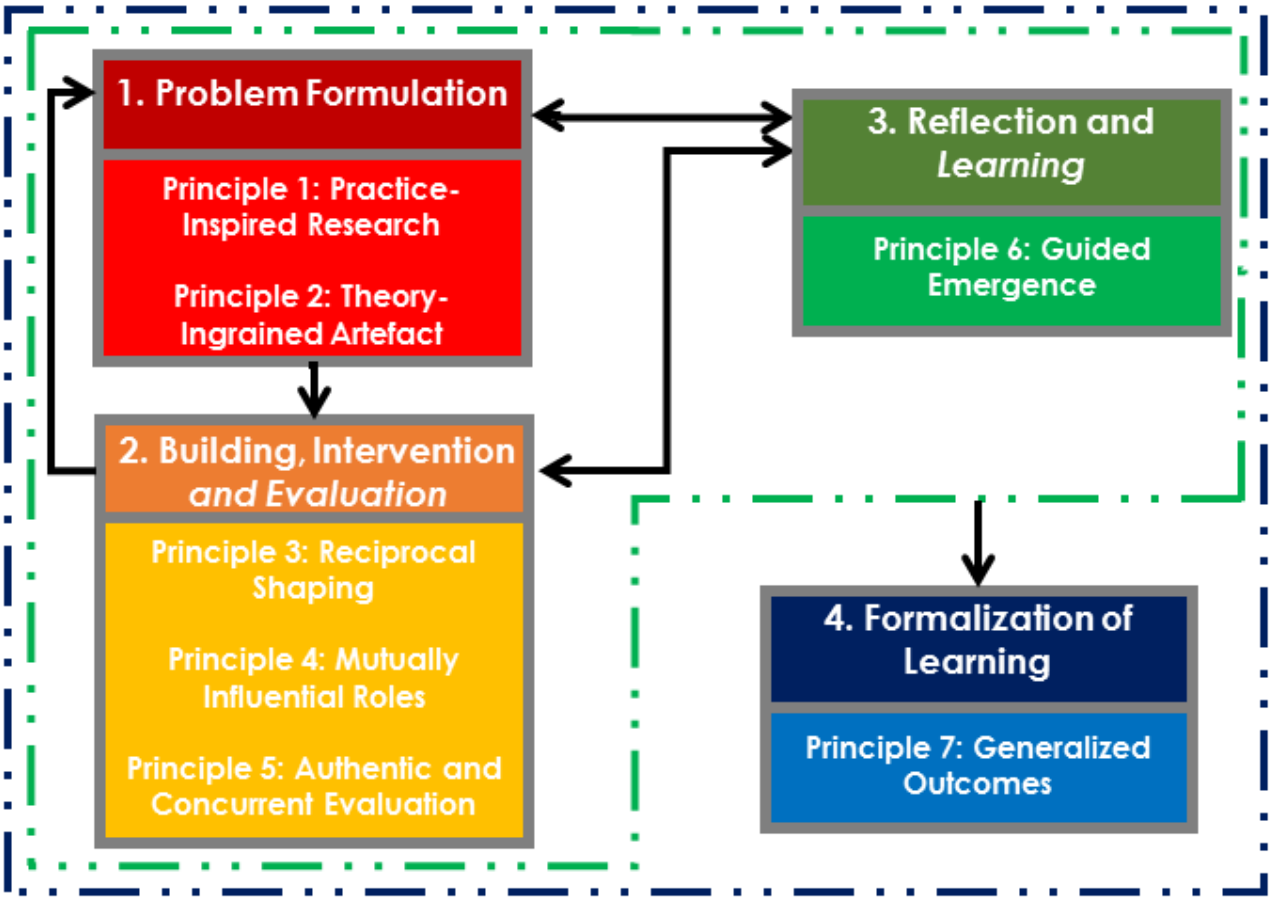


Figure 8: Action Design Research (Sein *et al.*, 2011:41)

Table 1: Explanation of 7 Principles of ADR (Henfridsson, 2011; Sein *et al.*, 2011)

Stage	Principle	Description
Stage 1	Principle 1	"This principle emphasizes viewing field problems (as opposed to theoretical puzzles) as knowledge-creation opportunities… The action design researcher should generate knowledge that can be applied to the class of problems that the specific problem exemplifies" (Sein *et al.*, 2011:40).
Stage 1	Principle 2	"This principle emphasizes that the ensemble artefacts created and evaluated via ADR are informed by theories" (Sein *et al.*, 2011:40). "Artefacts [seen] as carriers of theoretical traces" (Henfridsson, 2011).
Stage 2	Principle 3	"Emphasizes the inseparable influences from two domains: the IT artefact and the organizational context" (Henfridsson, 2011).
Stage 2	Principle 4	"This principle points to the importance of mutual learning among the different project participants. Action design researchers bring their knowledge of theory and technological advances, while the practitioners bring practical hypotheses and knowledge of organizational work practices. These perspectives and contributions may compete with one another or be complementary" (Sein *et al.*, 2011:43).
Stage 2	Principle 5	"This principle emphasizes a key characteristic of ADR: evaluation is not a separate stage of the research process that follows building" (Sein *et al.*, 2011:43). "There must be some form of formative evaluation" (Henfridsson, 2011).
Stage 3	Principle 6	"The terms design and emergence seem antithetical because the former implies external, intentional intervention, whereas the latter conveys a sense of organic evolution" (Sein *et al.*, 2011:44). Thus, ADR "captures seemingly incongruent perspectives" (Henfridsson, 2011).
Stage 4	Principle 7	"Generalization is challenging because of the highly situated nature of ADR outcomes that include organizational change along with the implementation of an IT artefact. The resulting ensemble is, by definition, a bundle of properties in different domains. This ensemble represents a solution that addresses a problem" (Sein *et al.*, 2011:44). This creates three levels: "generalizing the problem instance, generalizing the solution instance, [and] deriving design principles from the design research outcomes" (Sein *et al.*, 2011:44).

4.1.2. ADR in Enterprise Engineering (ADR-in-EE)

The problem with using ADR in the form described above is that it is strongly focused on IT artefacts. Attempting to force this methodology on artefacts of a softer system nature would result in several principles undergoing significant rewording and misalignment (which would detract from the quality and rigor of the methodology). However, a review of available ADR literature uncovered a variation which indeed might be suitable, known as ADR-in-EE. Given that this study will look at the field of IE as an organization or entity, several congruences with enterprise engineering can be drawn. The works of de Vries and Berger (2017) prescribe a more broadly applicable version of ADR that is much more suitable for this given study. The approach is summarized in Figure 9 below.

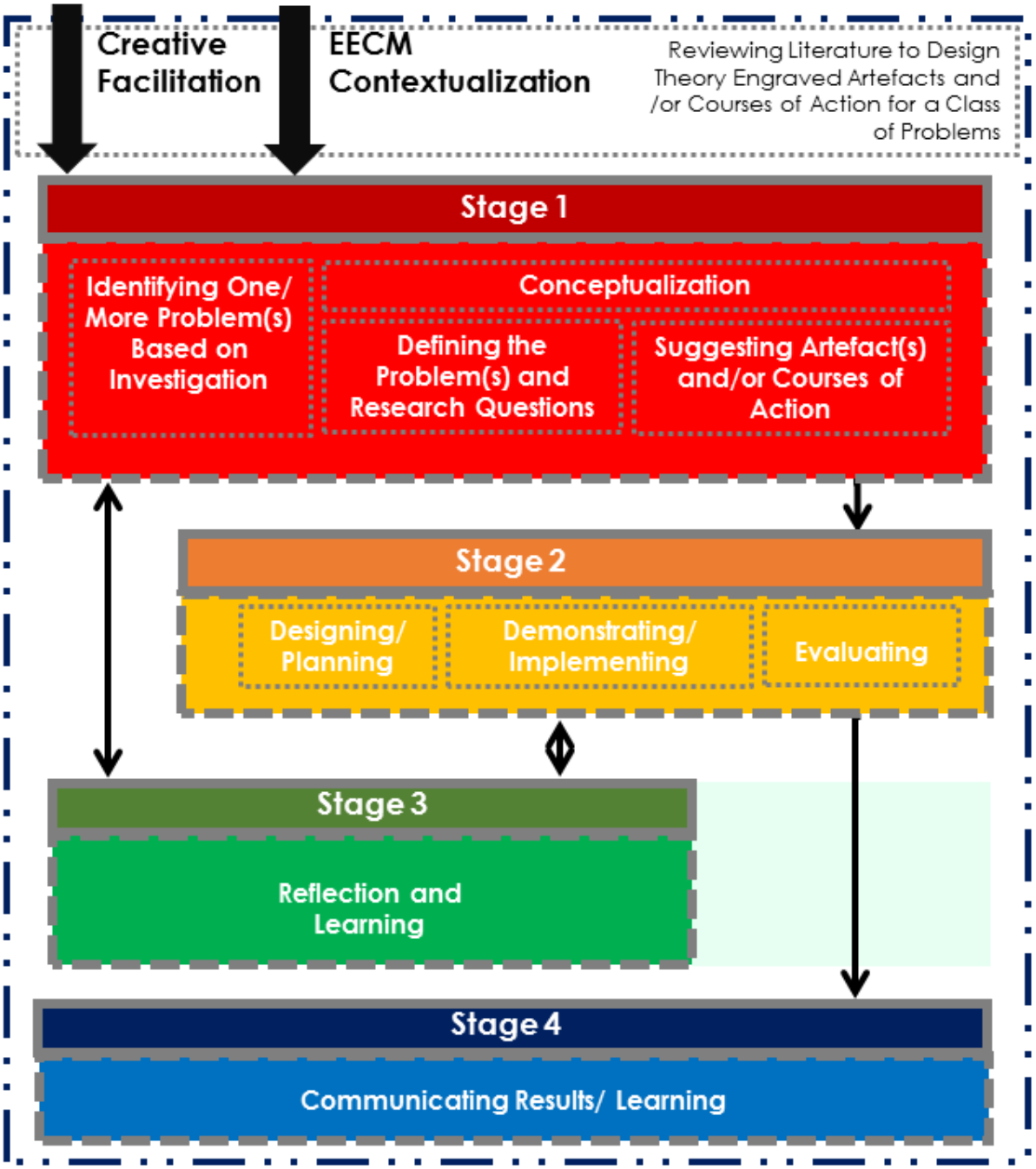


Figure 9: Action Design Research (de Vries & Berger, 2017:195)

The ADR-in-EE presents several new concepts, aligned with this study, which are worth further explanation further. The approach is still largely based on the works of Sein *et al.* (2011) First is the introduced concept of EECM contextualization in Stage 1. When involved in a study within or resembling an enterprise, the researcher "needs to have an understanding of the EE domain, since design requires 'interaction between understanding and creation'. EECM is a representation of the existing EE body of knowledge" (De Vries & Berger, 2017:196). Introducing this step provides a new way of looking at 'the problem' by "identifying deficiencies of an existing enterprise design approach" (De Vries & Berger, 2017:204).

De Vries and Berger (2017:197) clarify that although "initial investigation is qualitative in nature; further quantitative investigations may also be necessary to validate an identified problem". The second concept is that of creative facilitation guiding the conceptualization stage. This step helps create a way to brainstorm defined problems and research questions that can be further researched (De Vries & Berger, 2017). Based on this, one can ideate and suggest potential artefacts or courses of action that can be taken to resolve these issues. This is all done in Stage 1 before any 'design work'. This approach also strongly supports the idea of an iterative process within stages (dotted boundaries) with a detachment stage of reflection and learning (De Vries & Berger, 2017:196). However, the developed artefact(s) also have a clear path to move through [Steps 1,2,4 from Figure 9] before being communicated as results to the broader enterprise that the study is undertaken in.

The work done by appears to resonate more with the Stringer (2013:1) explanation of AR, which motivates that "action research is a systematic approach to investigation that enables people to find effective solutions to problems they confront in their everyday lives. Unlike experimental or quantitative research that looks for generalizable explanations related to a small number of variables, action research seeks to engage the complex dynamics involved in any social context. It uses continuous cycles of investigation designed to reveal effective solutions to issues and problems experienced in specific situations and localized settings, providing the means by which people in organizations may increase the effectiveness and efficiency of their work. In doing so it also seeks to build a body of knowledge that enhances professional and community practices and works to increase the wellbeing of the people involved". This definition is preferred for being largely aligned with the objectives of this study. Moreover, it proves to be a useful approach. Yet, given the nature of this PhD study, the soft system methodology may also contribute valuable structural insights.

4.2. Soft System Methodology (SSM)

The original soft system methodology (SSM), developed by Checkland and initially described in his 1981 book, followed a seven-step process which was used to create desirable changes to a system by expressing a problem situation, refining it in the system thinking realm, and developing conceptual models that are then compared with the real world before being implemented (displayed in Figure 10 below). This created a set of actions based on feasible, desirable changes to improve the problem situation. The SSM approach is seen as a suitable for dealing with fuzzy or wicked problems (Checkland, 1999), and is usually represented by fuzzy figures to distinguish it from step-based hard system methods. A vital distinguishing feature of SSM is the fact that it implicitly acknowledges that the process can only lead to an improved problem situation (especially when facing fuzzy problems). This highlights the continuous nature of improvement and that the best way to ultimately resolve such problems is through iteration.

The soft system methodology was developed through a 10 year action research program by the University of Lancaster (Checkland, 2001). Although SSM and AR are two unique approaches, their synergies cannot be neglected and they can be said to share a similar goal but differ in the level of involvement and role of the researcher (Sankaran et al., 2009:186). Sankaran *et al.* (2009:179) explain that "soft system methodology (SSM) and AR can both help in addressing ill-structured problems faced by managers, in collaboration with stakeholders… [because] both lead to an increased understanding about the problem situation. The difference is that SSM uses a more structured approach while AR is emergent in its application. SSM practitioners advocate that action researchers would benefit by declaring in advance an intellectual framework to guide their thought". That is why the works of Checkland and Holwell (1998) on AR were given special attention.

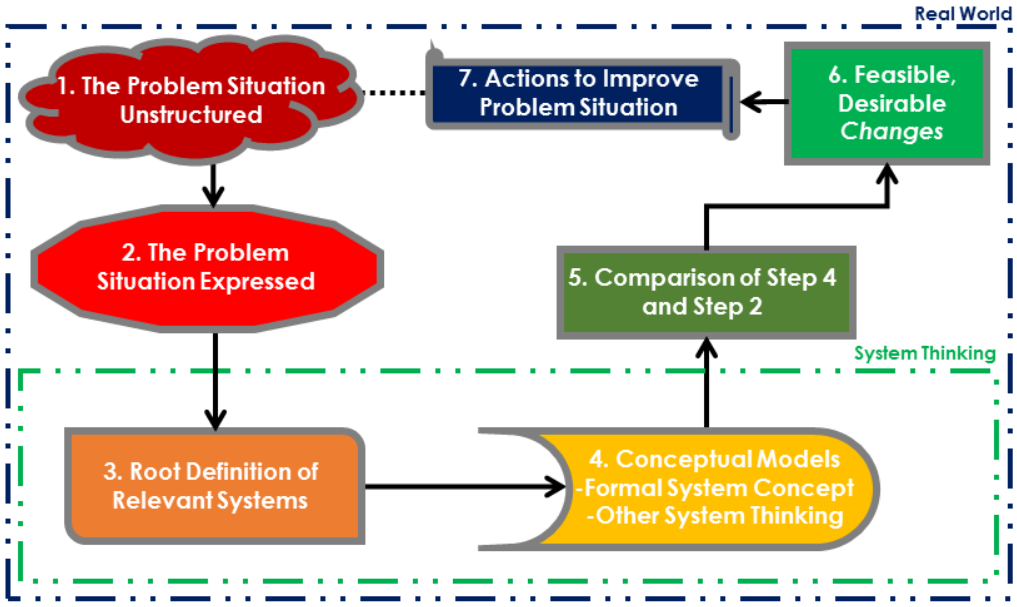


Figure 10: Soft System Methodology Original 7 Steps (Sankaran *et al.*, 2009:179)

This is perhaps why it might be more appealing to use SSM for this study given the nature of the problem and the fact that a systems perspective can definitely help in finding a better resolution. However, the awareness of the success factors of AR should be kept in mind when conducting the research. Yet, given that this is PhD is focused on developing an Industrial Thinking Systemigram and follows the article publication process, further research on more specific SSM approaches assists in finding a more aligned methodology.

4.2.1. Boardman Soft System Methodology (BSSM)

One of the variations of the standard SSM process is known as the Boardman Soft System Methodology (BSSM) (Clegg & Boardman, 1998). What distinguishes the BSSM from the standard SSM is that the former has a focus on adding a layer of process thinking to the developed artefact (Clegg & Boardman, 1998). This is naturally useful in modelling business and thinking processes. The main difference, as can be seen in Figure 11 below; BSSM creates what is known as a systemigram (systemic-diagram) instead of a conceptual model in attempting to instigate improvement. Clegg and Boardman (1998:701) elaborate that "the unique process representation produced by the BSSM is known as a systemigram. We suggest that each systemigram represents a process orientation holon [whole-part]… the systemigram represents a system which can be integrated into a hierarchy".

In short, this method does not challenge SSM in its general approach but provides a more valuable system representation (known as the systemigram) as its 'conceptual model' which incorporates process thinking. Cloutier *et al.* (2015:663) explain that "since their inception, they [systemigrams] have evolved into a tool to explore diversity in perspectives while maintaining a single objective… [because they] describe a method for better implementing project management control and for analysis of large-scale project planning problems".

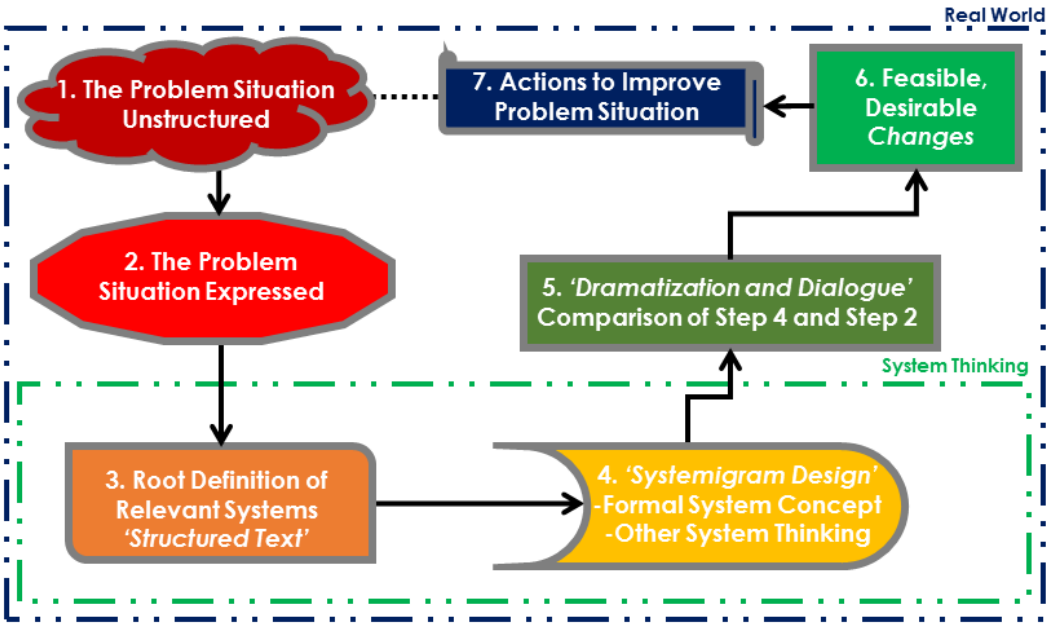


Figure 11: Boardman Soft System Methodology (Cloutier *et al.*, 2015:663)

Cloutier *et al.* (2015:665) elaborate on the systemigram concept and how to create a meaningful systemigram:

> *A systemigram is created by reading through the structured text and capturing the essence of the original conceptual thinking. A systemigram is a network, having nodes and links, flow, inputs and outputs, beginning and end… Some nodes can contain other nodes, for example to indicate breakout of a document or an organizational, product, process, or structure. The network must be legible, so this limits the number of nodes and links. There should be no crossover of links, improving clarity. The primary sentence (mainstay), which supports the purpose of the system, will read from top left to bottom right of the systemigram. The final node of the mainstay, in the bottom right, should be the system's goal or objective.*

Moreover, Wingrove and Sauser (2017) developed a systemigram depicting the role of the systemigram in improving the system of interest (shown in Figure 12). This highlights the strategic role of a systemigram as a visual tool that reflects the complexity of relationships between actors, artefacts and processes within an enterprise. In many ways the systemigram presents the qualitative version of a stock and flow diagram. Thus, it is ideally suited for the challenge faced by this PhD since it is theorized that the many problems facing the IE field are somehow connected by the thinking process used and thus can be addressed through a proper systemigram.

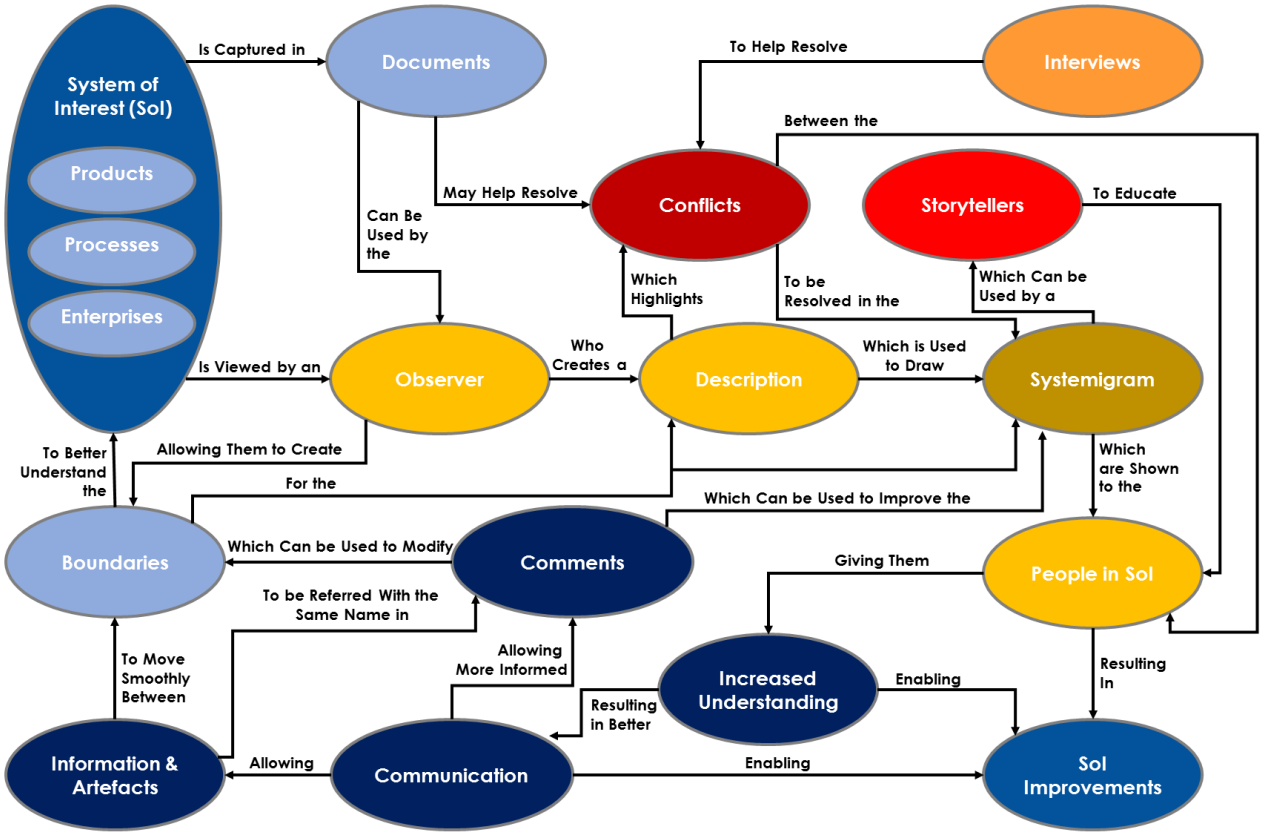


Figure 12: Boardman Soft System Methodology Systemigram (Wingrove & Sauser, 2017)

4.2.2. Two Streams Soft System Methodology (SSM2) [Mode 2]

Another iteration of SSM worth noting is the two streams version of SSM (also referred to as Mode 2 or SMM2 for short). Given the nature of standard SSM, a discrepancy between overarching cultural and specific technical situations arise. Thus, Checkland and Scholes (1990) developed two separate streams of inquiry to address this problem, based on further action research. Beynon-Davies (1998:252) explains that there are some essential features of this mode of SSM, and it starts with "a situation in everyday life that is regarded by at least one person as being problematic. The situation, being part of human affairs, will be the product of a particular history. Facing up to the problem situation are some 'would be improvers' of it… [Thus] SSM follows two interacting streams of enquiry: a stream of cultural enquiry and a stream of logic based enquiry. Both streams may be regarded as stemming from the perception of purposeful actions in the problem situation". Some scholars argue that Mode 2 SSM has changed the focus of SSM permanently since it shifts focus from methodology-driven to situation-driven action, and on interaction instead of intervention, and is inherently iterative in nature whereas traditional SSM was sometimes sequential, creating an internalized model instead of an external recipe (Houghton & Ledington, 2002:78).

The logic stream can be described as a revisited form of the traditional SSM process. There are some steps which are replaced with inputs from the cultural stream. Simonsen (1994:9) explains that "the starting point for the logic based inquiry is still the root definition of the selected systems but now the focus on the transformation process within the system is particularly emphasized". This stream identifies all possible systems which require 'improvement'. Thus, it recognizes that different models are required for each problem situation.

The cultural stream is the interesting addition to Mode 2 SSM. Inherently, it recognizes certain limitations that face an intervention when applying it to the real world. This is especially true in cases where social or political factors (macro factors) play an important role in determining the integration of the proposed changes (Beynon-Davies, 1998). The cultural inquiry is meant to compliment the logic-based stream by performing three analyses: 1) Analysis of the intervention 2) social system analysis, and 3) political system analysis. The analysis of the intervention concludes that that even resolving a problem is within itself naturally problematic (Holt, 2017). That is perhaps why Checkland often refers to the end resolution of this cycle as "the problem situation improved". The social system analysis aims to identify the key roles, norms, and values in a problem situation that need to be further explored or accommodated. Lastly, the political system analysis aims to identify "how differing interests reach accommodation, what are the commodities through which power is expressed [formal structures, intellectual authorities…etc.] and how these commodities are obtained, preserved and passed on?" (Holt, 2017).

The improved mode 2 SSM (SMM2) is visualized in Figure 13 below. Combining the two streams creates a collection of conceptual models (or artefacts) that address a real-world problem situation but have sensitivity towards the overarching culture (social, political…etc.). Thus, this creates systemically desirable but culturally feasible changes. It also gives history its fair weight in 'creating' the problem situation, which helps in developing a better solution. Thus far, SSM2 presented the most methodologically appropriate way of conducting this PhD study. This is because the PhD is also made of two distinct streams that need to be connected. The first can be described as the overarching golden thread of the PhD, which is directly linked to the real-world problem situation, and the second is the stream of articles, which each uniquely address a task or issue (from the root cause).

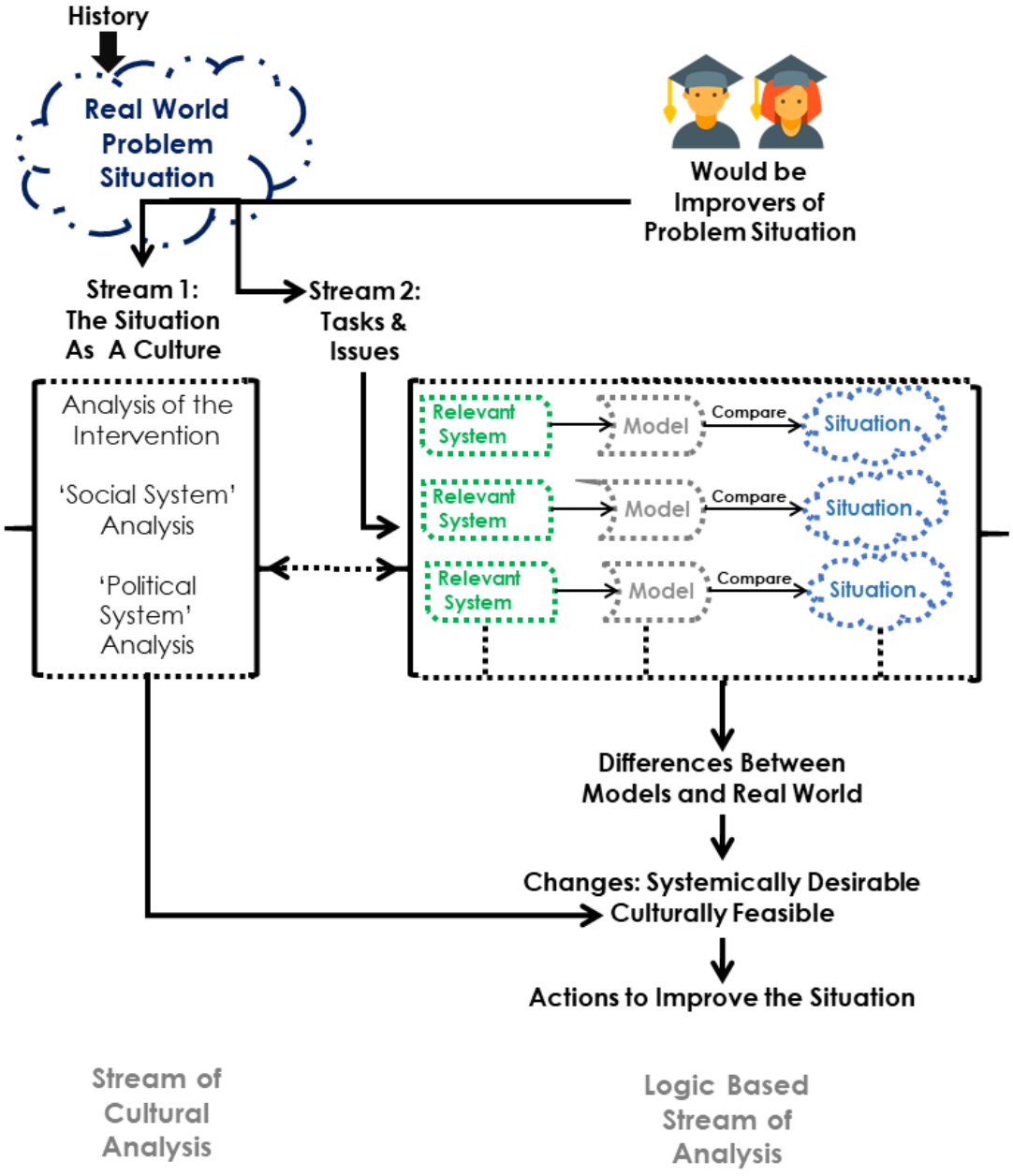


Figure 13: Mode 2 SSM Showing Two Streams (Simonsen, 1994)

4.3. Combining SSM & AR

Given the number of methodologies and approaches reviewed, a summary table of the helpful insights extracted from them has been compiled. It is acknowledged that, in theory, there are many ways to approach the selected research problem. Some scholars may argue that conforming to a specific research methodology or approach would be easier given that it would simplify verification and validation (using the literature on the matter). Others might argue that the since research, in reality, never follows a single method by the book, it is almost pointless to structure a methodology for this type of study. Both arguments may have their merits but a middle ground between them exists which may best suit this study. Given that this study is a PhD by article publication focused on solving problems at various levels (with various area-specific knowledge implications), it is almost impossible to select a single methodology to suit them all. However, sufficient room for creativity is available in the selected methodologies that allow for the integration of results. The selected insights from section 4.1 and 4.2 that helped create a combined AR and SSM for this study are summarized in Table 2.

Table 2: Selected Elements from Chosen Methodologies

Action Research	Soft System Methodology
Although AR cannot provide the necessary procedural rigor required in an engineering study, it does provide valuable insights on the role of the researcher and the nature of their interventions. Given that this study also crosses some boundaries to other disciplines, AR can be very helpful. Lastly, the works of Checkland and Holwell provide a meaningful verification checklist that can potentially improve the truth claim of the AR elements of this research.	Unlike AR, the SSM (even in its original mode) provides a meaningful process that can be followed. The focus on understanding the encompassing system surrounding the researcher gives valuable insights (even if the study was merely an AR study). Most importantly, SSM is one of the few approaches that accommodates for the fuzzy nature of real world problems. Additionally, it accommodated that the researcher could only hope to improve the problem situation being dealt with and then repeat the process for improved results.
Action Design Research (ADR)	**Boardman Soft System Methodology (BSSM)**
ADR provides this study with more relevant guidance given that it implicitly includes design thinking in the process. It is more structured and provides meaningful guiding principles, but a genuine disconnect was found when trying to apply it to this study (given its nature). It was designed for an individual artefact which is iterated. Thus, only insights from the guiding principles can be said to have been extracted.	Similar to the above, BSSM provides a way of modelling the problematic situation but gives a more specific 'artefact' known as a systemigram to do so. For this reason, the modified approach was not used but the helpful literature from Chapter 2 and 4 on systemigrams is very valuable in creating the core deliverable of this study. Thus, the insights from this approach are relevant specifically to the Industrial Thinking Systemigram.
ADR in Enterprise Engineering (ADR EE)	**Two Streams Mode 2 SSM (SSM2)**
A comparison is drawn between the collection of industrial engineers (their interests and interactions) and the nature of an enterprise. Furthermore, given the structured research stages of this methodology, it is clearly ideal for guiding the research portion of this PhD thesis. However, given that the comparison above is merely a simile, changes to the approach are needed in order to create significant value.	The modified (Mode 2) SSM is perhaps the most meaningful piece of literature reviewed because of the matches that can be made between it and a PhD by article publication approach. The cultural stream can be matched with the core problem and appropriate culturally feasible changes that this PhD proposes. Whilst the logic stream matches the aims of the articles, which is to extract systemically desirable and meaningful insights to support the overarching goal.

4.3.1. Visualized Research Methodology

A visual comprehensive summary of the PhD Methodology can be found in Figure 14 below:

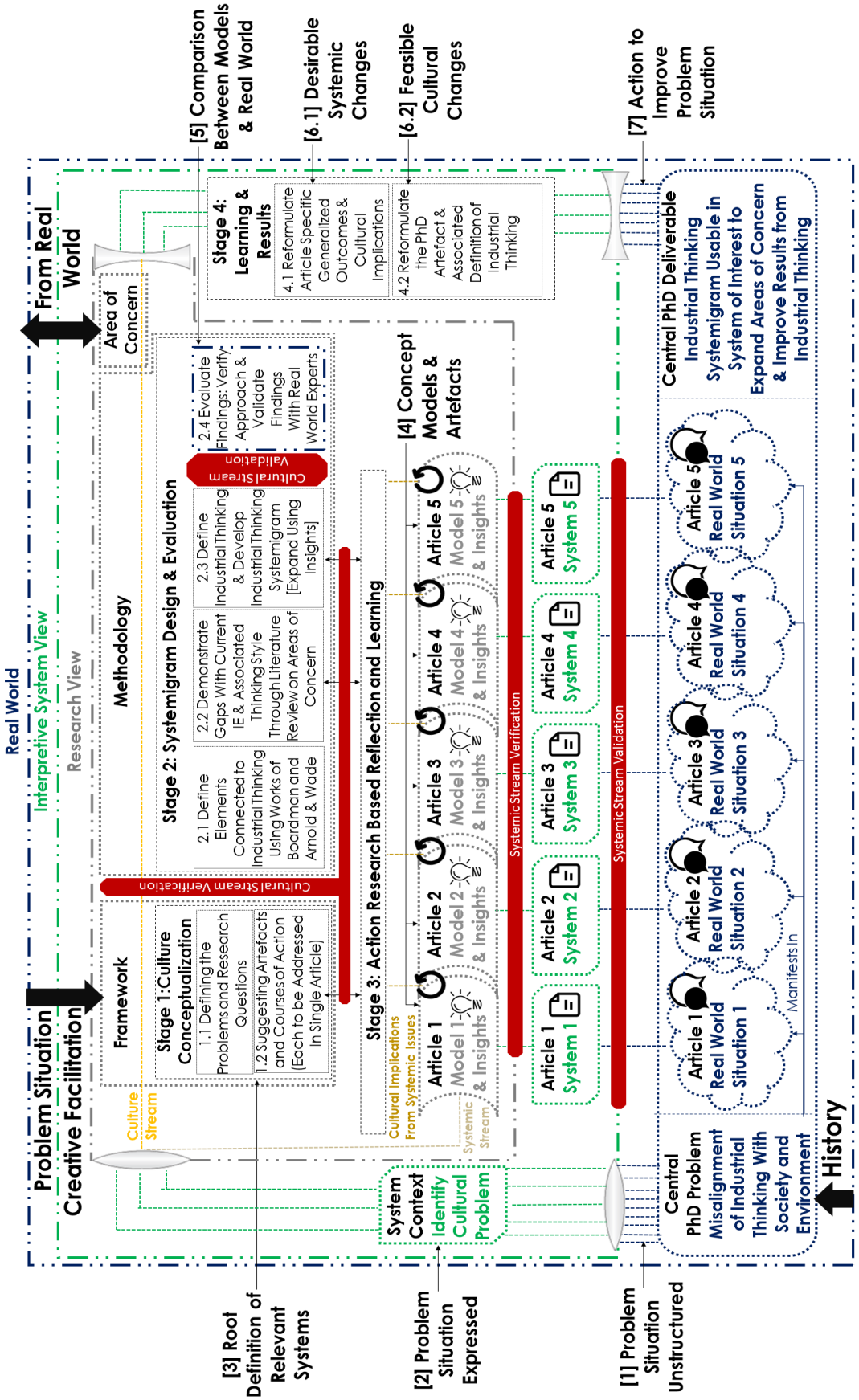


Figure 14: Visualized PhD Research Methodology [Own Work]

4.3.2. Step by Step Description of Methodology

As discussed previously, the main focus and subject of the golden thread of this PhD is the development of an Industrial Thinking Systemigram (which is not available in literature at the moment) and the expansion of its area of consideration through helpful insights uncovered by the PhD-specific literature review and the insights of the articles. Thus, by carefully selecting the areas of concerns reviewed and developing structured interventions (the articles) for said areas, insights that weave into the overall golden thread can be extracted. To achieve this, it was decided that, as a general step by step methodology, the SSM is best geared to 'track' and evaluate the development of the PhD.

Treating the research as a system of its own, it was found that the best approach for distinguishing deliverables within the research boundary is by using the stream idea of SSM2 (separating the deliverables of the overall PhD golden thread from the article thread). In its own right, each article deals with a specific system and aims to model it and do an internal verification and validation. However, the articles (within the context of the study) can be seen as an action taken by the researcher in the system of interest to gain increased knowledge and refine the interfaces between the interacting parts of the research system. Where applicable, the strings of insights from the articles relevant to the overall PhD.

What remained, however, was finding a structured way to conduct the core research itself. For this, the staged process of ADR-in-EE was the most helpful. After minor adaptation to the terms, it provided a way to integrate insights from within and outside the research process. For example, Stage 1 of this process had already been completed as part of the framework definition. Also, given that the nature of the artefact is a systemigram, Stage 2 (design and evaluation) was restructured using the knowledge and processes extracted from the works of Boardman and other scholars. A textual description of the methodological approach (SSM steps with ADR-in-EE stages) followed in this PhD (explaining Figure 14) is given below:

Step 1: Problem situation unstructured

This step was conducted in Chapter 1 of this study. In a sense, this step simply aims to identify some of the elements surrounding the fuzzy problem in an unstructured way. In a nutshell, it was identified that there is some or other misalignment between the IE profession, society, and the environment. This misalignment is not necessarily because of negative problematic situations, but arises from potential opportunities into which can be expanded. A sense that the problem might come from the nature of industrial thinking was identified. However, before clarification, this can only be described as an unstructured problem. Additionally, given the fuzzy nature of the problem and its manifestation in wicked problems, the problem situation can only hope to be improved, and not completely resolved. However partial, even this improvement holds great value for the stakeholders.

Step 2: Problem situation expressed

This step was conducted in Chapter 2 of this study. After some review on systems, their nature, and features (before delving into them), a clear directive was given expressing why the problem is a problem. In order to do this, a system context diagram was drawn visualizing a real world, system, and research domain. They are ultimately linked but require different approaches to the problem that allow it to be expressed. This section does not go into the detail required to identify root causes but agrees with the works of Checkland and Holwell (1998), that a proper framework, methodology and area of concern are required.

Step 3: Definition of relevant systems

This step was performed in Chapter 3 of this study. A formal framework defining the required elements are presented in Figure 6, and followed Stage 1 of the ADR-in-EE process:

> ***Stage 1 (Culture Conceptualization:*** This stage was performed in Chapter 3. A framework identifying the relevant research problems was clearly defined in the form of research questions. An overarching research question was also defined. Similarly, appropriate artefacts, models or courses of action were suggested as objects with a single ultimate objective in mind. This naturally split the two streams. The overarching objectives became part of the cultural stream (golden thread). The cultural stream would follow through the ADR-in-EE staged process to identify the core problem facing the profession as an 'enterprise'. The other objectives would become part of the systemic stream as single standalone articles. The systemic stream would follow through with the SSM2 process of developing conceptual models and artefacts to suggest systemically desirable changes. Each article would address a single relevant system and real-world situation associated with it and ascend the relevant insights to Stage 3 of the ADR-in-EE staged approach.

Step 4: Conceptual modelling and artefacts

This step is performed in Chapter 11 of this study (for the overarching PhD deliverable) with insights from the articles provided in Chapters 6-10. The overarching PhD follows Stage 2 of the ADR-in-EE process (using insights from Boardman and other scholars):

> ***Stage 2 (Systemigram design and evaluation):*** As discussed above, this stage merely structured the design stage to match the predefined deliverable. Only the culture stream would follow through with this stage. It consists of 4 sub-stages: ***Sub-stage 2.1*** Define elements connected to industrial thinking (for the latter design) ***Sub-stage 2.2*** Demonstrate gaps with current thinking style through literature review and research gaps in areas of concern ***Sub-stage 2.3*** Define industrial thinking and develop Industrial Thinking Systemigram (expand using insights) ***Sub-stage 2.4*** Evaluate findings and validate using interviews with real world experts.

Step 5: Comparison between models and real world

This step is performed in Chapter 11 of this study (for the overarching PhD deliverable) and in Chapters 6-10 (for each of the articles). The overarching PhD performed a comparison using the expert evaluation in sub-stage 2.4 of the ADR-in-EE process directly and indirectly received insights from Stage 3:

> ***Stage 3 (Action research reflection and learning):*** This stage can be described as unstructured and is present throughout the document. Essentially, it attempts to represent the emergent learning from the entire process (of writing articles, publishing them, writing the PhD and other forms of reflection and learning). However, it plays an important role in connecting the outputs of the articles with the ADR-in-EE process.

The articles undergo a slightly different process for comparison. Each article goes through a double-blind peer review and is refined further before being presented to a community of industrial engineers (at a conference). During and after this process, feedback is received for the articles that allows the researcher to evaluate whether the model represents real world aspirations.

Step 6: Feasible desirable changes

This step is conducted in Chapter 12 of this study. All the meaningful learning from the various subcomponents (articles) and overarching system are extracted and reformulated to create feasible, desirable changes to the system of interest. However, given that this study follows the two streams concept, a differentiation between systemically desirable (Step 6.1) and culturally feasible (Step 6.2) changes is drawn. This step links with Stage 4 of the ADR-in-EE process:

> ***Stage 4 [Communicated results and learning]:*** After evaluating the results that are extracted from research, they must be communicated in a way that creates meaning to the real world. Each finding has certain implications that arise from the articles or the generalized findings of the PhD. This is the last step of the ADR-in-EE process, but it is followed by identifying what actions can be done since there is a difference between creating new findings and applying them.

Step 7: Action to improve problem situation

This step is discussed in Chapter 12. Naturally, the research undertook both research and actions within the context of a real world. The aim of research, ideally, is to extract meaningful results that have a high truth claim. The aim of action, ideally, is to create positive value for those involved in the system of interest and society at large. Thus, the researcher concludes the steps that will be taken through future research to further create meaningful research and action (alongside other 'would be improvers', 'storytellers' and professionals in the system of interest).

4.3.3. Verification and Validation Method

Research, by nature, must be internally verified and externally validated in order to ensure rigorous and meaningful results (Morse *et al.*, 2002:14). From an engineering point of view verification has two parts: [1] Checking against the specification and [2] representing in a readable form for judgement concerning validity (Van Gennip & Talmon, 1995:52). Validation on the other hand "concerns only the performances of the system itself… at the level of the integrated system [one must ask], do all the modules working together produce the intended result? The result is normally judged against clinical criteria. In the absence of an absolute or gold standard, this normally involves some measure of agreement with the consensus of a panel of experts" (Van Gennip & Talmon, 1995:52).

The definitions above can guide the evaluation of technical or quantitative projects. Yet, they do not particularly resonate with the nature of AR and SSM (both being qualitative). Morse *et al.* (2002:17) explain that "in qualitative research, verification refers to the mechanisms used during the process of research to incrementally contribute to ensuring reliability and validity and, thus, the rigor of a study. These mechanisms are woven into every step of the inquiry to construct a solid product… If the principles of qualitative inquiry are followed, the analysis is self-correcting. In other words, qualitative research is iterative rather than linear, so that a good qualitative researcher moves back and forth between design and implementation to ensure congruence". Morse *et al.* (2002:17) further adds that, in qualitative research, verification is strengthened by thinking theoretically, creating methodological coherence and undertaking theory development.

From an AR point of view this means ensuring that the findings have the highest potential truth claim before being validated. External validation, on the other hand, confirms that the research outputs can be used to make generalizations about the world beyond the research context. Although AR can produce some generalizations, its nature is fundamentally different to that of quantitative studies and requires different evaluation criteria. At times AR research appears as a narrative or storytelling (Heikkinen *et al.*, 2007). Yet, this does not negate the ability to assess AR work critically. Thus, by using appropriate principles and engaging the community of practice, AR can produce meaningful valid results and findings.

The article-based nature of this PhD thesis and the division between the two streams of action (systemic and cultural) creates a need for two verification steps and two validation steps. In principle, whenever a finding (within the research boundary) crosses into the system boundary it must be verified. However, when a finding crosses the real-world boundary it must be validated. These are visualized in Figure 14 as red gates. To some extent the dual verification and validation of both streams assists in evaluating both the research process and deliverables. This serves the above-mentioned goal of rigor and meaningfulness.

The chosen method for verification and validation of both streams can be described as follows [details are discussed in Chapter 11 – Section 11.4.2].

- Internal Verification
  - **Cultural Stream - Verification of PhD Framework:** In Figure 14 this is visualized as a red gate between the components of the PhD (framework, methodology and articles). Before any other form of evaluation takes place, it is vital that the internal cohesion of this document is verified against the requirements set out for a PhD thesis as well as against the thesis' own framework. They university manual for postgraduate research provides a set of criteria defining the nature of PhD research. It goes into detail on the expected contributions of a PhD study, the conduct of the researcher and other important elements. The research must naturally adhere to these guidelines. Moreover, given this is a PhD by article publication, it becomes apparent that the various chapters are components of the overall system (the study) and a strong argument needs to be formulated to verify the link and contribution of this study to the defined framework.
  - **Systemic Stream - Verification using AR Verification Checklist:** In Figure 14 this is visualized as a red gate between the AR reflection and learning, and the articles since the internal process used to generate insights (through reflection and learning) is ultimately AR. Therefore the study should use the works of Checkland and Holwell (1998:20) to verify the internal truth claims of the PhD. The checklist defining the nature of 'good' AR is used as an internal verification mechanism.
- External Validation
  - **Systemic stream – validation using AR validation principles:** In Figure 14 this is visualized as a red gate between the deliverables (systems) of this study and the real world. Above and beyond verifying that the thesis followed 'good' AR, it is important to ensure its external validity. For this, a set of principles discussed in the work Heikkinen *et al.* (2007:8-9) proved valuable since they provide a comprehensive evaluation mechanism that caters for research reports (a thesis being one of them). Although, in theory, this should be done by an external evaluator. The evaluation mechanism does assist in performing a self-assessment on the validity of the AR process.
  - **Cultural stream – validation using semi-structured interviews:** In Figure 14 this is visualized as a red gate between steps 2.3 and 2.4. A mechanism must be used in order to validate the cornerstone of this study, the Industrial Thinking Systemigram, and its associated findings. The IE 'community' needs to be consulted to gain participation in refining the findings of this study. For this, it is found that semi-structured interviews with experts from the IE community (pointed out in Stage 2.4) would be the best approach for evaluation.

5. Research Area of Concern

Areas of concern often have negative connotations. Yet, one cannot deny that there is great value in treating them as opportunities for improvement or themes for research. A generalized definition of the area of concern was used for this study, namely an area in which something is problematic, missing, misaligned or worth exploring further for its potential to generate insight about Industrial Thinking, the field of IE, or the nature of industry in general.

This study used two basic industrial principles in determining whether an area is worth resolving in a stand-alone article: theory of constraints (ToC) and the Pareto principle. ToC was used in a philosophical sense by identifying the weakest link or most important limiting factor preventing the 'system' as a whole from performing optimally or as it should, mainly because improvements in other parts of the system do not lead to an overall improvement; if the ToC process is followed iteratively, the time for improving those elements will come once they become the limiting factor. As for Pareto, the areas worth resolving are those causing 80% of the problem but would require only 20% change or realignment. Naturally, it is impossible to deal with all issues at once or in a single PhD. Thus, focusing the efforts on the 20% of changes which show promise to create 80% of the value is the selected approach.

To avoid a reductionist approach to areas of concern, a holistic literature review of everything related to Industrial Engineering and Industrial Thinking was required. This considered the full system context of its users, instillers, application areas, benefactors and impacts. Thus, a systems approach was taken to identifying areas of concern. Additionally, what was needed was a clear way of portraying these systems. Principles extracted from Chapter 2 helped with this process. The concept of structure (system of systems) whereby each system is viewed as part of a larger system (which creates interfaces and relationships worth exploring), and the concept of cause (end goal) that gives that system meaning, were used. Given that literature defines tens of ways to destructure systems to identify their elements, a practical decision of finding the method of destructuring that most resonates with Industrial Thinking is selected. A high-level system of systems model was extracted from Figure 5 to guide the destructuring process (showing the physical one-to-many and conceptual relationships):

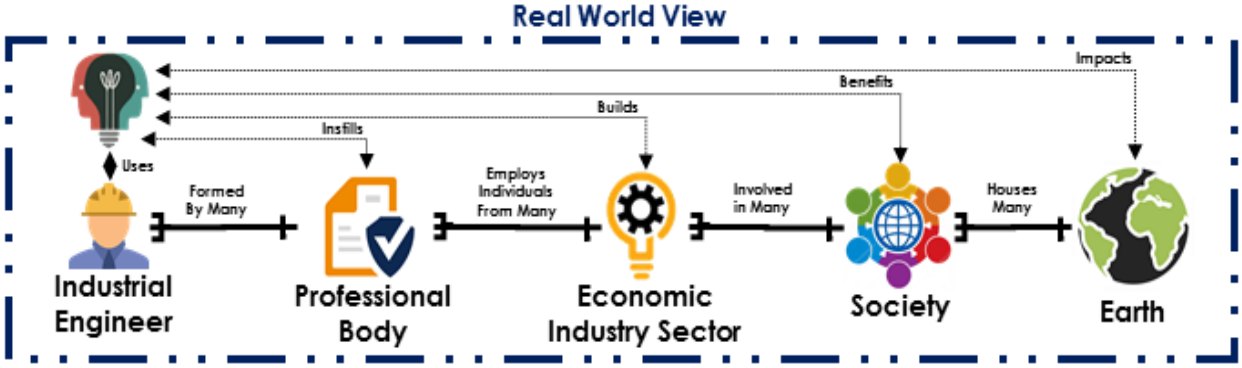


Figure 15: Element-System Relationships for Industrial Thinking [Own Work]

[1] Destructuring: Industrial Engineer

Industrial Engineers must be considered in uncovering Industrial Thinking and related gaps to explore. Individuals choose this field as a profession as a means of living **[Cause]** when it is aligned with certain skills **[Element]** or thinking styles **[Element]** they may possess. Ideally, this field should motivate them and influence certain behaviors **[Element]**. To uphold the profession, the industrial engineer applies their asymmetrical knowledge **[Element]** to benefit society, which helps develop a mutually beneficial relationship. All these elements form a certain professional identity **[Gap]** which is communicated, maintained and furthered by the IE profession **[Supra-System]**.

[2] Destructuring: IE profession

Logically, many industrial engineers form a single 'profession' system which seeks to protect the interest of its members and further develop the field **[Cause]**. This system is typically realized in a professional society **[Element]** and attempts to unite members who share a similar origin or history **[Element]**. This system is also made up of statutory bodies **[Element]** which help with the formal accreditation process of education institutes. Members of the profession maintain a certain asymmetrical body of knowledge which is continuously developed through professional training courses **[Element]**. This helps ensure progress which must be collaborative in nature to ensure that the voices of all stakeholders are heard **[Gap]** in industry which forms the building blocks of the economy **[Supra-System]**.

[3] Destructuring: Economic Activity

In the real world, many professions attempt to differentiate themselves with different value offerings and asymmetrical knowledge. The economy exists to generate wealth through the production and use of goods and services **[Cause]**. There are many ways to view the economy. It can be split into sectors → industries → organizations → business units. However, more relevant to Industrial Thinking is the nature of the activities taking place. The economy can also be viewed as being made up of primary **[Element]**, secondary **[Element]**, tertiary **[Element]** and quaternary **[Element]** economic activity. Significant literature discusses the role of IE in primary, secondary and tertiary economic activity. Yet, given the development of Industry 4.0 technologies and knowledge era forces **[Gap]**, some attention can be given to quaternary economic activity. The economy is naturally part of human activity, but is one of many activities performed by human society **[Supra-System]**.

4. Destructuring: Human Society

Although often equated (alongside the environment) to the economy to form a Venn diagram, human society as a system is far larger in physical size and abstract activity than simply the economy. Only a minute amount of human activity appears in measures such as the gross domestic product. Human society is concerned with its development **[Cause].** For example, a great deal of time is invested in cultural and ethical development **[Element]**. Structurally, human society can be categorized in many ways. The most relevant to Industrial Thinking,

however, is the sociological or psychological classification differentiating pre-Industrial **[Element]**, Industrial **[Element],** and post-Industrial **[Element]** societies, based on their behavior, interactions, and human needs. Although sociologists may argue that these states apply universally, a closer investigation finds that all 3 exist simultaneously around the world and even within a country, given the societies' development and type of economic activity available. Significant work can be done to ensure equal development to benefit bottom-of-pyramid communities by addressing their human needs while respecting their cultures **[Gap]**. However, a genuine concern must be given to ensure that growth is balanced and environmentally sustainable **[Supra-System]**.

[5] Destructuring: Biosphere Environment

All the previous elements combined live under 1 roof: the biosphere. This forms the largest supra-system that can be practically reviewed or analyzed. The biosphere environment has one overall objective, that is to maintain balance **[Cause]**. It is made up of billions of organisms organized into millions of species interacting with various resources in order to thrive and/or survive. Yet, through the lens of Industrial Thinking, three things are relevant because of the type of impact they have on the ability to maintain balance **[Gap]**: Renewable resources **[Element]**, non-renewable resources **[Element],** and the flow of energy **[Element]**.

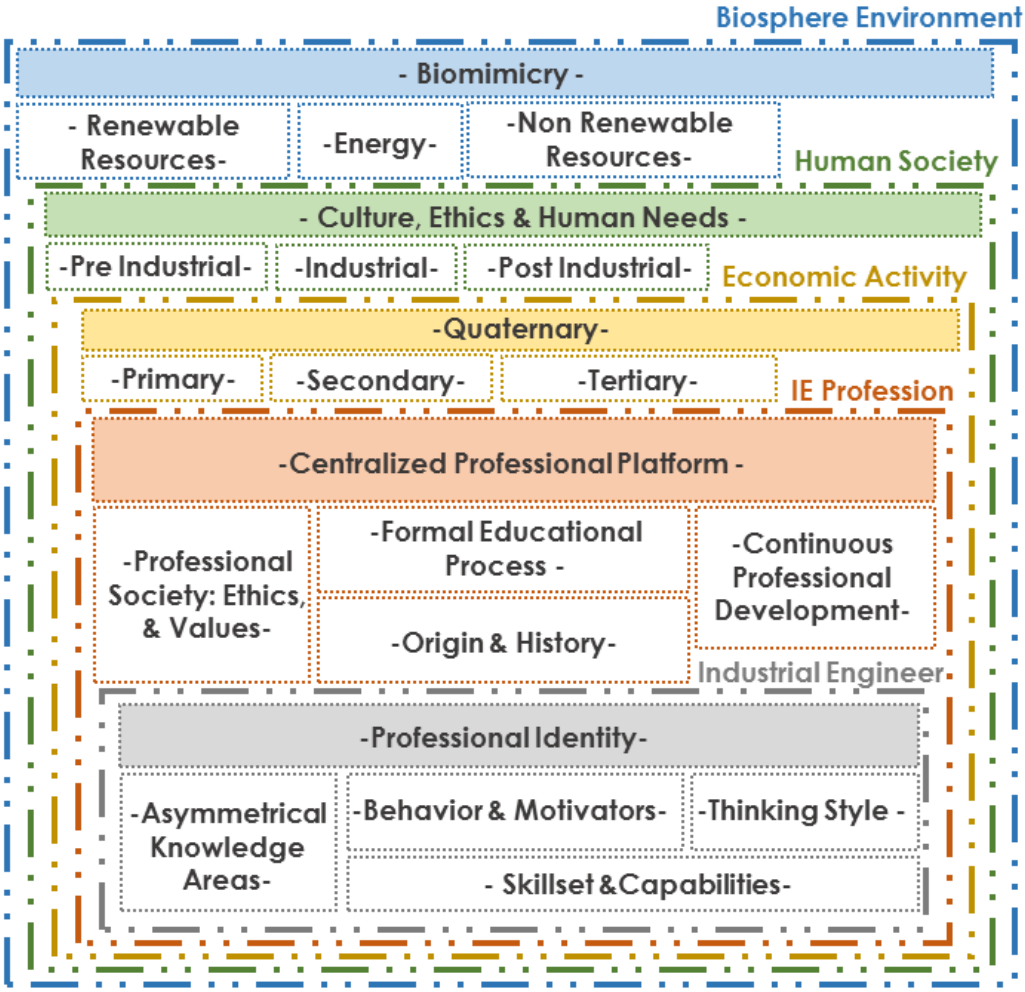


Figure 16: Visualized PhD Research Areas of Concern [Own Work]

5.1. The Industrial Engineer

5.1.1. Asymmetrical Knowledge Areas

The Industrial Engineer is often exposed to a variety of knowledge areas both at tertiary level and within the workplace. The interdisciplinary nature of the field allows for great flexibility in what an individual can become an expert in. Asymmetrical knowledge, however, is defined as knowledge possessed by one party and not the other. This imbalance creates a gap where the industrial engineer can offer their insights. Yet, given that an industrial engineer is not an expert in all the knowledge areas that they are exposed to, what then is their asymmetrical knowledge? It is clear from the Maynard and Zandin (2001) handbook that this asymmetrical knowledge is embodied in the idea of a balanced solution. This means immersing oneself in various knowledge areas and looking at problems from different points of view. Industrial engineers, thus, are exposed to a large body of knowledge to ensure that their solution adds value and considers the integration of their solution to the bigger system (economic, social and even environmental). Yet, these knowledge fields can be filtered down to the following specializations (commonly considered subdisciplines of IE). The most recent definition of these sub-disciplines (in knowledge era) are defined as: “management information systems; systems engineering; modelling and simulation; mechatronics and automation; robotics and artificial intelligence; operations research and operations management; facilities management and maintenance systems; quality management systems; project management; logistics and supply chain management” (Sperotto, 2015:6).

5.1.2. Skillset and Capabilities

An industrial engineer often adapts their skillsets and develops capabilities based on the work environment they are present in. It is also common to see industrial engineers select work based on pre-existing capabilities or future capabilities the individual would like to develop. A study done by Liezl van Dyk aimed to identify what industries employ industrial engineers and how these individuals self-describe their skills. It became immediately clear (in South Africa) how broad the field has spread itself, appearing in everything from mining to banking (shown in Chart 1) (Van Dyk, 2014). It is important to note that industrial engineers perform fundamentally different functions in each of these environments, unlike other fields which might be present there but performing similar functions (such as accounting or administration). Although internationally the industries with strong IE presence might be different, it is no less diverse. More importantly, the study discusses the skills that industrial engineers attribute to themselves once in the workplace. The top skills are: industrial engineering, supply chain management, business process analysis (design or mapping), process improvement (optimization), project engineering (planning or management), continuous improvement, and others (Van Dyk, 2014:8).

It is worth noting, however, that the first skill is the name of the profession (shown in Chart 2). This implies, interestingly, that individuals see “industrial engineering” as a function. The study itself points out that industrial engineering is also the most endorsed skill on LinkedIn (Van Dyk, 2014). This in itself prompts the need for further exploration because it shows that people recognize value in the skill/function. Yet, there is a justified concern about the vagueness of what the skill or term implies.

Chart 1: Industries Where Industrial Engineers are Employed in SA (Van Dyk, 2014)

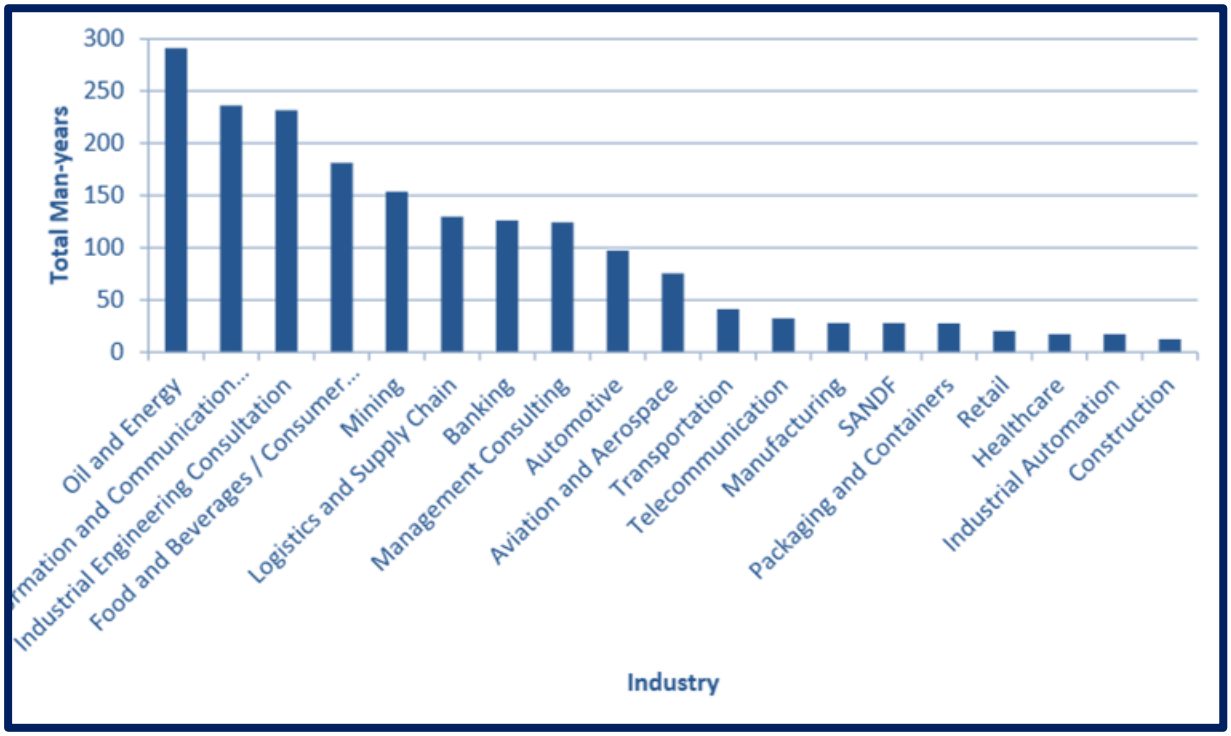


Chart 2: Skills that Industrial Engineers Attribute to Themselves (Van Dyk, 2014)

Skills	Endorsements Index
Industrial Engineering	28.6
Supply Chain Management	28.3
Business Process Analysis / Design / Mapping	28.2
Process improvement/ optimization	19.0
Project Engineering / Planning / Management	18.1
Business Analysis/ Development / Engineer / Architecture	14.8
Continuous Improvement / Kaizan / Six Sigma	13.0
Data analysis / data modeling / analytics / operations res	9.1
Strategy Management / Planning	8.7
Management	8.5
Process and system simulation	7.7
Engineering	7.6
Logistics	6.7
Lean Manufacturing	5.8
Operations Management	5.3

Another way to understand the skills required by an industrial engineer can be taken from an undergraduate recruitment perspective. My Majors is a USA-focused website that gives career advice to prospective students. It provides detailed accounts of the type of individual one must be in order to join a certain field by gathering information about their skills, knowledge areas and workstyle (MyMajors, 2017). The workstyles and their relative importance are shown in Chart 3 below.

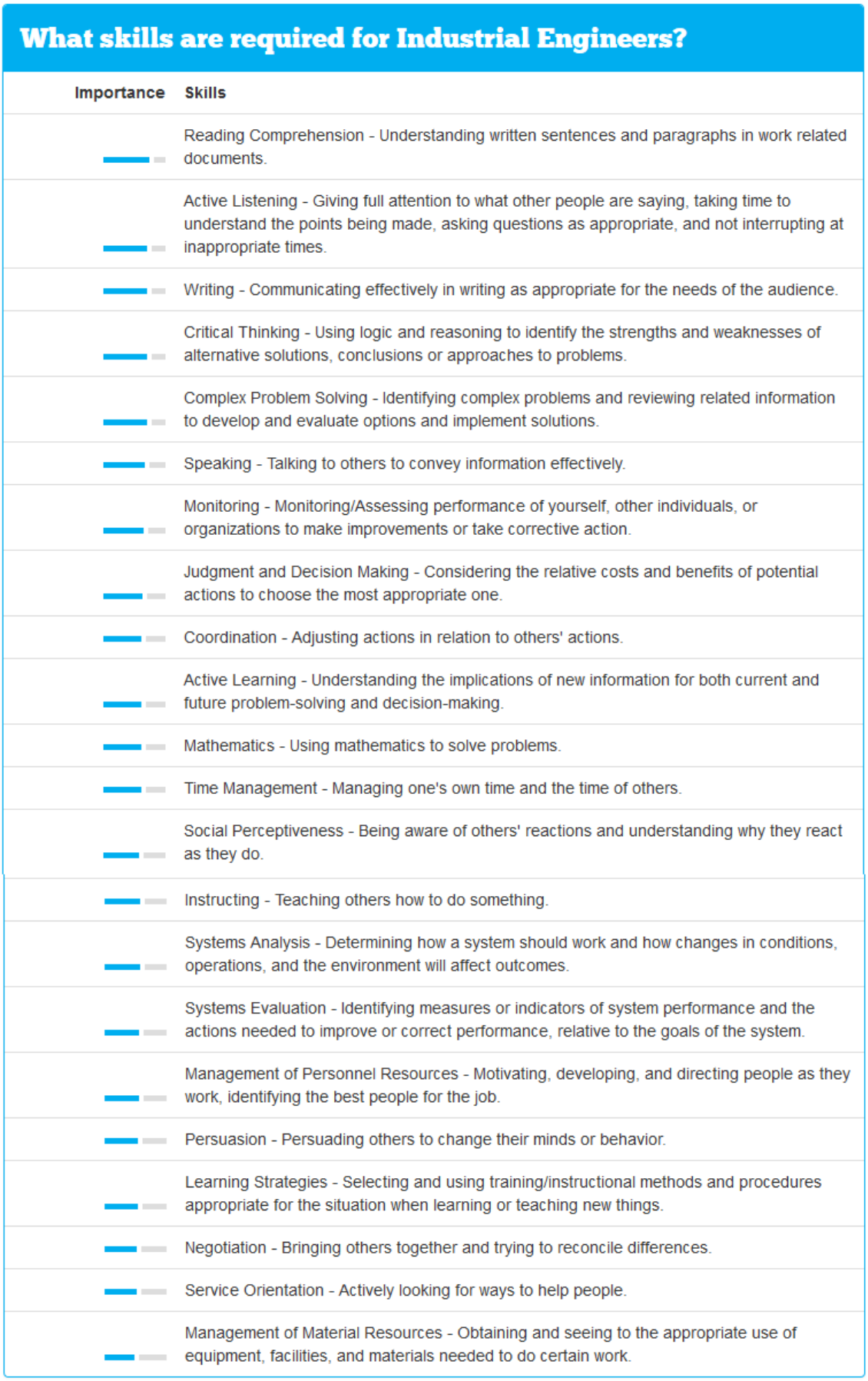
Chart 3: Necessary Work Styles for an Industrial Engineer (MyMajors, 2017)

Work Styles

Importance	Styles
	Attention to Detail - Job requires being careful about detail and thorough in completing work tasks.
	Dependability - Job requires being reliable, responsible, and dependable, and fulfilling obligations.
	Integrity - Job requires being honest and ethical.
	Initiative - Job requires a willingness to take on responsibilities and challenges.
	Analytical Thinking - Job requires analyzing information and using logic to address work-related issues and problems.
	Cooperation - Job requires being pleasant with others on the job and displaying a good-natured, cooperative attitude.
	Persistence - Job requires persistence in the face of obstacles.
	Self Control - Job requires maintaining composure, keeping emotions in check, controlling anger, and avoiding aggressive behavior, even in very difficult situations.
	Stress Tolerance - Job requires accepting criticism and dealing calmly and effectively with high stress situations.
	Achievement/Effort - Job requires establishing and maintaining personally challenging achievement goals and exerting effort toward mastering tasks.
	Adaptability/Flexibility - Job requires being open to change (positive or negative) and to considerable variety in the workplace.
	Innovation - Job requires creativity and alternative thinking to develop new ideas for and answers to work-related problems.
	Independence - Job requires developing one's own ways of doing things, guiding oneself with little or no supervision, and depending on oneself to get things done.
	Innovation - Job requires creativity and alternative thinking to develop new ideas for and answers to work-related problems.
	Independence - Job requires developing one's own ways of doing things, guiding oneself with little or no supervision, and depending on oneself to get things done.
	Leadership - Job requires a willingness to lead, take charge, and offer opinions and direction.
	Concern for Others - Job requires being sensitive to others' needs and feelings and being understanding and helpful on the job.
	Social Orientation - Job requires preferring to work with others rather than alone, and being personally connected with others on the job.

The skills and their relative importance are shown in Chart 4 below.

Chart 4: Necessary Skills for an Industrial Engineer (MyMajors, 2017)



5.1.3. Thinking Style

The Industrial Thinking style is peculiar. On one hand, it appears to have evolved naturally with a changing economy. On the other hand, it remains vague and needs increased awareness and definition. Existing descriptions focus on a central feature of Industrial Thinking which is its birth during the shift of society from pre-industrial to industrial. For example, *Evolution and Thought* by White (2010:39) explains that "one place to look for examples of what changed in thinking styles is the famous French revolution that started in 1789. The people of France wanted a change. They couldn't know that they were asking for a change from good agricultural thinking to good Industrial Thinking". Yet, no account of Industrial Thinking within the context of the knowledge era and Industry 4.0 exists. This lack of a definition made it easy for various sources to criticize the term industrial thinking. Industrial thinking was often viewed as reserved and developed by an elite within an industry. This lead to a disregard for the greater social good or environmental sustainability.

There are examples of applied Industrial Thinking that was shared with and expected of workers as well as managers. Perhaps the best approach which embodies this idea is Toyota's production system (TPS). In a nutshell, this production philosophy focuses on two things: Removing waste (for its economic, environmental, and health benefit), and improving quality (for its positive social impact on workers and customers). Quality in this sense is about the quality of the product, quality of the process and ultimately quality of the life of the people involved in the production. However, TPS saw this as the role of everyone in the organization. In fact, it was the means to gain a competitive edge. Figure 17 and 18, developed by Marksberry (2012), provide some clarity on describing the difference between the traditional way of viewing industrial lean thinking as opposed to TPS thinking.

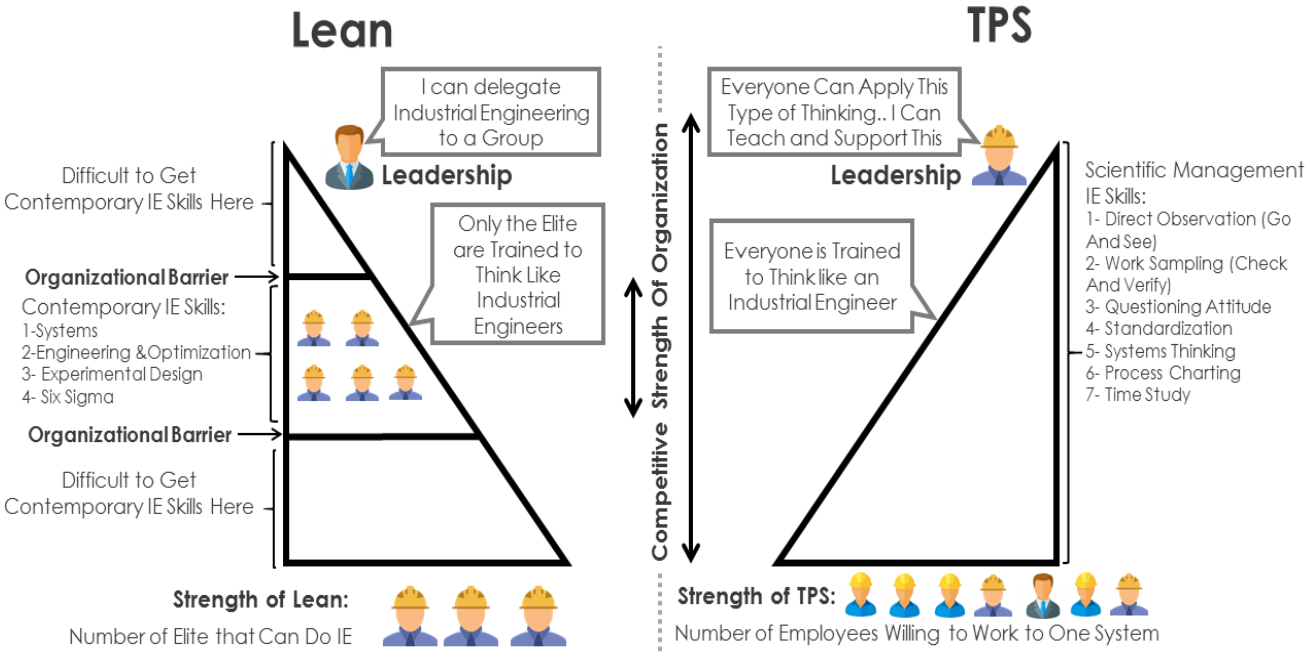


Figure 17: Traditional Lean (IE) Vs TPS Thinking (Marksberry, 2012:48-49)

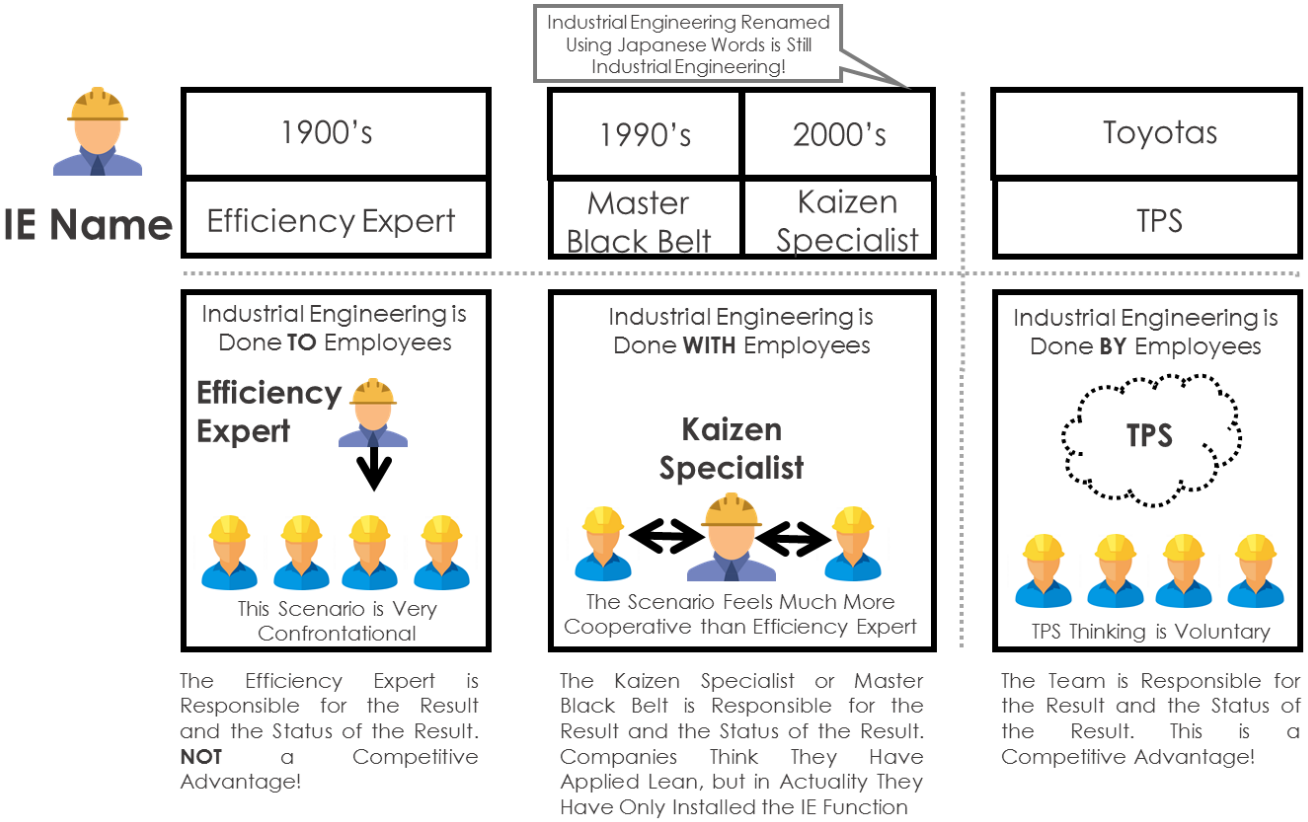


Figure 18: Evolution of IE Application of TPS Thinking (Marksberry, 2012:51)

Although often taken at face value, there is a unique strength in the approach TPS proposes to spread industrial thinking (using TPS) through the organization. Marksberry (2012) shows how Toyota has mastered this intricate balance. Furthermore, Marksberry (2012) argues that companies who apply more outdated methods of implementing an IE function simply do not hold true to the ideals of involving the workers in creating a continuous competitive advantage.

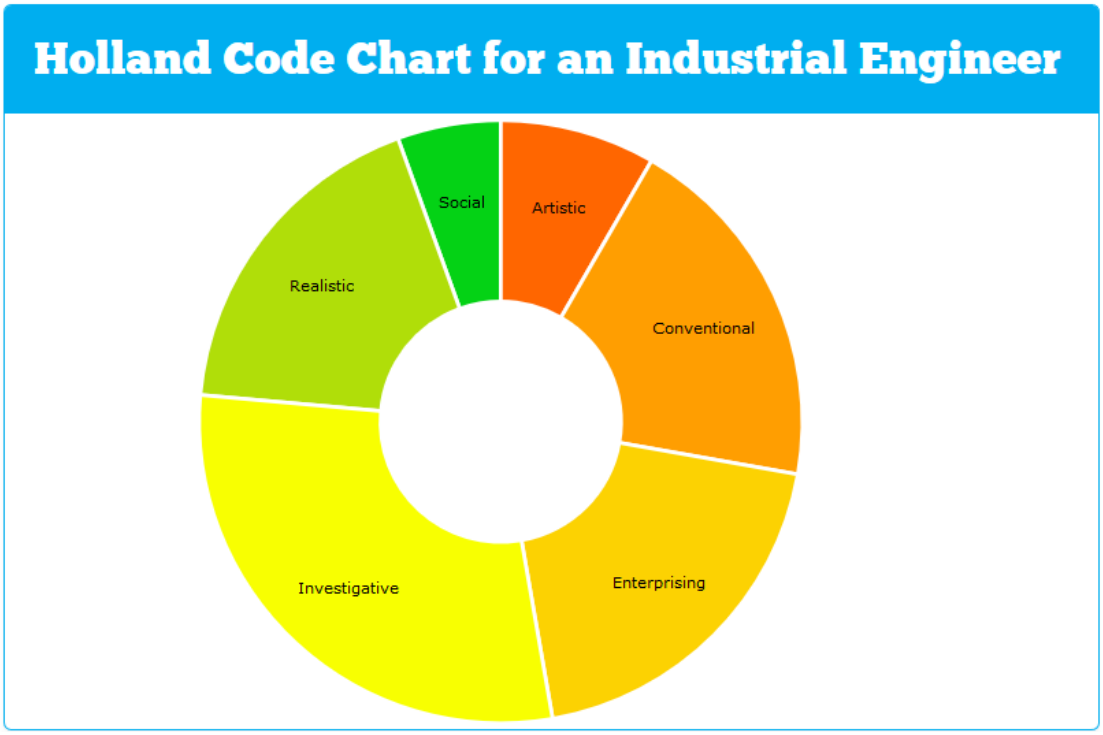
In a poetic sense, ideal Industrial Thinking should be comparable to the nervous system of an organization. Although a central 'brain' might be responsible for design and decision making – every cell should be aware of the organization as a system, collectively communicate decisions through receptive nerves (industrial thinking in the workers) and carry out meaningful activities (Marksberry, 2012). This involvement of the workers is about more than just economics; it is about creating dignity and self-actualization for the workers since they feel part of this larger entity [industry] which naturally improves productivity. It also removes waste which can positively impact the environment. Thus, the problem with current conceptions of Industrial Thinking is clear. As it stands it is viewed as a means of generating growth and cost savings. However, both historical and more modern systems (such as TPS) show that a true user of industrial engineering should understand that by applying this unique thinking style they are generating an entity with a life of its own… capable of largely impacting society and environment. Thus, utter care must be taken when designing industrial systems.

5.1.4. Behaviors and Motivators

Further exploring the psychology of an industrial engineer reveals some of the expected behaviors and motivators. There are various ways of identifying a personality type. However, one personality testing tool which was custom developed for matching individuals with a given profession is known as the Holland code chart. This tool was developed by Jogn L. Holland specifically to address the issue of making career choices. The tool is still used today. McKay (2017) explains that "[a] Holland Code is a three-letter code that is made up of an individual's three dominant personality types out of six possible choices… The six types Holland identified are collectively referred to as RIASEC, the initials standing for the first letter of each of the following personality types: Realistic, Investigative, Artistic, Social, Enterprising, and Conventional… According to Dr Holland, an individual's interests and how he or she approaches life situations determines his or her type. Since human beings are multi-faceted, Holland realized that one wouldn't only fall into a single category. Most people would fall into multiple categories". Uncovering these categories might reveal some of motivators and expected behaviors.

MyMajors (2017) provides a typical Holland code for the industrial engineer. The code is IEC representing investigative, enterprising and conventional. With that being said, there is a significant focus on the other three elements which form the industrial engineer's softer side. The industrial engineer, on average, scores a 7 in investigative, 4.67 in enterprising and conventional, 4.33 in realistic, 2 in artistic and 1.33 in social. The Holland code is shown in Chart 5 below.

Chart 5: Holland Code for an Industrial Engineer (MyMajors, 2017)



5.1.5. Research Gap at the Industrial Engineer Level: Professional Identity

A professional oath is perhaps one of the most interesting forms of promises made by an individual or collective group towards society. One of the longest surviving and well known oaths is the Hippocratic Oath used in the medical profession (Orr, 2009). In modern days, such oaths are usually complimented by more concrete codes of conduct that guide a professional when dealing with human life and society at large whilst providing guidance on the ethical way of using their skills. Yet, oaths can be seen as a collection of condensed ideals which the profession strives to, in turn allowing society to build certain ethical expectations of the medical professional identity. Thus, the attention to detail in the formulation of the oath and exclusivity in selecting those who can undertake that oath (usually through rigorous training) is an attempt to meet society's ethical expectations and uphold the professions ideals.

Orr (2009) discusses that in the modern era "the content [of the Hippocratic oath] has been steadily diluted and secularized, seriously diminishing the core values of the profession". Orr (2009) explains that society almost expects a medical professional to have taken the oath but in reality, a majority of students do not swear this particular oath and have rather developed their own versions or adapted the original oath by excluding certain provisions. The concern is that the "historic combination of skill and moral commitment has devolved in recent years to a lesser concept, that medicine is all about technique, ignoring the moral commitment. He [Robert summarizing Nigel Cameron] concludes that the current practice of medical professional oath-taking focuses more on the process rather than the content" (Orr, 2009). The reason these points are brought up is not to suggest that a professional will necessarily act unethically by taking an alternate oath; rather, it simply highlights that an oaths formulation affects the development of a profession and asking new entrants into a profession to choose their own values or standards can hinder the ethical relationship with society.

Identified Gap:

Various attempts to formalize an oath or code of conduct for engineers have been attempted in the past. However, by comparison to the medical profession (even with its problems) it is safe to conclude that none have truly rallied the support of the majority of engineers (globally speaking). This is perhaps because there are significant differences in the work that different engineers take (which is aligned with their identity). Most engineering disciplines lack a formal professional identity (including IE). Thus, one method of reaching the ideal of a professional oath (made to society) is by figuring out what fundamentally makes up the professional identity of an industrial engineer. From there, a set of promises that highlight the ethical responsibility of the industrial engineer can be formalized into an oath. This can be an area of concern (theme) and needs to be explored further in a separate article [Chapter 6: Article 1].

5.2. The Industrial Engineering Profession

5.2.1. Origins and History

The term Industrial Engineering (and its associated work style) was most likely "forged in mills and on shop floors at the turn of the 20th century, [where] industrial engineering sought to tame the social and economic turmoil that emerged as productive activity shifted from fields to cities, from hand tools to dedicated machines and from steam to electrical power" (Bailey & Barley, 2005:737). The Engineering Council of South Africa ECSA (2017a:3) defines the roots of Industrial Engineering "in the work of Fredrick Taylor, and Gillian and Frank Gillbreth, all of whom focused on the improvement of worker productivity in the latter part of the nineteenth century."

Problems related to productivity in industry were complex and scalable enough to warrant a dedicated engineer resolving them. What industry required at that stage (and still does today) was an individual with the technical skills, capabilities, and problem-solving mind-set of an engineer, but with the additional ability to step back and see the whole picture from beginning to end. Additionally, problems in industry most often manifest themselves as problems of scaling up and down, integrating properly, aligning demand with supply, and so on. Part of the focus of IE in the 20th century was on work studies, standardization, and production lines, which required a novel solution to problems resulting from the complex connection between workers and their health (human), productivity (economy) and resources (environment). They also, for example, "experimented with incentive plans, which they believed would enhance motivation and yield workers a fairer wage" (Bailey & Barley, 2005:737). industrial engineers became "widely known [for] organized and streamlined procurement, inventory, quality and accounting systems. They redesigned machine tools to increase accuracy and efficiency" (Bailey & Barley, 2005:737).

5.2.2. Professional Societies: Ethics and Values

Over time, industrial engineers naturally organized themselves into professional societies with the aim of protecting their profession. Around the world, different societies formed in the early 20th century to suit their specific legal structures. An interesting well-researched example comes from South Africa. The industrial engineering profession (although not formalized as of yet) rooted itself initially with the growth in industrialization in South Africa (prompted by the mining industry). Further developments in Industry (reaching over 10 000 industrial establishments by 1939) required a new type of engineer. Initially, the individuals collected themselves in the formal body known as production engineers (later titled manufacturing engineers) (Sperotto, 2015:3). Political and structural developments in government, around the late 1960's, allowed for the establishment of a council for professional engineers which "signaled official recognition for engineering as a self-governing profession" (Sperotto, 2015:5).

It was only around that time that the first department for industrial and systems engineering was developed. The South African Institute for Industrial Engineers followed after only 10 years when there were sufficient members worth protecting (Sperotto, 2015:7).

Yet, an often forgotten element alluded to in Sperotto (2015) is the importance of developing an identity and professional ethic which challenges initial assumptions or starting conditions of a profession (given for example that the engineering profession in South Africa was mainly male dominated). “All industrial engineering, product designers, and managers must at some point in their career face an issue that requires some amount of ethical or moral judgment” (Savory, 1999:1). Although the area of professional ethics and values in Industrial Engineering is still in development, its importance has been acknowledged. Different countries focus on different aspects of professional ethics (relevant to their culture). Two cases will be discussed to contrast east with west in this section. The first is the code proposed by the Institute of Industrial and System Engineers in the USA. The institute, with rightful reason, sees Industrial Engineering as a subset of engineering activity and in order not to drift away from the overarching professional responsibilities of the engineer, it endorses the canon of ethics provided by the accreditation board for engineering and technology (IISE, 2017a). The code lists that:

The Fundamental Principles: *Engineers uphold and advance the integrity, honor and dignity of the engineering profession by:*

1. *Using their knowledge and skill for the enhancement of human welfare;*
2. *Being honest and impartial, and serving with fidelity the public, their employers and clients;*
3. *Striving to increase the competence and prestige of the engineering profession; and*
4. *Supporting the professional and technical societies of their disciplines.*

The Fundamental Canons:

1. *Engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties.*
2. *Engineers shall perform services only in the areas of their competence.*
3. *Engineers shall issue public statements only in an objective and truthful manner.*
4. *Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.*
5. *Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.*
6. *Engineers shall associate only with reputable persons or organizations.*
7. *Engineers shall continue their professional development throughout their careers and shall provide opportunities for the professional development of those engineers under their supervision.*

The list covers many of the concerns society has towards engineering activity (including Industrial) and if followed can result in a significant improvement in proliferation of ethical engineering behavior.

Another case study of industrial engineer professional ethics and values comes from the Philippines, where Jose F. Rafols proposed an Industrial Engineering act that regulates and guides the field (Rafols, 2010). This builds onto ongoing discussions regarding laws in the Philippines that regulate the practice of Industrial Engineering (The Industrial Engineering Law of 2006) and the act that optimizes workload and ensures safety for employees (The Workload Optimization Act of 2006). The proposed acts define the field of IE, set responsibilities, and even provide penal provisions for not following the proposed law regulating IE activity. Most interesting is the reason justifying the need for the law which states that "the government recognizes the vital role of industrial engineering in nation-building and sustainable development through the adoption, development and implementation of effective programs in productivity improvement, industrialization and full and efficient use of resources. The government shall therefore develop and nurture competent, virtuous and productive and well-rounded professional industrial engineers" (Rafols, 2010). Furthermore, Rafols (2010:12) argues that the passage of the law will:

1. *Regulate the professional practice of Industrial Engineering in the Philippines.*
2. *Enhance the Industrial Engineering profession in the national and international level.*
3. *Require candidates who fulfill the education and experience requirements and passed the rigorous exams that, under licensure laws, permit them to offer engineering services directly to the public. Licensed industrial engineers take legal responsibility for their engineering services and are bound by a code of ethics to protect the working environment, public health and safety.*
4. *Generate improvement in the quality of industrial engineering education as educators of industrial engineering courses will be required to have an IE license before they can teach.*
5. *Mandate that office and manufacturing layouts and equipment will be designed, evaluated and signed off by a license Industrial Engineers prior to installation or constructions of such facility.*
6. *Require that project feasibility studies for new office buildings, production plants, warehousing or other operation facility for profits be submitted to financial institutions for funding should be prepared and signed off by a licensed industrial engineer.*
7. *Require consulting engineers in industrial engineering to possess an IE license before they can practice.*
8. *Require that new development of automation processes should be approved and in consultation with a licensed industrial engineer.*
9. *Require licensed industrial engineers to support the Workload Optimization Act of 2006.*

10. *Require licensed industrial engineers to perform office and manufacturing ergonomics as a requirement for providing employees comfort in the workplace and reduce workmen's compensation payments.*
11. *Require licensed industrial engineers to have manufacturing and office establishments comply with occupational safety and health act.*
12. *Require that resolution of capacity, quality and productivity issues when brought to trial in local court will have the services of a licensed industrial engineer.*
13. *Require employers that engineers tend to or are working as an industrial engineer shall have a licensed to practice otherwise will be subject to fines or penalty.*
14. *Will require educational institutions and employers to follow the guidelines of the industrial engineering licensure laws as mandated.*
15. *Will not be able to use the title of "Industrial Engineer or Professional Industrial Engineer" unless he or she passed the licensure requirements.*

The two cases above are obviously not the only ones globally. The developed culture of Industrial Engineering in countries like Germany and Japan has led to various regulations which indirectly manage professional ethics. Moreover, in Japan (being one of the instigators of many quality and production philosophies), values that match overarching cultural values of the country are instilled in Industrial Engineering. The same can be said for Germany where cultural and legal norms heavily regulate the field.

5.2.3. Formal Education Process

The first formal IE department was founded at the Pennsylvania State University in 1909 (Van Dyk, 2014). The next 20-30 years saw the rise of the discipline globally. In South Africa, the University of Pretoria launched its IE department around 50 years later, in 1962, with Stellenbosch and Wits following soon after (Van Dyk, 2014). The North-West University is the most recent to launch an IE department. Students typically start out with a 3 or 4-year undergraduate degree in Industrial Engineering (BEng or BSc). Universities in South Africa that are accredited by ECSA receive the benefits of the Washington accord (which grants the comfort of knowing the degree will be accredited internationally in Australia, UK, USA, Canada and other countries). Upon completing their undergraduate degree, industrial engineers can go into the work world to gain experience, before returning for postgraduate studies, or enroll directly in a BEng Honors or MEng degree in Industrial Engineering. For some time, it has been possible to achieve PhD status in the field of Industrial Engineering upon completing a relevant master's degree. Whether in academia or the workplace, however, IE professionals are encouraged register as candidate professional engineers and undergo professional development to gain professional engineering status (Pr Eng).

5.2.4. Continuous Professional Development

Globally, a variety of techniques are used to assess professional status ranging from examinations to mentorship. Professional Industrial Engineering status in South Africa can usually only be achieved after a certain number of years of training under another professional engineer, displaying managerial and ethical capabilities and showing excellence in the field of Industrial Engineering (ECSA, 2017b; NSPE, 2017). A report with relevant forms are then submitted to ECSA for evaluation. Typically, it is beneficial for a student graduating from an ECSA accredited course in Industrial Engineering to be registered as a candidate professional engineer (after graduating).

Students are not expected to undergo Continuous Professional Development (CPD) per se as part of the first registration (ECSA, 2013). However, every 5 years following their initial registration, a professional engineer is expected to collect a number of points in different categories (ECSA, 2013). ECSA (2013:5) defines the purpose of CPD as “the systematic maintenance, improvement and broadening of knowledge and skills, and the development of personal qualities necessary for the execution of professional and technical duties throughout a person’s Engineering career”.

The three categories defined by ECSA where a professional engineer can receive CPD points during the 5 year cycle are: 1) Developmental Activities 2) Work Based Activities and 3) Individual Activities (ECSA, 2013). The professional engineer must achieve at least 5 credits from at least 2 of the 3 categories. Activities which count towards professional development include conferences, lectures, mentoring other engineers, publishing papers, evaluation of academic works and even self-study (ECSA, 2013).

Currently, the system used for continuous professional development in South Africa and in many emerging countries remains somewhat static. Additionally, it has been noted that there is a challenge in getting young engineers to register as candidates and achieve professional status. When investigating the reasons, it appeared that the cost-benefit of doing so does not justify the decision. Additionally, there is lack of understanding of the importance of professional status. However, it appears that some of the blame is to be placed on the professional entities for engineering and industrial engineering who have, unfortunately, not taken the steps towards rectifying problems with their own system (application and CPD). Additionally, their understanding of their role needs to change radically to become more involved in the profession they are set up to protect.

5.2.5. Research Gap at the Profession Level: Centralized Professional Platform

In their handbook on Industrial Engineering, Maynard and Zandin (most recent is the 5th edition published in 2001) provide what can be described as the most comprehensive resource about IE, its sub-disciplines, its future and the often-forgotten intricacies surrounding the field. The 2000+ page handbook remains an important reference point and guide for the development of the profession. One of the most stimulating sections in the Handbook of Industrial engineering is titled “Is Industrial Engineering Dead?” (Maynard & Zandin, 2001). Although the section might seem controversial at first (due to the proposed question), it is actually a forward looking predictive analysis of what sub-disciplines can emerge and be directly attributed to IE especially since “the ability to forecast the direction of a profession is extremely difficult, if not impossible” (Maynard & Zandin, 2001:95). The authors explore what alternative terms can replace/enhance the term ‘industrial’ in order to more accurately reflect the work undertaken by an industrial engineer. The authors prefer utilizing terms beginning with ‘I’ in defining the alternatives and define “innovation engineering, integration engineering, information engineering, involvement engineering, instruction engineering, intellectual engineering and international engineering” (Maynard & Zandin, 2001) as possible substitutions. Yet, it appears that there is consensus that the term and field of IE is here to stay even if in an overarching capacity to other more specialized forms of IE.

Identified Gap:

Almost 17 years after the publication of this handbook, there remains to be a lack of global communal effort to discuss the current state of the profession and shape its future. The problem, however, does not lie with a lack of literature (journal articles and electronic resources). Rather, it is with the lack of a dynamic and interactive platform that involves the full lifecycle of the profession (to ensure continuity). Ideally, every stakeholder in the profession (stemming from high school graduates to current employers all the way to retired professionals) would benefit from having a place to congregate. Centuries ago, guilds had physical locations. In the knowledge era, electronic platforms can serve the same purpose. Developing a centralized platform that allows everyone involved in the profession to be on the same page needs to be explored. This platform should be global with localized sub-pages. As a general approach, gamification has proven successful in attracting the attention of generation Y and Z learners (which appear to have similar behaviors globally). This centralization would also allow some of the problems with professional registration to be resolved (by adding badges and awards, for example) for excellence in aspects of IE. Moreover, centralizing this platform would allow for the development of an internal ethic of this online society (which can be enforced by senior members). This can be an area of concern (theme) and needs to be explored further in a separate article [Chapter 7: Article 2].

5.3. The Economy

Typically, in IE discourse, the economy is seen as more important than society and the environment. A systems perspective of this concept finds two major flaws: 1) The economy should not be equated with the above supra-systems because it creates an implicit idea that economic, social and environmental considerations should be treated the same way, and 2) Treating the system in silos is a drastic oversimplification which tends to inflate the importance of the locus of control (which typically falls within the economy) and generates unbalanced and unsustainable solution (StatsNZ, 2008; Hermes, 2011). Additionally, a variety of sources tend to treat each factor as a silo and sub-divide it further into smaller silos (OziPolitic, 2006). A Venn diagram was created to display the development in understanding which must be catered for in IE discourse.

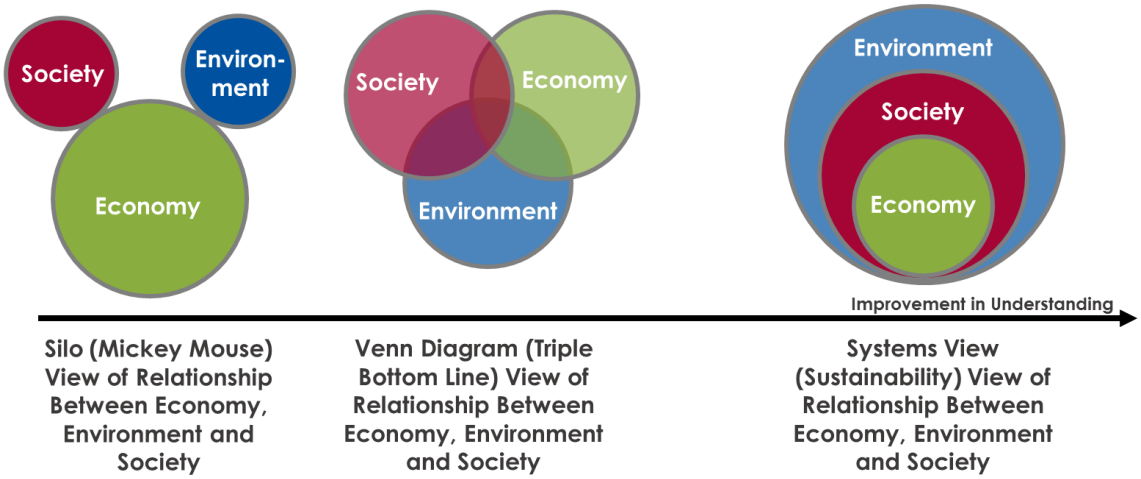


Figure 19: Evolution of Economy, Environment and Society Relationship [Own Work]

Our understanding of this relationship has evolved over time (displayed in Figure 19 above). However, a fundamental understanding of how the economy works and a critical analysis of why economic activity is a subset of the two supra-systems is needed. In this section, de-structuring the economy based on the type of activity taking place is the best approach. Once again, in order not to fall into a reductionist mindset, it must be highlighted that this de-structuring is merely to assist in understanding the economy. Economic activity can be very intertwined with blurred barriers between sectors (due to technological forces) (Pol *et al.*, 2002). Yet, a critical system perspective can assist in compartmentalizing economic activity. For the purposes of this section, economic activity will be broadly defined as "actions that involve the production, distribution and consumption of goods and services at all levels within a society" (BusinessDictionary, 2017b). A sector is "an area of the economy in which businesses share the same or a related product or service… [or] shares common operating characteristics" (Investopedia, 2017c). Typically speaking, the economy is subdivided into 4 or 5 major sectors: primary (gathering of raw materials), secondary (manufacturing of products), tertiary (delivery of services) and quaternary (utilization of knowledge). Some sources also add a Quinary sector focused on governmental and public services (Rosenberg, 2017).

5.3.1. Primary Economic Activity

Primary economic activity is centered around the "extraction and harvesting of natural products from earth" (Investopedia, 2017c). It "includes agriculture, mining, forestry, farming, grazing, hunting and gathering, fishing and quarrying. The packaging and processing of raw materials are also considered to be part of this sector" (Rosenberg, 2017). Although this sector has changed drastically, due to technological development, the nature of its output remains to be the raw materials which typically defines it. Due to operational efficiencies brought about in industrial revolutions, this sector does not employ many people in developed and developing countries. However, its importance is undeniable since it forms the foundation for the rest of the sectors (Rosenberg, 2017). This is especially true in developing countries where a majority of the poor and unskilled find subsistence and fulfilment in this sector. For example, Tripathi (2016:17) shows how despite the helpful impact of industrial development on economic growth, agriculture in the Uttar Pradesh economy remains the main engine of economic growth because "despite substantial increase in the share of both the industry and the service sectors in GSDP, the results suggest that the agriculture sector plays the main role in determining the overall growth rate of the economy through its linkages to the other sectors. The analysis of intersectoral linkages identifies agriculture as the main economic activity that controls other economic activities. This finding is also sustained at the disaggregate region level analysis. Thus, economic development can be accelerated by concentrating on the agriculture sector." This holds true for many countries and an appropriate investment in infrastructure and governance in this sector can yield positive results (Tripathi, 2016).

The primary sector employs a fair number of industrial engineers (especially in developing economies such as South Africa). Typically, the role of an industrial engineer in this sector is the optimization of the extraction of resources. Yet, a critical analysis of this approach finds that perhaps it requires significant re-alignment. Wolfe (1955:406) points out that "an increase in productivity [in the primary sector], in terms of goods and services per man-hour, is limited by ***natural growth factors***". Modern accounts confirm that it is detrimental, at times, to approach this sector in the same way that one approaches secondary (manufacturing) and tertiary (services) sectors (Lister & Donaldson, 2011). This can mainly be attributed to social and environmental factors. Socially, the communities surrounding primary economic sectors are fundamentally different to those of urban communities. Efficiency and productivity measures must be adjusted in order to cater for their culture and lifestyle. Additionally, the seasonal nature of economic activity in this sector brings about its own challenges (This aspect will be discussed further in 5.4). Environmentally, it is important to realize that growth is not unlimited. Everything done within this sector should be limited by the biosphere's ability to regenerate (otherwise local peaks in production will result in long term devastation) (This aspect will be discussed further in 5.5).

5.3.2. Secondary Economic Activity

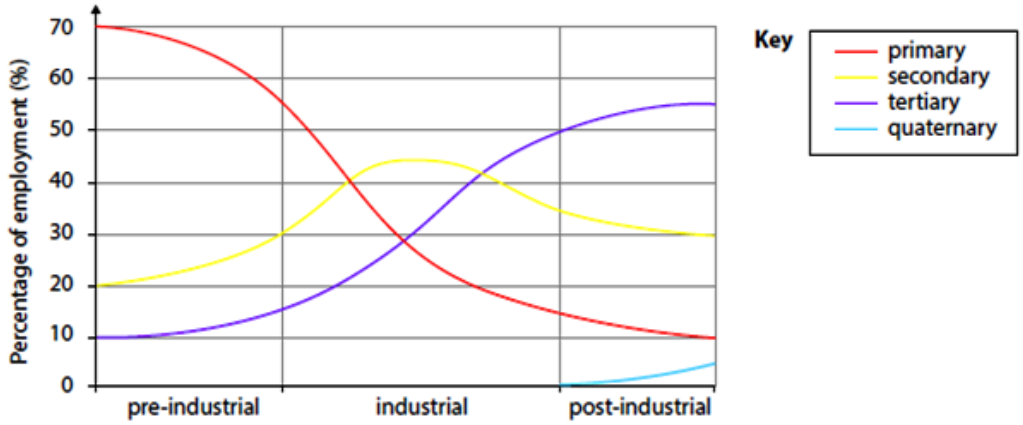
Secondary economic activity is centered around the "processing, manufacturing and construction companies" (Investopedia, 2017c). It "produces finished goods from the raw materials extracted by the primary economy. All manufacturing, processing, and construction lie within this sector. Activities associated with the secondary sector include metal working and smelting, automobile production, textile production, chemical and engineering industries, aerospace manufacturing, energy utilities, engineering, breweries and bottlers, construction and shipbuilding." (Rosenberg, 2017). Many countries are shifting away from this sector and outsourcing their production. However, this sector (much like the primary sector) holds a unique importance to economic development; the ability of a country to manufacture its own goods allows it to achieve a level of self-reliance which has notable value. Typically speaking, countries that are said to be in the post-industrial age find themselves de-industrializing (from a manufacturing point of view).

Although the secondary sector has existed for centuries (if one takes a broad definition of its product or manufactured goods-based output), its undeniable link with the first and second industrial revolution is strong. In fact, it should hold a special place in the memory of the industrial engineer since its rise was marked with the birth of the profession (Sperotto, 1994; Maynard & Zandin, 2001). Although many of the initial IE tools and techniques are still applicable in this environment, developments in machinery are changing the role of industrial engineers in this sector. However, much like the primary sector, the secondary sector too has an overarching limiting factor (on its outputs). Wolfe (1955:406) points out that "an increase in productivity [in the secondary sector], in terms of goods and services per man-hour, is limited by ***mechanical factors****".* Developments in additive manufacturing and robotics technology deserve special attention when analyzing productivity in this sector. In a nutshell, additive manufacturing operates on the idea that raw material (typically in the form of liquid or powder) is added to form the final product instead of subtracted from large chunks of material (using traditional manufacturing processes). Although each process still has its place in secondary sector industries, additive manufacturing is arguably one of the most environmentally friendly due to its focus on wasting as little energy and as little material as possible (This aspect will be discussed further in 5.5). Robotics, on the other hand, is an important development in this sector which replace human workers with intelligent machinery. This too has various social connotations which need to be considered since one of the main reasons for the development of robotics is to reduce risk exposure to workers (from dangerous processes and material), improve working conditions and ergonomics (by ensuring that workers are given more meaningful jobs less focused on repetitive activities), and ensuring productivity & quality (This aspect will be discussed further in 5.4). It is not uncommon to see IE departments recognizing these factors as subdisciplines of IE (Maynard & Zandin, 2001).

5.3.3. Tertiary Economic Activity

Tertiary economic activity is centered around the "comprised of companies that provide service" (Investopedia, 2017c). It "sells the goods produced by the secondary sector and provides commercial services. Activities associated with this sector include retail and wholesale sales, transportation and distribution, restaurants, clerical services, media, tourism, insurance, banking, healthcare, and law" (Rosenberg, 2017). In developed countries, most of economic activity takes place in the tertiary sector. A prominent chart that shows the shift from primary to tertiary based economies is known as the Clark-Fisher model. As can be seen in Chart 6 below, levels of employment in primary sectors drop dramatically with the rise of the tertiary sector. This is perhaps due to other factors such as urbanization and an increased demand for luxury services as society enters a post-industrial state.

Chart 6: Clark-Fisher Model on Sector Employment Vs Society Type (Kokkinos, 2014)



Ever since the third industrial revolution, industrial engineers have heavily focused on various fields centered around service design. Yet, given that many developing countries in the world are still transitioning to the tertiary economy, significant work is still possible in this economic sector. industrial engineers in academia and industry have often provided very valuable case studies in literature discussing just how much inefficiency exists in this sector of the economy. The past 10 years, however, have seen the transformation of the retail, banking and logistics industry (typically seen as the core of this sector). Wolfe (1955:406) points out that "an increase in productivity [in the tertiary sector], in terms of goods and services per man-hour, is limited by ***relatively unaided human skill***". This transformation embraced technological change, clarified value propositions and built more accurate financial models. Interestingly, the two major problems with this sector lie with its connection to the two supra-systems. Firstly, it is no surprise that the way in which this sector is designed caters only for higher earning segments of a society. Bottom of Pyramid (BoP) segments are left to envy services and offerings priced for specific income groups. Even in developed countries, some aspects of this chasm hold true (This aspect will be discussed further in 5.4). Secondly, various sources are cited highlighting their concern for the sustainability of this sector given its high resource and maintenance requirements (This aspect will be discussed further in 5.5).

5.3.4. Research Gap the Economic Level: Quaternary Economic Activity

History and countless case studies uncover how a genuine understanding of the role of the industrial engineer in development can unlock unimaginable value. This is because IE has continuously realigned itself as a mediator between technology and society in order to maintain its problem-solving capability as a profession. Nick von Tynzelmann (1997:10) in quoting Henry Palmer states that “an Engineer is a mediator between the philosopher and the working mechanic, and, like an interpreter between two foreigners, must understand the language of both...Hence the absolute necessity of his possessing both practical and theoretical knowledge”. This description, although simple, highlights the important role of balance in the profession (which in some way is part of an unspoken ethic when implemented). Thus, ideally, the mindset is one of designing system (based on scientific knowledge) to benefit mankind and for that it is instrumental to understand the needs of society and the potential impact of IE activity. Sheena *Ong (2015)* accurately summarizes this in her post for Engineers Without Borders (EWB):

> *When it comes to the "infrastructure" of our lives, the fingerprints of engineers are everywhere yet are so often overlooked. Our basic needs - shelter, warmth, clothing and so on - are met through the ingenuity of those who have harnessed science to creatively solve the problem of humans (7 billion of us!) having needs and desires. Engineers design and deliver the systems, processes, devices and structures that fulfil them, enabling us to live the way we do or move towards how we'd wish to. Engineering is central to our lives, and when I say it provides “infrastructure” I don’t just mean it in the roads-and-bridges sense. When I talk about the infrastructure of our lives, I mean the whole shell that encloses what it means to be me, to lead the life I do. I mean the surroundings, the settings, the devices and the objects that define my condition – identity, experience – in the world. Engineers are responsible for so much of this*

The question, however, is what type of infrastructure does an industrial engineer create? On one hand it can be argued that physical factories used to be the output of IE in the first industrial revolution; however, every Industrial revolution since has shifted the field towards more system based intellectual infrastructure. The handbook (Maynard & Zandin, 2001) provides case studies and forward-looking observations that immerse the reader in the world of IE. Surprisingly, even at 16 years old (as of 2017), the handbook foresaw developments in technological infrastructure such as Virtual Reality (VR), advanced manufacturing and simulation technologies that it predicted would largely change the world of IE (Maynard & Zandin, 2001). Yet, the rapid development of these technologies and other global macro forces has outpaced and challenged a significant amount of the knowledge present in that handbook.

Identified Gap:

The question above highlights the industrial engineer's strongest value proposition: ***Intellectual Infrastructure***. Unlike most professions, the IE profession has always maintained a macro-view of problematic situations. This way of thinking became extremely valuable since problems are very rarely localized and often manifest in the system as a whole. That is particularly why intellectual infrastructure created the value that it did. Intellectual infrastructure provided a way to make improvements to physical systems using abstract ideas. It was the 'software' of the factory or facility's physical hardware. This view is particularly attractive if one takes a connectivism view of knowledge.

Connectivism conceptualizes and visualizes knowledge as a mere set of nodes and links (AlDahdouh *et al.*, 2015). Although simple, this method has attracted much attention for its ability to understand value generation from connections. Still, one can only wonder how modern this method or idea really is. Although largely evolved and developed in our modern time (due to technology and the terabytes of available data), a brief historical overview shows countless cases of individuals and collectives observing the effects of interaction and using them to create and grow industry (Sperotto, 1994). Optimizations in local 'nodes' will only result in local maxima and can have the reverse effect on the overall system, while optimizing available networks (of various factors) holds the key to unlocking more knowledge, wealth, value, joy, and prosperity. This reflects core ideas resonated in ToC and the Pareto principle.

Intellectual Infrastructure is valued most in the quintenary sector of the economy. In literature, this sector is often linked to the rise of Industry 4.0 and Knowledge era technologies. In a nutshell, an industrial engineer's strength in this sector lies in developing the links between nodes in order to maximize value extraction. Typically, this takes the form of designing socio-technical systems or intermediary frameworks that assist in the deployment, interface or feedback between larger node systems. This helps knowledge move, merge or communicate between nodes.

It is important to note that in this sector, building on the works of Wolfe (1955), an increase in productivity in the quaternary sector, is limited by ***available knowledge.*** The quaternary deserves special attention and was identified as the gap to work from since it connects all previous sectors. It appears that virtually all concerns highlighted in the discussion surrounding each sector is in fact a quaternary concern since it deals with the utilization of available knowledge (or technology) to create value. This can be an area of concern (theme) and needs to be explored further in a separate article [Chapter 8: Article 3].

5.4. Human Society

One of the sectors left out of the economic analysis, purposefully, was the quinary sector. Rosenberg (2017) explains that "some economists further subdivide the quaternary sector into the quinary sector, which includes the highest levels of decision making in a society or economy. This sector includes top executives or officials in such fields as government, science, universities, nonprofit, healthcare, culture and the media. It may also include police and fire departments, which are public services as opposed to for-profit enterprises. Economists sometimes also include domestic in the quinary sector. These activities, such as childcare or housekeeping, are typically not measured by monetary amounts but contribute to the economy by providing services for free that would otherwise be paid for." The reason this sector was left out of the economic analysis was because the type of value of its outputs is more closely linked to activities of society.

Knowledge, in itself, is only recently appearing on balance sheets as an intangible asset but the age of measuring collaboration remains in the future. However, it can be argued this sector, if calculate properly, can potentially measure total value generated by the collaboration of society. Thus, it is possible to deduce that , based on the works of Wolfe (1955), an increase in productivity in the quinary sector is probably limited by ***human collaboration.*** Although more abstract, collaboration is an element worth noting in the IE field. Building on the ideas of TPS, an industrial engineer should ideally strive to convey their thinking style in order develop receptive interfaces with the workers. A similar argument and view can be developed for the role of the field towards society.

An interesting visual developed by Staron (2006:23) highlights that "an era is a particular period of historical time having distinctive characteristics. Every era has a signature (or preferred) style of organisation" [Figure 20]. It is notable is that in the knowledge era all structures are present simultaneously which demands a new way of thinking. Sociologists typically distinguish between three types of societies: pre-industrial, industrial and post-industrial based on their collaborative behavior. Some modern accounts also cite a 4th type (the Network Society) which is currently being studied. This will be explored further in this section.

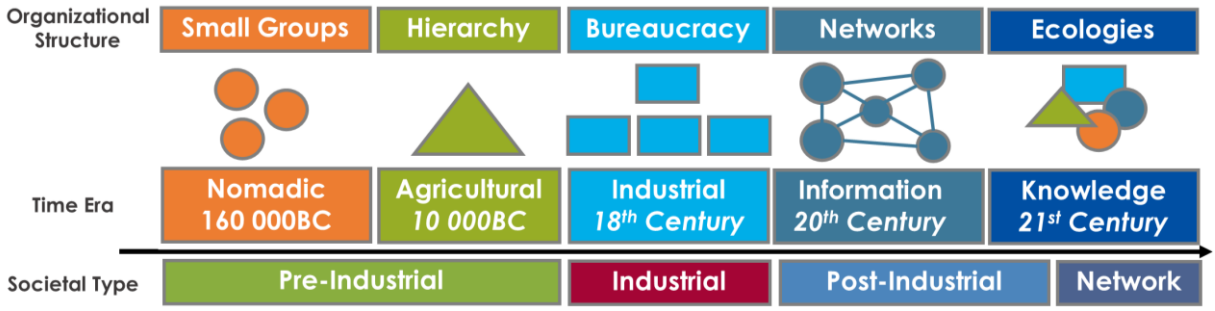


Figure 20: Evolution of Human Organization – Adapted from (Staron, 2006:23)

5.4.1. Pre-Industrial Society

Society can be defined as “a group of people who live in a definable community and share the same culture” (LumenLearning, 2017). Many classifications have emerged throughout history attempting to classify societies based on their behavior. Interestingly, these definitions searched for modes of organization for inspiration rather than cultural differences. Given the focus, of this study, is on the level of industrialization (activities related to Industrial Thinking and engineering); the classification of pre-industrial, industrial and post-industrial society will be used (LumenLearning, 2017). This classification is the most prominent and is widely used in sociology due to unique differences in behavior and structure that can be observed between the three types.

Pre-Industrial societies are often divided to hunter-gatherer, pastoral, feudal, agricultural or horticultural societies. Agricultural societies, for example, developed in a region largely depended on the availability and abundance of natural resources (LumenLearning, 2017).. Additionally, certain beliefs and power structures also largely impacted how a given society develops. As a general definition, pre-industrial society is a type of society which existed “before the Industrial Revolution and the widespread use of machines, societies were small, rural, and dependent largely on local resources. Economic production was limited to the amount of labor a human being could provide, and there were few specialized occupations” (LumenLearning, 2017). Although many people still work in similar settings as that described in the definition, in pre-industrial society there was not much of a choice. However, it is understandable that some may point out that pre-industrial societies still exist today in parallel with other society types.

Industrial engineering, as a profession and discipline did not exist formally in pre-industrial society. Yet, the Industrial Thinking style made many contributions to developments in logistics, quality management and even optimization throughout history. A comprehensive resource on this issue is Frank Sperotto’s Homo Industrialis (1994) which highlights how the industrious nature of humanity demanded individuals with the ability to take a macro-view of a problem and suggest courses of action to create the largest amount of benefit. Sperotto (1994) cites the Hammurabi code, the need for proper logistics in the military and the continuous improvement in task efficiency by technological development as signs of this Industrious nature. In short, although the discipline was only recognized in the 19th century, its rise was almost predictable. The main reason for this growth was that as societies got bigger and more diverse, individuals in those societies were more likely to need collaboration. As they collaborated, communication and other barriers are identified which stopped them from reaching a desired objective. industrial engineers, even if not formally acknowledged at the time, were some of the first to step back and try to solve the problem preventing the social system of moving forward with its goal of being industrious hence the start of industrial society.

5.4.2. Industrial Society

Industrial society is very rarely subdivided into different types. Although several sources acknowledge that impact of culture on the type and extent of industrialization in a country, the overarching features that distinctly point out that a society has become an Industrial one are hard to miss. Many sources cite this type of society as emerging in 18th century Europe where "a dramatic rise in technological invention, ushering in an era known as the Industrial Revolution. What made this period remarkable was the number of new inventions that influenced people's daily lives. Within a generation, tasks that had until this point required months of labor became achievable in a matter of days. Before the Industrial Revolution, work was largely person- or animal-based, and relied on human workers or horses to power mills and drive pumps" (LumenLearning, 2017). This often leads to the definition of industrial society as one "characterized by a reliance on mechanized labor to create material goods" (LumenLearning, 2017). It is interesting to note that "much of our social structure and social ideas—like family, childhood, and time standardization—have a basis in industrial society" (LumenLearning, 2017).

As alluded to above, IE as a discipline was instigated by the needs of the industrial revolution. "Even though historians of science and technology continue to argue about when industrial engineering began, there is a general consensus that the empirical roots of the profession date back to the Industrial Revolution, which began in England during the mid-eighteenth century" (Maynard & Zandin, 2001:1.4). Various visionaries contributed philosophies that helped advance the field from one strength during this era of turmoil to the next such as: Charles Baggage, Matthew Boulton, Henry Ford, James Watt, Frederick W. Taylor, Frank & Lillian Gilbreth, William Kent and many others (Maynard & Zandin, 2001). Although their contributions were in different fields, these individuals shared a certain connection with industrial society and its needs which allowed them to be better engineers. Even today, it appears that the best industrial engineers are those who never forget the importance of involving and serving society in their design activities. This relationship helped both society and the development of IE.

Even though some sources discuss early versions of Industrial society, typically achieved after a golden age of a certain civilization, the key issue which differentiates localized innovation from true industrial society is the mass rollout and true ***reliance*** on mechanized labor Sperotto (1994). This only came to be in the past 200 years globally and was furthered by the first two industrial revolutions. Yet, the third and fourth industrial revolution generated a new reliance: ***Information*** and more recently ***knowledge***. Even in the most rural society, individuals can use mobile phones and the internet to make decisions about their life. This type of society is typically defined as a post-industrial society. However, there is an unequal distribution which prohibits certain societies from displaying post-industrial features.

5.4.3. Post-Industrial

"At the turn of the new millennium, a new type of society emerged. This post-industrial, or information, society is built on digital technology and nonmaterial goods" (LumenLearning, 2017). Although some features of post-industrial society have emerged, it can be said that the nature of relationships and social structures of this type of society are still being formed. This is largely because, even though there are certain countries who have embraced a post-industrial nature, the world at large is still grasping what implications post-industrial society entails. Some things are clear such as that "Digital technology is the steam engine of information societies. Since the economy of information societies is driven by knowledge and not material goods, power lies with those in charge of storing and distributing information. Members of a post-industrial society are likely to be employed as sellers of services… [And] Social classes are divided by access to education, since without technical skills, people in an information society lack the means for success" (LumenLearning, 2017).

The industrial engineer's role in this new type of society has been clarifying and growing since the second half of the 20th century. With the rise of computing and technology; various leaders in the profession adapted the profession to use developments in information technology to the professions benefit. Today, virtually all subdisciplines of IE have a foothold in using information and knowledge for decision making. "The decade of the 1950s marked the transition of industrial engineering from its pre-war empirical roots to an era of quantitative methods…. The decades of the 1960s and 1970s are considered by many to constitute the second phase in the history of industrial engineering during the twentieth century. During these years the field became modelling-oriented, relying heavily on mathematics and computer analysis for its development" (Maynard & Zandin, 2001:1.9-1.10). These events largely overlapped with the third Industrial revolution which largely re-defined what an industrial engineer could do.

Gradually, industrial engineers started to enter other workplaces (in the service industry) where they proved immensely helpful. It was in the next 20-30 years that the most important realization came to be: **Systems!** One of the reasons why many departments, globally, refer to the field as industrial and systems engineering. Realizing that the industrial engineer must think in systems allowed them to emerge "as a systems designer, software developer, systems integrator, entrepreneur, consultant, and/or manager" (Maynard & Zandin, 2001:1.12). Currently, industry was merely seen as a system intertwined with economic and social factors. Yet, this presents the biggest challenge because the field has significant growth to do in aspects relating to social system design. Acknowledging and protecting the diversity of cultures available in knowledge era ecologies is vital. Moreover, a certain ethic needs to be displayed in doing so. This, however, needs to be explored from a non-engineering perspective.

5.4.4. Research Gap at the Human Level: Culture, Ethics & Human Needs

"Standing at the beginning of the twenty-first century, with slightly over 100 years of history under its belt, there is no reason to doubt that this dynamic field will continue to mature in its role as a global leader of societal change and provide its members with a wealth of new and challenging opportunities" (Maynard & Zandin, 2001:1.17). Sections 5.4.1-5.4.3 showed how the field developed with the developments in society. However, a follow-up question is: Where to from here? One way to answer this question is to look at developments in societal behavior and, much like in the past, adapt to them. Yet, it appears that all IE-related sources reviewed in this PhD have a similar implicit message which is that a leadership role is necessary. This leadership will not be like traditional leadership. If anything, it will represent a model similar to TPS where industrial engineers share and embed their knowledge within organizations, industries, governmental structures and society at large to help develop and refine industrious behavior. Severe negative results can arise if two major aspects relating to the field's history are not addressed.

Firstly, it must be acknowledged that IE holds a large responsibility towards the culture it impacts. This has, unfortunately, in the past not received the attention it deserves. Secondly, it is unfortunate to see many industrial engineers still part of an outdated thinking style of growth and profits. This is unfortunately, at times, concealed due to models (like the triple bottom line) highlighting that social and environmental considerations are included in the thinking process. Yet, even at its best this is a weak form of sustainability. Industrial engineers globally must realize the serious responsibility they hold towards society (and their culture) and the biosphere environment. Although this may appear external, it is in fact rooted in the profession's identity. Localized optimizations and solutions cannot and have never solved systemic problems. That is specifically why theories like ToC and Pareto focus on identifying the weakest links/areas that must be focused on.

If the field is to truly mature and develop dynamically as cited by the various sources, it must revolutionize its thinking style to truly embrace the severity of social and environmental concerns. Part of social aspects can be resolved by engaging in ethical social system design. However, the social aspects require the introduction of two vital revolutionary models that assist in bridging this gap which must become embedded in the philosophy, application and tools used by the profession. The first is known as the Lewis model for cultural types. The introduction of this model will, ideally, help IE develop an understanding and respect for different culture types. It can also assist in predicting the best ways of integration and mitigation of risks based on the reactivity. The second is known as the Manfred Max-Neef model for human needs which provides a much more developed and elaborated view of how to help society thrive. If embraced by the field, both those models hold the potential to promote ethical behavior.

Ethics:

There is a widening economic gap between industrialized & non-industrialized countries and even within developing countries that have a mixed economic structure made up of Bottom of Pyramid (BoP) and mainstream economies (Lister & Donaldson, 2011). This unfortunate gap leads to a 'brain drain' towards the more economically prosperous side of the metaphorical fence. This is largely due to the expected social and economic status of being an engineer, amongst other things. In BoP economies more specifically, the 'brain drain' effect is multiplied due to other professions facing similar decisions (such as medicine and law). Over time, the effect above leads to the economically prosperous getting their problems attended to by the best engineers whilst the economically disadvantaged see their problems pile up and merge into Wicked problems (especially when 'infrastructure' problems are interrelated with health or financial need) and build economic dependency on the mainstream.

Bowen (2009) summarizes that there are imbalances in engineering which tend to "prioritise technical ingenuity over helping people… In some instances, appropriate technology is available but not being applied [an example being water shortages affecting 2 billion people which results in over 25 000 deaths a day] … In other instances, complex and appropriate technology is developed and applied [but for the wrong use purpose since]… peaceful and military uses of engineering compete for the same skilled personnel" Bowen (2009:6-7).

This gap in designing solutions that benefit society is what led to the rise of social system design as a discipline, advanced by various scholars, in order to provide design theories for considering social, ethical, cultural and other interactions of society. The formal definition of social systems is "the patterned series of interrelationships existing between individuals, groups, and institutions and forming a coherent whole" (Merriam-Webster, 2017). Farooq (2014) summarizes various definitions to provide more insight and uncovers that social systems have certain features which are necessary such as interaction, multiple entities (people) and highlights that there is a degree of effectiveness in operating this way (as a system rather than elements) by creating bonds of intimacy, honesty and a frame of reference for individuals in the community. Although these take on different definitions given the context of social systems, a review of each of their definitions shows that many technical systems have similar features (even if they are defined differently to be context appropriate). Banathy (2009:109) explains:

> *Social systems design is a relatively new intellectual technology. It emerged in the 1970s and 1980s as a manifestation of open systems thinking, the soft systems approach, and critical systems theory. It came on the scene just in time to deal with highly complex and dynamic social systems that are faced with the new realities: the massive changes and transformations of the information/knowledge age*

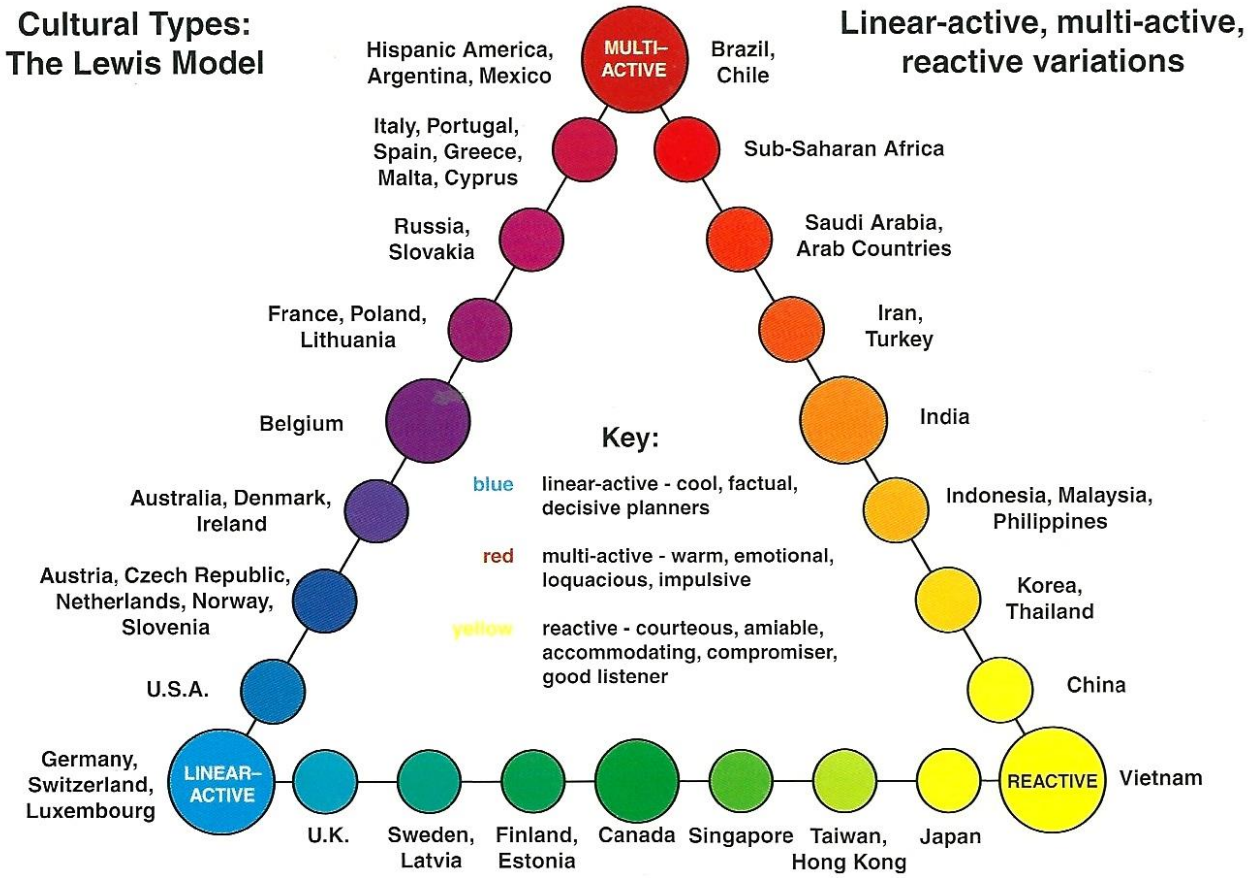
Culture:

AbuZaher (2015) conducted a study trying to link between a country's culture and its impact on project management effectiveness in that country. Using a quantitative analysis, AbuZaher (2015:41,62) found that "the construction industry of UAE is very multi-cultural in nature and many ethnic people work in the industry. The industry is thus prone to many cultural issues… the experience of living in multi cultured society has actually helped them in leaning about other cultures". This diversity needed proper management and a continuous focus on aligning the project workplace culture with the diverse multi-cultural environment of the workers (AbuZaher, 2015). For this, it was necessary to take a broad perspective on cultural models.

One of the models, which might be most suited to this study, is the Lewis cultural model. "Richard D. Lewis is a British polyglot, cross-cultural communication consultant, and author. His own research and experience led him to believe that culture can be classified in three groups: linear-active, multi-active and reactive" (Riskó & Wiwczaroski, 2014). Lewis (2005:xvii) describes the process "determining national characteristics is treading a minefield of inaccurate assessment and surprising exceptions". Yet, the Lewis (2005) model helps draw some general features which are worth noting when engaging in different cultures. "Shaping organizational structure, communication methods, and ways to conduct meetings and social gatherings, all influence how interactions with a specific culture can be made effective" (Katz, 2005). The model is presented in Chart 7.

With relevance to the project environment (which is closely related to the industrial engineer's perspective in Industry), AbuZaher (2015:24) notes that "Linear-active individuals tend to be private, exhibit not emotion and task-oriented. They only focus on what they are supposed to do and always create a plan for all their events. They tend to enslave themselves on their schedules and mostly focus on one thing at a time. Multi-active persons are the opposite of the linear-active individuals. They are outgoing, emotional and tend to be inquisitive. This group is virtually unpredictable concerning following a fixed timetable. These people can multi-task, tend to disregard their timetables due to frequent change of plans, and do not mind seeking favors if it can help them get what they need. They do not fear confrontation and are always prepared to defend themselves. Reactive individuals for the third segment of the triad and possess features of both linear-active and multi-active individuals in their environmental response. They are quiet and caring at the Same time and thus pass as very good listeners. They also avoid confrontation and never go about interrupting others. They are only reactive after analyzing the general principles of a circumstance… [An Example of how this affects the workplace is] the impulsiveness and loudness exhibited by the multi-active category appear to the other groups as a show of impoliteness and if they take this behaviour to the work environment, then they are perceived as being unprofessional".

Chart 7: Cultural Types Using the Lewis Model (Becher, 2016)



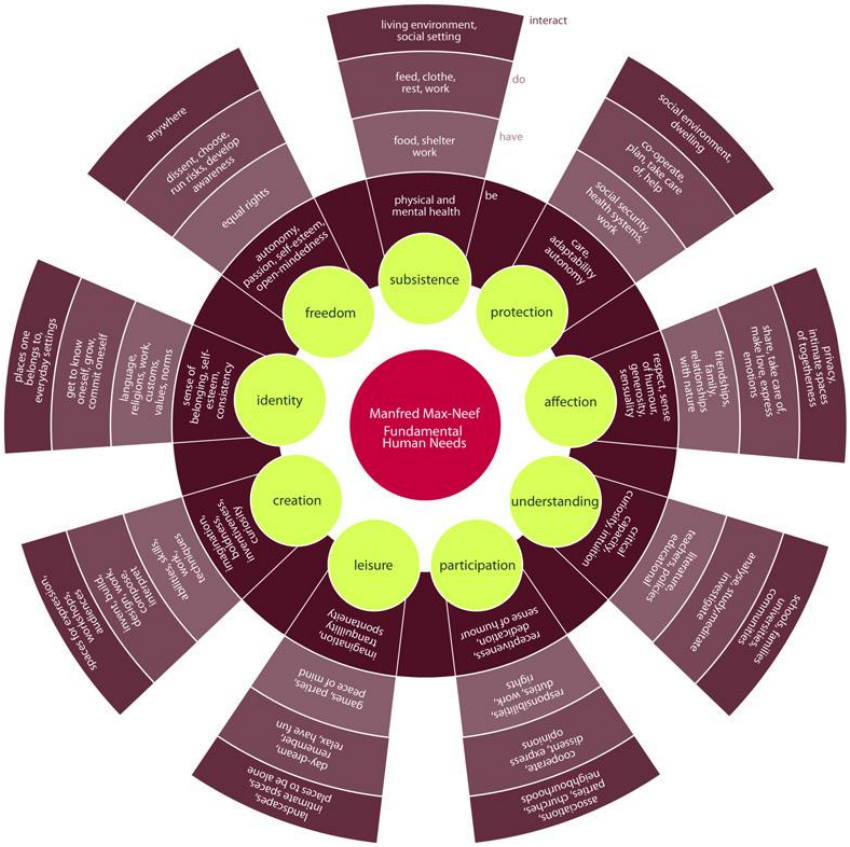
Human Needs:

Last but not least comes the important issue of human needs. When thinking about human needs, many, if not most, individuals will refer to Maslow's hierarchy of human needs. Yet, the hierarchy has come under major criticism for not having fundamental empirical evidence to support it, looking at human beings in an animalistic manner and implying that individuals need to satisfy a certain level of needs before progressing to the other (Wahba & Bridwell, 1976; McLeod, 2007). For example, many individuals around the world lead fulfilling and happy lives without necessarily rising up the hierarchy.

In short, what makes Maslow's hierarchy unfit for this study is that it fails to consider that human needs are largely intertwined with ethics. A more appropriate, humane and ethical model can be found in the works of Manfred Max-Neef model for fundamental human needs. "Manfred Max Neef is a Chilean economist who proposed to explain the crisis of Latin America countries not only in an economic way" (Tonon, 2012:548). His model presents an ethical and environmentally considerate view of human needs (alongside his other works on human development, growth and quality of life). Tonon (2012:548) explains that Manfred Max Neef "produced a human scale approach to international development based in the idea that the development is about people not about objects. He considers that 'needs' should be understood as finite and universal, and 'satisfiers' are infinite and culturally determined".

What is particularly interesting in the works of Manfred Max Need is the classification of human needs along two axes: Existential and Axiological (Max-Neef *et al.*, 1992). Max-Neef *et al.* (1992:199) lists the existential categories to "demonstrate the interaction of… the needs of Being, Having, Doing and Interacting". The axiological categories are defined as needs of Subsistence, Protection, Affection, Understanding, Participation, Creation, Leisure, Identity and Freedom" (Max-Neef *et al.*, 1992:199). The intersection of these two axes creates a visual representation of fundamental human needs. This is visualized in Chart 8 below. It is important to note in this visual representation that the basic human needs are closer to the center and should be available to all. Yet, the aim is to reach the ultimate state of that category. For example, one might classify the basic human right of freedom as having autonomy. However, the aim of that category is to then **have** equal rights followed by being able to **[do]** choose and develop awareness followed by the ability to do this everywhere **[interact]**. What makes the works of Max-Neef *et al.* (1992) even more suitable is it lists human behaviors which are often seen as satisfiers but in fact they violate the human rights or needs of the person themselves or of society at large. These are defined in the works of Max-Neef *et al.* (1992) as violators, destructors, inhibiting and pseudo satisfiers. Furthermore, Max-Neef's other works give special attention to environmental sustainability in his other works (Max-Neef, 1995). This helps understand "human needs as a system; that is, all human needs are interrelated and interactive" to the immediate environment and earth's biosphere (Max-Neef *et al.*, 1992; Max-Neef, 1995) [This aspect will be discussed further in 5.5].

Chart 8: Manfred Max-Neef Fundamental Human Needs (Masha, 2016)



Identified Gap:

The context above typically falls outside the range of engineering consideration which can have negative consequences. However, whilst it can be successfully argued that engineers in general are not the individuals qualified to deal with such considerations, the fact of the matter is that industrial engineers design systems which interact with society. This naturally places a responsibility to give some thought to design of social systems. Lister and Donaldson (2011:48) explain that "current industrial engineering paradigms aim to improve quality and profits, and emphasize labor-reduction, specialization, analysis and optimization. This can be at odds with the needs in a developing country…. [In addition to this] relatively few industrial engineers are employed in South Africa and Kenya, and not many are produced by the educational systems in these countries. Those who are available, work in organizations such as manufacturing industries, government, parastatals and the services sector". Namibia, for example, "aspires to be an industrialized nation by 2030 facing significant challenges like poverty. (Only about 47% of households have a main source of income) … The Namibian, like the South African, economy is diversified…. [Which is why there is a] … need for industrial engineering tertiary education. Of course, real wealth comes from people with ingenious ideas and tenacity to make them work to the benefit of all. In the process, they change themselves, change those who work with them and will industrialize Namibia. While designing and running superior systems are at the heart of industrial engineering, it is the people in them who matter both consumers and producers… [And] Ethical behavior is paramount in producing a good society" (Snaddon, 2011:1-2).

Thus, the important role of IE in being a social system (embodied by the professional society) that shapes other social systems needs to be acknowledged; it attempts to instill and strengthen the considerations and thoughts highlighted above as a path to expanding the area of concern of this specific community. The major concern that needs to be reflected on when considering IE as a social system is whether the system is maintaining its initial desired outcome which can largely be described as practical solutions to benefit society. Social concerns also have economic connotations, but the focus of this area of concern is the social element. The main question is: how can industrial engineers better address social causes using their existing knowledge and design skills? Answering this question is especially important since there is sufficient theory within and outside field that shows that there is room for improvement in the lives of BoP communities (who form 80% of the world's population). Part of this shift requires a return to basics of IE which focuses on improving the work conditions of employees (who represent a similar segment). The other part is a genuine focus on being the mediator and focusing on applying technology for human benefit rather than attempting to create new technology. This can be an area of concern (theme) and needs to be explored further in a separate article [Chapter 9: Article 4].

5.5. The Biosphere Environment

Earth… The biosphere that we sustain ourselves from and call our home…A pale blue dot in the vastness of space, yet, “look again at that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every ‘superstar’, every ‘supreme leader’, every saint and sinner in the history of our species lived there--on a mote of dust suspended in a sunbeam… In our obscurity, in all this vastness, there is no hint that help will come from elsewhere to save us from ourselves…The Earth is the only world known so far to harbor life. There is nowhere else, at least in the near future, to which our species could migrate. Visit, yes. Settle, not yet. Like it or not, for the moment the Earth is where we make our stand” (Sagan, 1997:6-7)

It is truly surprising that the ideas highlighted in the extract above rarely feature in the IE body of knowledge. Sometimes it may appear that, even when accounting for some environmental impacts, industrial engineers do not fully comprehend the impact of their activities on the larger biosphere. The solution, however, does not lie in simply adapting some IE tools. A genuine rethinking of IE philosophies needs to be done. An industrial engineer must remember that, unlike personal liability, indirect consequences of their direct actions need to be analyzed. This is, after all, part of professional conduct. For example, when an industrial engineers makes a certain service faster; this may prompt customers to behave like consumers and utilize resources at unreasonable rates. In the long run this can lead to undesirable consequence arise. Although ideally one should be able to appeal to ethics for highlighting why considering the biosphere is absolutely necessary, even a self-preservation view should yield the same result (a concern about the environment).

Some, of course, may argue that the future of humanity is in space and earth is merely a means to an end. Such view is often promoted by individuals and entities which constantly push growth agendas in an attempt to prepare a minute percentage of humanity for space exploration and travel. To support this, there will be a worrying design of systems that constantly feed off resources (in the broadest sense) to keep a cycle of consumption instead of integrating humanity into the available ecology. Industrial Thinking by nature wishes to adapt the environment to suit human needs and that is precisely why it needs to expand and become more harmonious in its consideration of resources and energy.

5.5.1. Non-Renewable Resources

It is not uncommon to see people having very negative views on non-renewable resources. Yet, a majority of society (whether they acknowledge it or not) depend on this type of resource. A broad definition a non-renewable resource is “is a resource of economic value that cannot be readily replaced by natural means on a level equal to its consumption" (Investopedia, 2017a). One may cite the polluting effects of non-renewable resources (like oil and gas) as one of the reasons for their dislike; yet, this view can be seen as overly simplistic view, especially since it is not by ‘nature’ that these resources are polluting and non-renewable. Rather, it is the way and rate at which humanity uses them that leads to these negative effects. This section aims to highlights the fact that non-renewable resources are not an inherent ‘evil’ that cannot be used. However, how humanity uses these resources and the level of disregard shown to the impact of using them excessively is the real problem. Furthermore, the interest of companies and countries in wanting to control resources is part of the problem. This, for many reasons, appears to be easier done with non-renewable resources.

Industrialists and politicians of the 18th and 19th century are often blamed for the current dependence on fossil fuels as a means of generating power. Various sources cite how large monopolies, especially in 19th and 20th United States, destroyed any and all opposing ideas that would challenge the complete dominance on resources imposed by these monopolies (Zinn, 2014). More worryingly, these monopolies degraded any initiatives to find alternatives that would lessen the reliance of global economy on non-renewable resources (Zinn, 2014). Yet, the environmental aspect of the problem truly took form and became toxic when the use of non-renewable resources was mixed with the problematic concept of continuous growth as a sign of development (promoted by capitalism). This led to government of the United States (at that time) to pretend “neutrality to maintain order, but serving the interests of the rich. Not that the rich agreed among themselves; they had disputes over policies. But the purpose of the state was to settle upper-class disputes peacefully, control lower-class rebellion, and adopt policies that would further the long-range stability of the system” (Zinn, 2014:258).

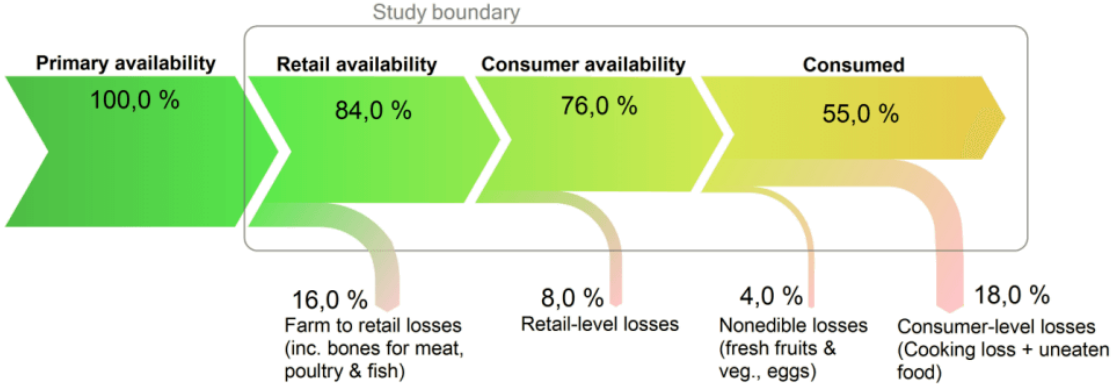
It is odd, at first, to see a discussion about the environment leading to politics and power. Yet, if one understands the important role of policy-making in promoting certain behavior and economics in measuring impact, the connection becomes clear. industrial engineers, in many universities, are exposed to an introductory level of accounting and economics. Yet, this is merely not enough to truly understand the greater problem at hand and its impacts. To conclude this section, it is apparent that although the inclusion of certain accountability tools (such as carbon taxation calculations) into the IE curriculum, the real problem remains that the philosophies are, in most cases, engrained with concepts that promote unsustainable uses of non-renewable resource.

5.5.2. Renewable Resources

Renewable resources, on the other hand, can be defined as “substances of economic value that can be replaced or replenished in the same or less amount of time as it takes to draw the supply down. Some renewable resources have essentially an endless supply, such as solar energy, wind energy and geothermal pressure, while other resources are considered renewable even though some time or effort must go into their renewal, such as wood, oxygen, leather and fish” (Investopedia, 2017b). If one takes a limited view of resource, they will conclude that only resources like oil and gas are non-renewable since they take billions of years to regenerate. However, this shows a problem with our understanding (which often drives our behavior). Trees, for example, are renewable given that when planted they can grow back within a few decades. However, when one destroys a forest, the entire ecosystem becomes unbalanced. Although the trees may be replanted, all of the lost ecology is a resource that cannot be so easily replenished and may be lost for centuries (if not millennium). Thus, it appears that the one distinguishing feature of renewable resources is that they regenerate if allowed to do so. The reforestation and return of biodiversity to forests (like the amazon) is an example of this when proper policy is taken to protect the environment (Chazdon, 2014).

Although using renewable resources can viewed as favorable over non-renewable alternatives, there are still are three important things to consider: [1] Renewable resources should not be consumed at a rate faster than their ability to regenerate - otherwise they can deplete [2] When utilizing renewable resources, one must account for black swan events which can tip an entire ecology or ecosystem beyond repair especially when multiple renewable resources are being exploited, and [3] A genuine focus on using renewable and sustainable ways of generating and harvesting renewable resources is necessary. This further highlight that the utilization of resources in general appear to share a common problem. It is not inherent in them by virtue of being renewable or non-renewable but rather it is with the way in which we use them. One of the best examples is that of food. Food production uses both renewable and non-renewable resources. Yet, the highest loss in ‘availability’ comes from the consumer behavior as shown below in Chart 9 below. This loss can be reduced using IE knowledge.

Chart 9: Food Supply Chain Wasted Resource Sankey View (Lisle, 2017)

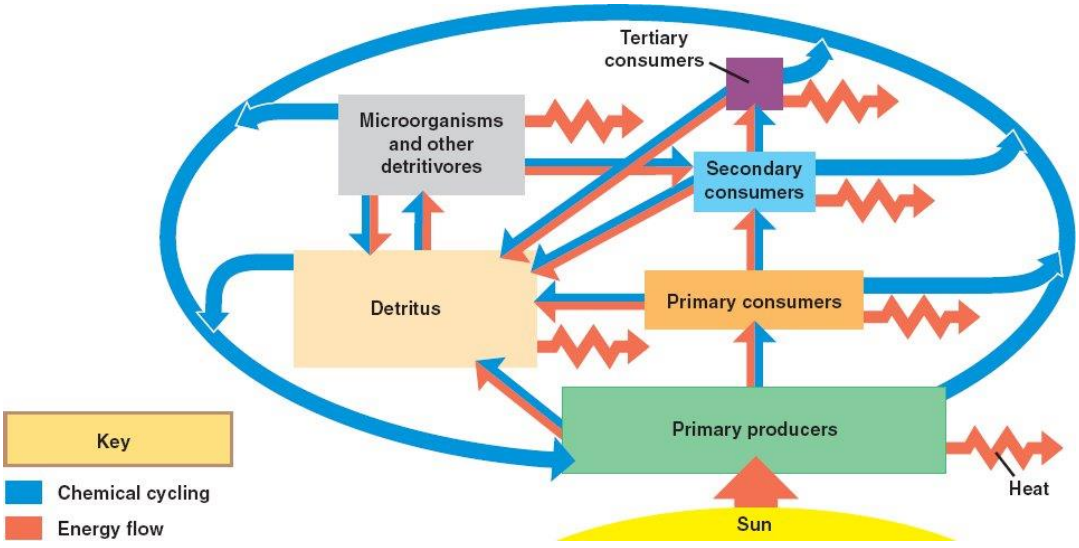


5.5.3. Energy

Equally as important as the concept of resources is the concept of energy. Although energy is an abstract concept that is utilized interchangeably in different contexts, energy can be most broadly defined as “measure of the ability of a body or system to do work or produce a change. No activity is possible without energy and its total amount in the universe is fixed. In other words, it cannot be created or destroyed but can only be changed from one type to another. The two basic types of energy are (1) Potential: energy associated with the nature, position, or state (2) Kinetic: energy associated with motion” (BusinessDictionary, 2017c).

When accounting for energy flow, one quickly realizes how much energy is lost as heat. There is currently no readily available technology that converts heat back into energy. Thus, according to the laws of thermodynamics, it is lost in the ecosystem. The example given in Chart 10 shows an example from the natural ecosystem. However, a similar pattern emerges when considering the relationship between primary, secondary, tertiary and quaternary industry. Building on the food example, one must also consider that “to produce 1,000 kcal of food energy… the food production industry in the Western Society uses between 7-10,000 kcal in Sweden and 11-14,000 kcal in USA (about 22,000 kcal in Japan). This enormous energy mark-up is used by the agricultural industry (fertilizers, pesticides, farm machinery), retail sector (transportation, refrigeration, processing, packaging, displaying and advertising) and in the kitchen (refrigerating and cooking the food)” (EDRO, 2009). The generation and efficiency of energy in natural and manmade systems, however, falls outside the domain of IE. Yet, energy effectiveness is something that the field can contribute to. In the words of Frank Sperotto – “Place Effectiveness before Efficiency. When you place Efficiency before Effectiveness you may end up with neither. When you place Effectiveness before Efficiency you will end up with a good measure of both”. Thus, for an industrial engineer, is recommended the effective flow of energy should be considered more carefully than the efficient flow.

Chart 10: Flow of Energy in Natural Ecosystem (Bio1151.net, 2017)



5.5.4. Research Gap at the Biosphere Environmental Level: Biomimicry

Industrial engineers already have and do contribute to a significant saving of resources and energy using their efficiency toolbox. This, however, has often led to criticism of the Industrial Thinking style as one based on triadism. Semashko (2013:18) takes an extreme but points out that "disharmonious Industrial Thinking is based on monism, i.e. on the recognition of one absolute, primary origin (part), which generates and suppresses other parts and constantly causes conflict among and the parts as well as within the whole. The priority belongs, instead, to the disharmonious parts and particulars, which are at enmity with each other and which aspire to domination over the whole. An ideal of this thinking is the industrial civilization and the one-dimensional economic person – homo economicus or homo industris, whose primary target is profit rather than harmony. This way of thinking in aggregate of its attributes, progressive in due time from second half of the 20th century, shows its inconsistency in the decision of the global problems, which it only multiplies and under pressure of which its industrial society collapses. This thinking may be defined [by being synonymous by]: disharmonize, monism, and others".

Although the modern industrial engineer has overcome many of the problems pointed out by Semashko, one cannot deny the massive environmental and social degradation caused by this type of thinking by Industrialists and, to some extent, industrial engineers of the 18th to 20th century. In fact, some of the negative effects remain to the modern day. Yet, it is arguable that IE has also contributed to the problem as well; by making things faster, cheaper and better it also increases their consumption. This is not to say that all of these improvements are necessarily negative. However, negativity must be considered. In industries where customer behavior is transformed to consumer behavior, the environmental impact of efficiency needs to be studied. Efficiency does not necessarily change the current paradigm of how we use resources.

Identified Gap:

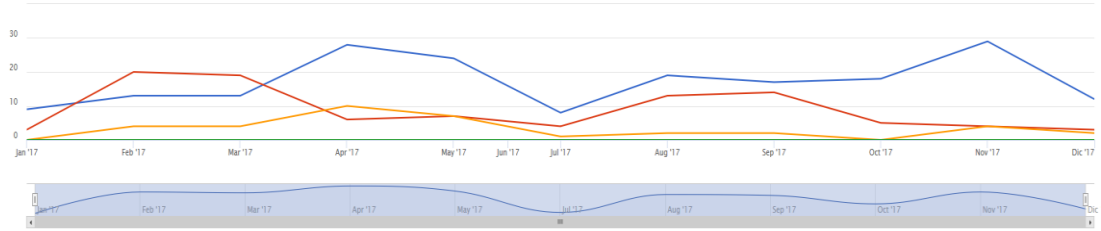
IE has a golden opportunity to adapt its associated thinking style to keep up with knowledge era developments. A historical analysis does indeed show that certain parts of the IE history were affected by predominant ideologies which have affected the environment negatively. However, the knowledge era improved human understanding of the global impact of industrial activity. Luckily, developments in environmental, social and other fields can be used to re-think some of the IE body of knowledge. More specifically, by adapting some of the philosophies and tools used in the IE field, interdisciplinary balanced and harmonious ideals can be encouraged instead of outdated growth and profit ideals. The field of Biomimicry and the works of economist Manfred Max Neef can assist in this regard due to their focus on creating sustainable ecologies. This can be an area of concern (theme) and needs to be explored further in a separate article [Chapter 10: Article 5].

6. Article 1 – Individual Level: The Industrial Engineering Identity: From Historic Skills to Modern Values Duties and Roles

6.1. Details of Article 1

All relevant administrative details of this research output were submitted on the NWU system and are available in Appendix D1.1. This article was originally submitted for the 27th annual conference of the Southern African Institute for Industrial Engineering (SAIIE), held from 27-29 October 2016 at Stonehenge in Africa, North West, South Africa. The article was completed using the author guidelines for the South African Journal for Industrial Engineering (SAJIE) available in Appendix D1.2. The article underwent two rounds of a triple blind peer review (feedback available in Appendix D1.3) before being selected for the special edition of the SAJIE journal. The article was first available online on 11 November 2016 in Vol 27 No 3. This article was co-published with the esteemed Prof Liezl van Dyk. The article has already been cited by an author working on redefining STEM Education and was accessed 415+ times (325+ SCIELO and 90+ ResearchGate). The following SCIELO chart displays the reach of the article:

Chart 11: Article 1 SCIELO Access Chart (SCIELO, 2017)



6.2. PhD Golden Thread in Article 1

This article addresses the first identified area of concern which falls within the industrial engineer himself. The article aims to shed light on the gap discussed in Chapter 5 under this area. This article is the first article to be published. Thus, since it is focused on the Identity of the industrial engineer, it also sets the tone for future articles. More importantly, it achieves one of the overarching objectives of the framework (the “How?”) and formalizes an identity model based on history and literature review. This expands by giving a correct foundation.

6.3. Extracted Insights from Article 1

- **S1.1:** Historically, industrial engineers were seen as jacks of all trades but masters of none
- **S1.2:** The view above is one of the reasons that hindered the progression of a formal identity
- **S1.3:** The commonality between the thinking style and sub-discipline’s tools used in industrial engineering is that they focus on designing balanced solution for industry.
- **S1.4:** A critical review of the current state of IE finds that the modern identity is centered around being connected to various fields of knowledge whilst being masters of some
- **Conclusion 1 [Desirable Systemic Change]:** In order to hold true to their professional identity (IE-ID) of designing balanced solutions; an industrial engineer must continuously advance their interdisciplinary awareness (to connect) and cognition abilities (to master).

6.4. Article 1 Manuscript

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ABSTRACT

Over the past 100 years, Engineering has sub-divided into tens of disciplines in an attempt to deal with the different problems arising from the wide spectrum of human endeavours. One particular field, however, arose from problems relating to industry, interdisciplinary integration, growth, balance, and connectedness. This field is known as industrial Engineering (IE). Yet the IE identity and role, although useful, often remains vague. This article presents a review of the factors that made IE what it is today, as well as the fields differentiating the skills. It begins with a brief historical overview of the factors that shaped IE. More importantly, though, the article focuses on the modern identity (made up of the values, roles, and duties) of industrial Engineers in the 21st century. This is done by showing that the long-standing cliché of industrial Engineers being 'jacks of all trades and masters of none' has actually become 'connected to all trades and masters of some' due to a significant evolution of skills and identity. An industrial Engineering identity (IE-ID) tree model is developed by extracting concepts and elements from existing identity models to give structure to the IE-ID model. The model is then populated with questions and answers arising from the literature review. To conclude, the future utility of such a model is anticipated.

OPSOMMING

Oor die afgelope 100 jaar, is ingenieurswese verdeel in tientalle dissiplines, in ''n poging om verskillende probleme te hanteer wat voorspruit uit ''n wye reeks menslike ondernemings. Een van hierdie velde het voortgespruit uit probleme wat verband hou met bedrywe, interdissiplinêre integrasie, groei, balans, en gekoppeldheid. Hierdie veld staan bekend as bedryfsingenieurswese (BI). Tog is die bedryfsingenieursidentiteit en –rol steeds nie duidelik nie. Hierdie artikel sluit ''n deeglike ondersoek in na dit wat BI maak wat dit vandag is (asook hulle onderskeidende vaardighede). Dit begin met 'n kort historiese oorsig van die faktore wat BI gevorm het. Meer belangrik nog, fokus hierdie artikel op die moderne identiteit (bestaande uit waardes, rolle, en plig) van bedryfsingenieurs in the die 21ste eeu. Dit word gedoen deur te wys dat die cliché dat bedryfsingenieurs 'alles doen, maar niks bemeester nie' uiteindelik, deur 'n 'n proses van beduidende evolusie van vaardighede en identiteit, sodanig verander het dat hulle nou 'gekoppel is aan alles en heelwat bemeester'. ''n bBedryfsingenieurs identiteit (IE-ID) boom-model is ontwikkel deur konsepte en elemente van bestaande identiteitsmodelle te gebruik om struktuur te verleen aan die IE-ID model. Die model is toe ingekleur aan die hand van vrae en antwoorde wat uit die literatuuroorsig gespruit het. Om af te sluit, word die toekomstige nut van hierdie model geantisipeer

Available Online: http://sajie.journals.ac.za/pub/article/view/1638

[1] Introduction and Background

[1.1] Introduction

In the words of Nadeem Aslam, “Pull a thread here and you’ll find it’s attached to the rest of the world” [1]. When one looks at the development of industry over the centuries, one of the main conclusions to be reached is that industrial development surges when the barriers between separate technologies, knowledge fields, or specialisations are converted into connections [2]. Sometimes, the ‘thread’ that matures these connections can be an overlooked idea, equation, technology, philosophy, or shared method. This is often due to certain ideas or philosophies, belonging to a specific knowledge area, being applied more broadly or being merged in a way that answers a problem in another field. More often than not, identifying these connections can cause the development of entirely new industry sectors, sub-specialities, or synergies between two seemingly different fields (which can often have immense value-adding effects). Conversely, this same barrier removal has led in the past to reverse effects such as a loss of identity and an inability to deal with complexity.

Owing to the rapid increase in the need to understand complexity (due to its immense beneficial influence on humans and its ability to avert potentially dangerous interactions), a more modern view of knowledge has started to emerge: Connectivism. Connectivism conceptualises and visualises knowledge as a mere set of nodes and links [3]. Although simple, this method has attracted much attention for its ability to understand value generation from connections and exchanges. Still, one can only wonder how modern this method or idea really is. Although largely evolved and developed in our modern time (due to technology and the terabytes of available data), a brief historical overview shows countless cases of individuals and collectives observing the effects of interaction and using them to create and grow industry [2]. Optimisations in local ‘nodes’ will only result in local maxima, and can have the reverse effect, while optimising available networks (of various factors) holds the key to unlocking more knowledge, wealth, value, joy, and prosperity.

It would be unfair to attribute this way of thinking to a specific type of individual, discipline, or collective only. Throughout history, innovators and entrepreneurs (those who are capable of thinking in an interconnected and industrial manner) have appeared from every possible discipline and field. Yet an often overlooked and unknown discipline has these ideas of interconnectedness, value, systems, complexity, and synergy at the heart of its tertiary curriculum and work description [2]. Perhaps what this field has, other than being able merely to see complexity differently or recognise connections, is its ability to Engineer and design physical and mental artefacts that are capable of improving human life by extracting value from those connections. Inherent in this desire and need to improve human life is the realisation

that the environment and economy are also relevant. And the broad set of skills (legal, financial, and other) and mental connections at the disposal of the individuals in this discipline (which often leads to the criticism that these individuals are jacks of all trades but master of none) allows for more sustainable, humane, value-driven, and environmentally-friendly solutions [4, 5]. People are often unaware that such a discipline exists. Yet this discipline is known as industrial Engineering.

[1.2] Research Problem, Purpose, and Methodology

Currently, the formal identity of the industrial Engineer remains vague. The word 'industrial' in the title can even be misleading, mainly because it is linked to manufacturing rather than to 'industry' in the broadest sense. Due to the broad knowledge base and application areas made available to industrial Engineers, pinning down the commonality has proven difficult. Various works touch on some elements that can help to form an identity (such as IE skills, work preferences, thinking styles, etc.), but they have not been combined. *Homo Industrialis*, a book discussing the evolution of industry and industrial Engineering by Frank Sperotto, provides an excellent review of industrial Engineering (or, more broadly, Industrial Thinking) before it was called 'industrial Engineering', and leading to its development as a field [2]. In it a window opens to the true core of the industrial Engineer's interests, capabilities, and way of thinking.

To formalise an identity is no easy task, but for the sake of the field it must be done. There is no doubt that IE knowledge is valuable and has proven itself, but employers rarely hire a person with the title 'industrial Engineer'; rather, it is 'process Engineer', 'supply chain manager', etc. Defining this brand and identity can greatly improve awareness about the field itself, create a resource to which to refer students, and help develop new application areas for Industrial Thinking and modernising industrial Engineering methods. In short: the problem this paper aims to address is the lack of a formal industrial Engineering identity. The purpose is to develop an industrial Engineering identity module.

The scene is set in Section 0 with current knowledge about industrial Engineering, in terms of Industrial Thinking, the inherent skill of 'industrial Engineering', the term 'industrial Engineering' itself, the nature of industrial Engineering work, and modern-day employers of industrial Engineers. This is followed by the development of an industrial Engineering identity model in Section [3], where three existing identity models are considered, concepts are extracted, and elements to serve as inputs to the industrial Engineering identity model are identified. Seven exploratory questions are then formulated and addressed, before the industrial Engineering identity tree model is presented in Section 0.

[2] What we Know About Industrial Engineering

[2.1] Industrial Thinking

A unique thinking style is shared by industrial Engineers that is not often articulated. This could be the topic of an article on its own. This goes beyond process thinking (shared with chemical Engineering), shares some tools with (but is different from) systems thinking, and contains strands of creativity and entrepreneurial thinking but with a different end goal in mind. That being said, it is absolutely clear that systems, process, creative, and entrepreneurial thinking are vital to the industrial Engineer. Yet IE solutions would be lacking without some Industrial Thinking (the real crux of what makes an industrial Engineer unique). Few articles use the term 'Industrial Thinking' or offer a proper definition of it — although collectively they clarify the idea. Industrial Thinking "must begin by differentiating value for the customer from munda — the Japanese term for waste" [6]; it is needed "within research in academia… [due to] the obvious discrepancy between state of the art in robotics research versus actual utilized technology" [7]. "Prefabrication action is a good example of when building industry is utilizing industrial thinking" [8].

Some even go as far as to differentiate between disharmonious Industrial Thinking and harmonious Industrial Thinking by arguing that Industrial Thinking, largely in the second half of the 20th century, focused on profit and growth rather than on harmony (between economy, environment, and society) and often stressed the importance of a single part rather than the synergy of various parts [9]. Unfortunately, the position of the industrial Engineer in that era, within the organisational hierarchy, might have forced the Industrial Engineer to optimise the immediate environment or company that causes disharmony with the greater environment — much as systems Engineering was largely limited, during that timeframe, to develop better weapons for the military. Yet the clarification of roles and the concept of industrial and systems thinking over the decades, and the expansion of the area of consideration, have led to a more aware industrial Engineer. Thus the industrial Engineer becomes more responsible for taking special care not to repeat the mistakes of the past committed during industrialisation (towards workers, the environment, and even the economy).

For Industrial Thinking, there are inescapable impulses to consider certain concepts: supply and demand, optimisation, standardisation, end goal, scale, work, value, and human extraction and perception of value. Each of these concepts holds deeper understandings of how the world around us works. For example, supply and demand as an idea is not just about supply chains or commodities; if one filters out the details one can see that virtually everything is a supply-demand relationship, and that there are consequences for not being able to supply or not getting what you demand. This idea can be applied to trees, organisms, and multi-billion Rand

organisations alike. An apple tree demands sunlight and supplies fruit; and a failure to meet its demand will affect its supply (it might even affect the long-term growth of the tree). For systems thinking, there are inescapable impulses to consider other concepts: hierarchy, sustainability, flow, interconnectedness, interface, states and system behaviour. Both consider stakeholders — although it could be said that systems thinking applies the definition more broadly. Yet it seems that industrial and systems thinking have a *yin yang* (an Eastern symbol for symbiotic and balanced affiliation) kind of relationship with one another. If the world is viewed in an interconnected manner, where nodes represent factories, buildings, houses, gardens, and forests, systems thinking would be best-suited to understanding the complexity of it all, but Industrial Thinking would be best-suited to understanding how humans can extract value from it. Systems thinking would be best-suited to differentiating levels of the hierarchy, while Industrial Thinking can scale activities to different levels of the hierarchy.

In many ways the necessity and benefits of both types of thinking to the industrial Engineer can be shown in an article by Ad Sparrius: *The Economy is not a Toaster* [10]. Although there is no direct mention of Industrial Thinking, it would be fair to assume that Industrial Thinking is at work, since most economic activity takes place in industry, and Industrial Thinking (not to be confused with manufacturing) is best geared to deal with those problems. In Sparrius' paper, the reason that systems thinking requires special care when being applied to larger-scale systems is explored [10]. The paper differentiates between 'hard' and 'soft' systems thinking, while showing the importance of recognising that models do not represent reality [10]. A brief summary of the relevant text is given below [10:

> *The principle of a hierarchy states that all systems exist in a multi-layer-hierarchy, and the principles valid at one layer are equally valid at all other layers. Nevertheless, extreme care is needed in applying this principle since it contains a hidden danger. A toaster may properly be viewed as a system, although a very simple one. The economy of a country may also be viewed as a system, although a much more complex one…. [Does that mean that] the economy is thus similar to a toaster…. There are fundamental differences between a toaster and the economy.... the toaster has a simple objective but what is the objective of the economy? To grow the domestic product?... or to eliminate poverty? …. or to reduce unemployment? … at higher levels in a hierarchy, for instance an economy, there are many more stakeholders with many more diverse and inherently-conflicting values… Hard system thinking, such as system Engineering, tackles well defined problems… whereas soft system thinking is more suitable for poorly-defined problems, for instance determining a health care policy in a resource-constrained situation.*

[2.2] The inherent Skill of 'Industrial Engineering'

Why did industrial Engineering come to be? And what makes it different? One cannot understand this without first understanding why Engineering developed in the first place. The term 'Engineering' is commonly thought to stem from the Latin *ingenium*, meaning (based on several definitions): to do things in a talented, ingenious manner — solution-approached way [11]. This way of life and approach to knowledge is clearly different from that of fields such as law, the humanities, and art (even if there are strong connections between all such fields). However, Engineering is often confused with the sciences. The difference is that "while the aim of the scientist is 'to know'; the aim of the Engineer is 'to do'. What we do, as 'doers', is apply science to our work" [11]. Early in human development, the distinction might have been unclear because there was no point in creating knowledge for the sake of creating knowledge; the discovery and application of knowledge was often done by one person. This is also due to the limited amount of available knowledge, making it impractical to create specialisations and disciplines. This affected virtually everyone, from doctors (who were seen as people you go to with any disease) to lawyers (who you went to with any kind of legal problem). The practice of Engineering in the broadest sense is perhaps best defined by the Straszacker Commission (in Sperotto [12]):

> (a) *Involves the use of brains (intellect), energy, materials, systems, money and labour in the conception, operation and maintenance of undertakings for the conservation and optimum utilization of natural resources, for the provision of the means of communication and transportation, as well as the actual production, of a great variety of things.*
> (b) *Bridges the gap between science and human needs, and*
> (c) *Requires the knowledge and skills of several different categories of workers: entrepreneurs, managers, professional Engineers, technologists, technicians and manual workers, artisans, operatives and labourers.*

However, in modern times, the sheer amount of work that can be done in both the discovery and the application of knowledge has warranted a split between the sciences (often seen as responsible for discovery) and Engineering (often seen as responsible for application). Specialisations and disciplines developed as a response to increased available resources, questions available to answer, and the human need to deal with complexity and complicated systems. Naturally, Engineering also had to adapt and develop disciplines to deal with the different problems arising from the wide spectrum of human endeavours: motion and flow (mechanical), extraction of resources (mining), conversion of chemicals into more valuable chemicals (chemical), and so on.

Interestingly, the advances in these fields, each in its own silo, created a new type of problem that often resulted in uneven advances across the sciences, gaps between theory and practice, and a failure to recognise that the overall value was obtained by designating integration systems that used a balanced combination of Engineering and non-Engineering knowledge. For example, a car that can travel 10 000km (mechanical artefact) is less valuable if the longest road (civil infrastructure) is 300km. Similarly, a phone that has 10 years of battery life (chemical/electronic product) is less useful if the best processor can only perform five calculations an hour (electronic/computer component). More importantly, both of those would have no applied value (as opposed to inherent value) if they were not integrated with human activity, designed to be safe to use, and catered for business and legal considerations. The resolution of such problems is often found in the curriculum of industrial Engineers, and is advanced by departments of industrial Engineering (academic and industrial).

In the broadest sense, industrial Engineering is concerned with a balance between environment, economy, and humanity/society (variations of this formula exist — such as man, money, machine, method, and material — but they rarely capture the true meaning as the three-way relationship identified above does). That is why, more often than not, 'value' in IE does not use units. Rather, it is a unit-less amalgamation of factors. Thus industrial Engineering not only exemplifies this definition; it inherently recognises the intricate balance between the factors and the complexity in their interaction. In contrast, other disciplines narrow their focus to specific elements of the definition above (rightfully so in most cases, to further specialise knowledge and increase focus in that field). Interestingly, a brief review of Linkedin shows that industrial Engineers will often refer to what they do as 'industrial Engineering' [13].

[2.3] The Term 'Industrial Engineer', and the Nature of Industrial Engineering Work

The first formal industrial Engineering department was founded at the Pennsylvania State University in 1909 [13]. In South Africa, the University of Pretoria launched its IE department around 50 years later, in 1962; with Stellenbosch and Wits following shortly after [13]. The North-West University is the most recent to launch an IE department. Yet the term and work nature of industrial Engineering was most likely "forged in mills and on shop floors at the turn of the 20th century, [where] industrial Engineering sought to tame the social and economic turmoil that emerged as productive activity shifted from fields to cities, from hand tools to dedicated machines and from steam to electrical power" [14]. This is most likely because problems complex and scalable enough to warrant a dedicated Engineer resolving them belonged to industry. What industry required at that stage (and still does today) was an individual with the technical skills, capabilities, and problem-solving mind-set of an Engineer, but with the additional ability to step back and see the whole picture from beginning to end.

Additionally, problems in industry most often manifest themselves as problems of scaling up and down, integrating properly, aligning demand with supply, and so on. Part of the focus of industrial Engineering in the 20th century was on work studies, standardisation, and production lines, which required a novel solution to problems resulting from the complex connection between workers and their health (human), productivity (economy) and resources (environment). They also, for example, "experimented with incentive plans, which they believed would enhance motivation and yield workers a fairer wage" [14]. Industrial engineers became "widely known [for] organized and streamlined procurement, inventory, quality and accounting systems. They redesigned machine tools to increase accuracy and efficiency" [14].

It is noteworthy that there is global disagreement about the actual term to describe this type of Engineering. In some countries the term 'applied Engineer' is preferred (in an attempt to distinguish themselves from industry and factories), and is often defined as the "field concerned with the application of management, design, and technical skills for the design and integration of systems, the execution of new product designs, the improvement of manufacturing processes, and the management and direction of physical and/or technical functions of a firm or organization. Applied Engineering degree programs typically include instruction in basic Engineering principles, project management, industrial processes, production and operations management, systems integration and control, quality control, and statistics" [15].

Others prefer to promote, use, or merge IE with systems Engineer (in an attempt to link the ability to think holistically and use systems thinking in Engineering activities). Yet there are minimal differences between the curricula of the different labels. Although those terms might more correctly reflect the nature of this discipline of Engineering, the term 'industrial Engineering' seems to be the preferred term by far by departments and industry (even though it can sometimes cause a mental link only to industry-related things). Perhaps this is best understood when reviewing where industrial Engineering developed, as opposed to systems Engineering (which, for a large part of the 20th century, was limited to complex military system development) and applied Engineering (a very modern term mainly used in the USA).

[2.4] 21st Century Employers of Industrial Engineers

Various academic departments boast that their scholars are employable in virtually every sector. Yet a deeper look discovers that this commonly-used statement about showing flexibility in job opportunity does not tell the full story. Although it is true that various professions can be employed in various sectors (accountants, administrators, etc.), this does not directly mean that they do different work in different sectors. Accountants will be used as an exhibit in

contrast to industrial Engineers. Bearing in mind that the work accountants perform is vital and adds value to industry as a whole, it cannot truly be said that the nature of the work varies fundamentally from industry to industry. It revolves more-or-less around certain functions required by companies in general, with specific regulations for carrying out these functions. Some might argue that certain investigative or actuarial branches create diversity; but even then they remain largely confined to certain tools and methods.

On the other hand, industrial Engineering as an occupation not only differs from industry to industry, but is also radically changed by different business structures and models. In addition, industrial Engineers within the same company but from different departments might use fundamentally different tools and methods. Several studies of the spread of industrial Engineers in industry show that their skills, jobs, and specialities vary from very technical Engineering-based occupations to softer business- and law-based consulting professions across tens of sectors [5, 13].

[3] Developing an Industrial Engineering Identity Model

[3.1] Identity Models

Now that a formal introduction to the field has been conducted from various starting points (employers, thinking processes, and the nature of the work), it is time to show how they fit together. The 'iceberg' and several other identity models are often used to conceptualise brands and individual identity [16]. The basic idea is that part of the identity is always visible to the external environment, on which certain assumptions are based about the true identity. Yet the true identity (almost 90 per cent) is submerged, and requires real understanding and analysis for it to be revealed. Examples are shown below:

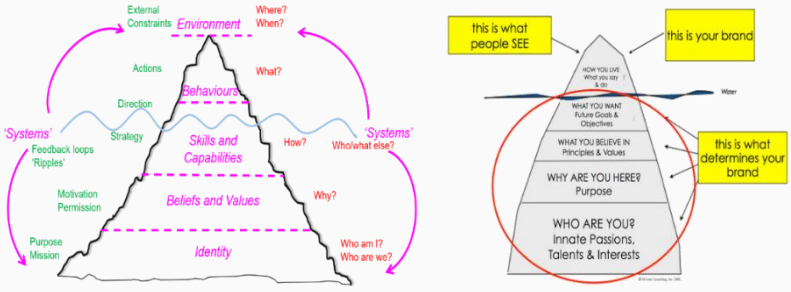


Figure 1: 'Iceberg' brand identity [16] and personal identity [17]

As one goes lower down the iceberg, the real core starts to show (as shown above). Exposed parts of the identity can often be perceived differently, depending on the environment in which they are exposed, or certain external constrains that govern behaviour. Although not traditionally used to express professional identity, these models can be merged with professional identity models to conceptualise and convey a clear message better.

[3.2] Professional Identity

It is not surprising that, in addition to their personal identity, people prefer to have a clear professional identity. This helps to define roles, strengths, responsibility allocation, and other important work-related aspects. Franziska Trede [18] argues that “every professional has a professional identity; the question is how conscious and purposefully chosen it is. It is impossible to imagine a professional without a professional identity; but it is possible that professionals cannot articulate their professional values and commitments, hence cannot purposefully draw on the core of their identity. Identifying with values and moral principles often remains tacit and non-conscious”. He further explains that “it seems that professional identity is closely interwoven with context, and moulded by past experiences and practice traditions” [18].

It is also important to recognise that “considering professional identity — that is, who are we and what do we do — is a natural part of maturation” [19]. It is strange that some sub-disciplines of industrial Engineering have moved towards developing this professional identity, while the field itself remains in a bit of a conundrum. For example, the surface level identity of supply chain management (SCM) as defined in an article discussing the professional identity of an SCM professional (in order to avoid the field being taken for granted) “is the value-creation engine of the modern organization” [19].

On the one hand, academics and individuals from industry who possess strong Industrial Thinking understand the intricacies of the field; yet the lack of formalisation has led other professions to incorrectly evaluate industrial Engineering; and this can have tremendously negative effects on the perceived value that the field could add to industry, and can even affect the recruitment of suitable students for the field. “In the undergraduate Engineering education context, it should come as no surprise that students may be grappling with future professional roles as part of their autobiographical reasoning processes. They are inundated with ideas and images of what Engineers do and what they should value” [20].

The industrial Engineering identity faces a special challenge, since it can often be criticised from within Engineering departments, based on the perception that it is “distanced from technology, has a less rigorous curriculum and is business Engineering” based, which makes it less technical [21]. In addition, some hint at the field’s distance from ‘real’ Engineering, due to the large proportion of females in the field [21]. These factors have given rise to the term ‘imaginary Engineering’, since “the perception that industrial Engineering is less technical, less hands-on, and less physical contributes to pushing IE to the margins of the Engineering hierarchy and establishes boundaries between ‘real’ Engineering disciplines and the

'imaginary' Engineering of IE" [21]. But this could not be further from the truth, since students assert that IE is the easiest of the Engineering majors, despite having common core curriculum requirements [21]. It would seem, however, that arguing these points does not really solve the problem. If anything, Section 2 should have highlighted how invalid such claims are; and the fact that IE generally has a more equal distribution of the genders should be seen in only the most positive light. Cindy Foor [21] summarises:

> *Due to industrial Engineering's marginalization as a result of the discourse of 'imaginary', we suggest that IE is a discipline where men and women encounter weakened boundaries of gendered norms and archetypes of masculine Engineering. Within IE both males and females have faculty role models: The female role models reinforce and even legitimize 'normative' femininity; the male role model confounds constructs of masculinity providing male students with new ways to practice and identify with Engineering, which in turn makes IE a more 'inviteful' place for women, too.*

The models discussed thus far can help to formalise the IE Identity, further the discussion on the role of the industrial Engineer in the knowledge era, and perhaps alleviate these preconceptions and nuances. An additional model — known as the total neuro-logical level model — could assist in finding a way to align the requirements of the individual with the requirements of the profession, and perhaps even improve the teaching of industrial Engineering. This model, shown below in Figure 2, is centred around the individual's relation to inner and external systems and the difference in the logical level of learning required to reach a higher level.

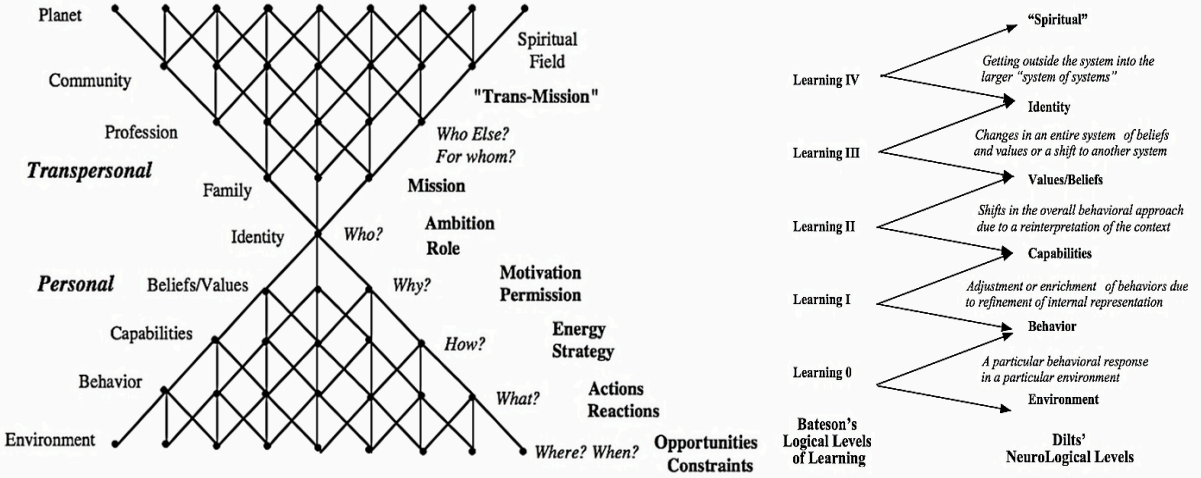


Figure 2: Total system of neuro-logical levels [22]

[3.3] Identity-Formalising Methodology

Thus far, the article has merely focused on identifying and discussing the various elements required to formalise the IE identity. This section focuses on the actual methodology used to bring the various pieces of knowledge together into a coherent structure. Although some elements in forming an identity model require a creative licence that is extremely difficult to verbalise, this section will attempt to describe the thought process by answering some necessary and key questions as input to the identity model before proceeding with the design and providing a structure for the identity model. Thus, to formalise the identity model, structural and content inputs are required. In order to form a professional identity, no single identity model is adequate, because the models mentioned above are designed to describe brand, personal, and logical forms of identity. However, they each have elements that could prove useful in formalising a professional identity. Thus the concepts in Table 1 were extracted to be used as inputs to the identity model proposed in 3.4.

[3.3.1] Content Input to Identity Model

In this section, the extracted questions from each identity model (from Table 1), along with existing questions about identity (extracted from the visual depictions of the identity models in 3.1 and 3.2) were phrased into exploratory questions that could help to pin down some of the finer details of the industrial Engineering identity. The answers are largely extracted from the literature review, with some space given for discussion and argument.

Table 1: Identity model — extracted inputs

Selected model	Extracted concept	Extracted elements in IE-ID model (structure)	Extracted questions (content)
M1. Brand identity (Section 3.1 — Figure 1 left)	The idea that any identity will naturally have a visible element (based on which society can form a perception), and a true hidden identity is absolutely vital in a professional identity, due to a clear discrepancy between what industrial Engineers actually do and what people think they do, enjoy, and are capable of doing.	M1.1. Societal perception — "What people see" [16] M1.2. Passion and interests — "innate passion talents, interests" [16]	1) What are your passions, skills and capability? 2) How are you perceived?
M2. Personal identity (Section 3.1 — Figure 1 right)	This model is used as the basis for the identity, since there is a correlation between personal and professional identity. The different levels are extracted, but can be compressed in the professional identity model. Important questions are extracted from different levels	M2.1. Environment M2.2. Behaviour M2.3 Skills and capabilities M2.4 Beliefs and values M2.5 Identity	1) How do you react to external constraints? [17] 2) What is your purpose and mission? [17] 3) What are your motivators?

	that can shed light on important elements of the IE professional identity.		
M3. Neuro-logical level identity (Section 3.2 — Figure 2)	This model, unlike M1 and M2, focuses more on the neuro-logical structure of learning and thinking (which is vital in this case, due to the uniqueness of Industrial Thinking). Additionally, it seems to suggest that transpersonal levels (spiritual, community, etc.) funnel into an ambition and role that affects the lower level (opportunities and constraints) in response to the external environment. It also separates the trans-mission from the mission that is usable in this instance, since there might be two different levels for core vs fundamental worldviews.	M3.1. Environment M3.2. Ambition/role [17] M3.3 Learning style "Learning levels 0-IV" [17] M3.4 Core belief "Mission" [17] M3.5 Fundamental belief "Trans-mission" [17]	1) How do you think about the world and its problems? 2) What do you see as your role? 3) What are your spiritual (worldview) beliefs? 4) What are your core beliefs?

Q1: What is the absolute core belief of the industrial Engineer without which the field would not exist in the way it does?

A1: It seems the only defensible answer to this question would be ***the maximisation of value through balanced means***. Whether it is through analytical hierarchy process (AHP), decision analysis, or other tools, the industrial Engineer inherently recognises that by failing to consider and include all relevant factors in a decision, the decision will ultimately be flawed, and thus will not result in maximum value because it is not the optimal [2] [9]. The ideal balance would be between economy, environment and, society (the largest macro-systems over which we have some influence or control). Yet, in some cases, it may be acceptable to state it as a balance between the relevant forces at that level.

Q2: How does this core belief manifest itself in thought?

A2: Industrial Engineers think about problems of balance, using several lenses. However, the two that make the industrial Engineer unique are industrial and systems thinking [2] [10]. For problems larger than the industrial Engineer's sphere of influence, systems thinking is preferred to get a macro view of high-level impact and interaction [10]. Although industrial Engineers cannot directly 'influence' those factors, they can design considerations into physical products and conceptual services [14].

Q3: What level higher than this belief is out of the control of the industrial Engineer [the way the world works]? What implications does it have for the field?

A3: More broadly, the industrial Engineer can be said to believe that the world strives for balance in its broadest sense, which is a desirable intermediary state between opposing forces [2]. The implications of answering this question is the definition of a boundary space where Industrial Thinking and systems thinking swap. In theory, this boundary area is continuously changing, and is largely affected by human ambition, technology development, and relevant factors such as stability, scalability, and sustainability [2]. Perhaps further defining this can clarify the role difference of the industrial Engineer as opposed to a systems Engineer.

Q4: What are some of the values and motivations of industrial Engineers?

A4: Industrial Engineers, like Engineers in general, should hold true to applying scientific knowledge for human benefit. The consideration of human benefit should be global, as opposed to localised efficiencies (which would make the optimisation of killing in war an acceptable practice) [2] [8] [9]. Industrial engineers value efficiency, human wellbeing, environmental sustainability, the application of knowledge, and the value of fairness (wages, work, and opportunity).

Q5: What types of skills and capabilities do industrial Engineers possess?

A5: Due to the complex nature of IE work and the sea of considerations from the macro-environments, the industrial Engineer's greatest capability is interconnectedness with all major nodes of other fields of study [5] [12] [13]. This presents a challenge in itself, since it requires industrial Engineers to be aware naturally of where the solution to any problem might lie, even if they do not possess the solution themselves. Yet it allows the Industrial Engineer to develop networks with fellow industrial Engineers with differing interests to create a type of knowledge-sharing 'mesh network' [12]. Other skills and capabilities unique to industrial Engineers are: modelling (business process, simulation, statistical, and other), conceptual design, rapid prototyping, needs analysis, systems design, interface design, facility and supply chain design, design of experiments, business analytics, strategy development, quality management, operation management, project management, requirements analysis, root cause analysis, change management, process mapping, and optimisation [13].

Q6: How are these skills and capabilities affected by the external environment 'behaviour'?

A6: These skills and capabilities might be used simultaneously, sequentially, partially, or consequentially. They might be adjusted for different environments, teams, or situations. Yet the common behaviour displayed in all these situations by the industrial Engineer is a

persistence in finding the relevant tools, knowledge, and individuals to resolve a problem. If the industrial Engineer is not qualified to use the specific tool/knowledge field, their role changes to a quality manager/integrator [2] [6] [14]. This handing-off is key to the success of industrial Engineering work, since it inherently recognises the capability of other disciplines and respects them. In this way tasks are done more efficiently and the network of the industrial Engineer is expanded.

Q7: What environments can they be applied to?

A7: Virtually any environment that can be classified as an Industry requires full-time industrial Engineers due to the sheer number of value/balance-driven problems that arise from internal activities and external forces affecting the work environment [5] [13] [21]. For more decentralised businesses that are still part of an Industry but cannot financially justify the employment of a full-time industrial Engineer, customisable artefact-based templates (with built-in Industrial Thinking/IE tools) that standardise or simplify certain high level concerns to an appropriate level for that business are often designed or built by industrial Engineers. This has often strengthened the perception that industrial Engineers are 'jack of all trades and masters of none'. However, the traditional perception that industrial Engineers are 'jack of all trades' and should be 'connected to all fields of knowledge and master of none' is, more realistically, that they are 'master of some'. Collectively, however, industrial Engineers span the network of knowledge, and can expand their networks and knowledge by integrating with their peers.

[3.3.2] Structural Input to Identity Model

This section focuses on forming the content into a coherent structure of different identity levels. Various potential levels were described and extracted from the identity models described in Table 1; but they created unnecessary repetition. Thus the identity levels were compressed into eight levels with a similar structure to that in Figure 2. The defined levels and the relevant instigator for the need for that level (extracted from the third column of Table 1) are listed below:

Level 1 (M1.1) — Societal perception lens: The social perception of IE should be that it is the field connected with all fields of knowledge and masters of some.

Level 2 (Merge M2.1, M2.2, and M3.1) — External behaviour: Industrial engineers are adaptive and proactive in responding to external environment stimulation and forces, much as the leaves of a tree react to different weather conditions. Yet the common behaviour displayed in all these situations by the industrial Engineer is a persistence in finding the relevant tools, knowledge and individuals to resolve a problem.

Level 3 (Merge M2.3) — Skills and capabilities: Industrial engineers define, design, deploy, and refine conceptual and physical solutions aimed at generating value for Industry. Industrial Engineering skills and capabilities might be used simultaneously, sequentially, partially, or consequentially. If the industrial Engineer is not qualified to use the specific tool or knowledge field, their role changes to a quality manager or integrator among specialists who are better suited to deal with the subject matter. This handing-off is key to the success of industrial Engineering work, since it inherently recognises the capability of other disciplines and respects them.

Level 4 (Rephrase M3.2 and M2.3) — Knowledge fields/disciplines: The fields in which industrial Engineers can prosper usually include elements of design and management such as: project management, information systems, systems Engineering, modelling and simulation, mechatronics and automation, robotics and artificial intelligence, operations research and operations management, facilities management and maintenance systems, quality management systems, and logistics and supply chain management. That list is not exhaustive.

Level 5 (Merge M1.2, M2.4) — Value and motivator: Application for human benefit is the greatest value and motivator of industrial Engineers. Other values include efficiency, human wellbeing, fairness, sustainability, and the application of theory and knowledge.

Level 6 (Merge M3.3, M2.2, and M2.5) — Thinking style: Industrial and systems thinking. These two thinking modes must be present to connect knowledge with the core belief in an Industrial's mind, just as a tree is simultaneously exposed to the environment above and below ground.

Level 7 (M3.4) – Core belief: The crux of what makes industrial Engineering different and valuable as a discipline is maximising the extraction of value through balanced means.

Level 8 (M3.5) – Fundamental belief: Balance is intrinsically valuable, and can be one of the most prominent beliefs.

[4] Industrial Engineering Identity Tree Model

The information from 3.3 provides the necessary structural and content inputs for a professional identity model to be developed. However, for the visual representation of the industrial engineering identity, a different analogy from that of the iceberg is used. The selected analogy is a tree: rather like the iceberg, a significant part of it is unseen, under the surface; but, unlike the iceberg, it better represents the idea of resources, value extraction, and balance with the ecosystem. The Pando tree (a variety of aspen) is often defined as the single largest organism because a massive underground root system connects each apparently individual tree [23]. Grant [23] explains that “a group of thousands of aspens can actually be a single organism, sharing a root system and a unique set of genes”. Thus the trees share resources, react in a common way to environmental factors, and share a similar genetic makeup [23]. In addition, the trees expand by sending out roots to grow (much as industrial Engineers encourage close members to join the field) [23]. Notably, environmental forces can sometimes create a separation between different ‘organisms’, yet they still maintain large networks.

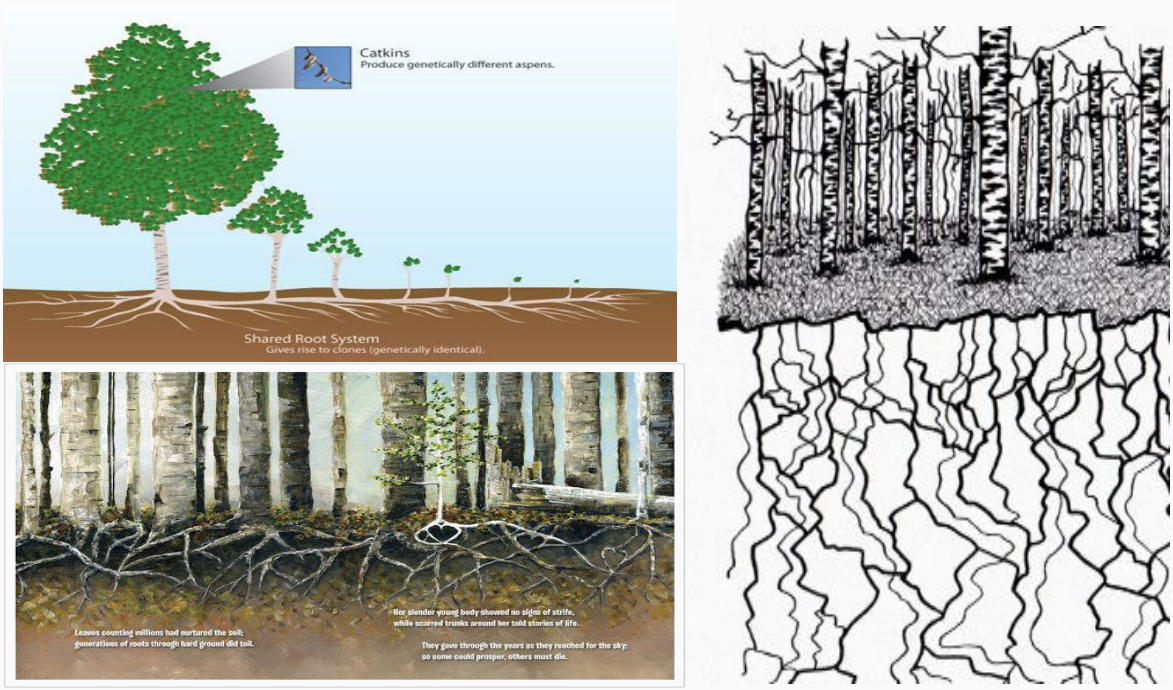


Figure 3: Visual depiction of Pando (aspen) tree interconnected root system [24-26].

The industrial Engineering identity (IE-ID) is represented visually below in Figure 4.

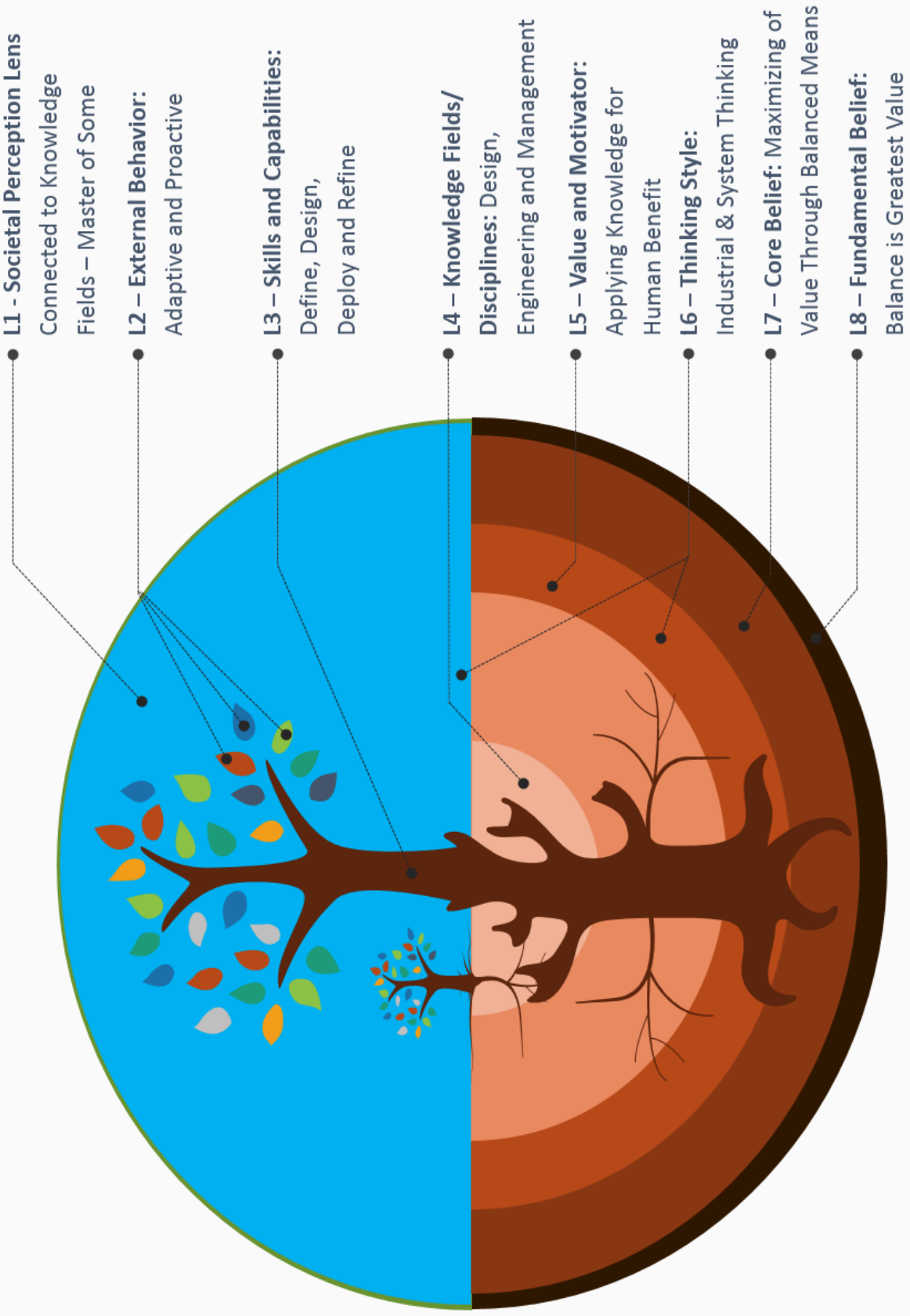


Figure 4: Industrial Engineering identity model (IE-ID) [own work]

[5] Conclusions and Future Research

This article was not an attempt to re-define industrial Engineering; rather, it was an attempt to formalise the identity in the hope of realigning it with the values that have made it a successful discipline. Although the article is largely targeted at professionals who seek an improved formal identity, the academic world could benefit from revisiting how it educates industrial Engineers. “The role of higher education is contested and includes educating students for global citizenship to producing work-ready graduates. The former tends to foreground the notion of values, ethics and developing professional identities whereas the latter focuses on work training and employability” [18]. This is worth special consideration if one bears in mind the generation differences about what is considered valuable, or the degree of loyalty that people have to certain parts of their life (including their profession) [27]. Sociologists classify the current entrants into university as part of ‘Generation Z’ (the first generation to spend their entire life exposed to the internet) [28]; and their beliefs, identity, values, and aspirations are radically different from those of the lecturers who teach them. The issues arising from such generational differences are better left for another article; however, it is important to note the great impact they could have.

The Engineering Council of South Africa (ECSA) and other entities involved in defining the work of various disciplines should also play a more proactive role in promoting and protecting Engineering work. At the moment, industrial Engineering work remains virtually unprotected. If professional registration is truly to mean something, it should be that the designs that result from industrial Engineering work are of a certain quality and display the capability of the industrial Engineer performing them. Formalising an identity is only part of this process. Much research needs to be done that will further define the nature of industrial Engineering work. Future research aims to show how the undergraduate curriculum should be revisited in order to place a greater emphasis on incorporating the industry identity and to develop certain capabilities that are suited to the knowledge era:

1. A focus on the ability to prototype and scale ideas rapidly.
2. An ability to know intuitively in what field of knowledge a solution lies. (The point here is that, even if industrial Engineers cannot solve a problem, they know who can, and they know how to measure and manage them.)
3. A greater focus on understanding complexity and on simplifying concepts to be communicated better.
4. Greater research ability that helps to develop knowledge rapidly, which can then be consolidated through a proactive learn-apply-adjust-repeat cycle.

5. An inherent ability to create, grow, strengthen, and sustain one's network.
6. The appreciation that time saved through technology and programmes is time that should be spent thinking on other aspects of the system.

Lastly, research can be done into why high school students who choose industrial Engineering should be developed, and how to ensure a more equal distribution of race. It is pleasing to see the number of industrial Engineers who lead global projects. Still, more projects or initiatives are shifting into rural regions in an attempt to serve low-income and rural communities (who make up 80 per cent of the world's population). In South Africa, more and more students from disadvantaged communities should be shown the potential that industrial Engineering (as a field of study) could have for their communities, and how this body of knowledge could help them to give back to their communities.

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7. Article 2 – Profession Level: Gamifying the Industrial Engineering Profession

7.1. Details of Article 2

All relevant administrative details of this research output were submitted on the NWU system and are available in Appendix D2.1. This conference paper was submitted for the 7th annual conference of the Industrial Engineering and Operations Management (IEOM) society, held from 11-13 April 2017 at Sofitel Jardin des Roses, Rabat, Morocco. The conference paper was completed using the author guidelines for the conference available in Appendix D2.2. The article underwent a single round of a double-blind peer review (feedback available in Appendix D2.3) before being published online. The paper was first available online in June 2017 on the electronic version of the conference proceedings. The paper received the award for best paper in the engineering education track for 2017. There are no statistics on the article access from the proceedings. However, the paper was accessed 8 times on ResearchGate.

7.2. PhD Golden Thread in Article 2

This paper addresses the second identified area of concern which falls within the Industrial Engineering profession. There is a lot of development that is needed in this field. Currently, there is no official ethical code or professional oath that guides the entire profession. However, for various practical reasons, this article took a different focus on developing the professionalism and ethic within the profession by creating a transparent gamified platform that connects all the stakeholders in the profession. This provides a centralized resource platform which can help in collaborative development of the profession (which suits the generation Z).

7.3. Extracted Insights from Article 2

- **S2.1:** Engineering education in the knowledge era (21st century) requires a significant amount of experiential learning and work-based learning to successfully transfer knowledge
- **S2.2:** Current entrants into university belong to generation Y and Z and their exposure to technology and games from birth suggests that gamification techniques can be an effective teaching method
- **S2.3:** The Baader-Meinhof Phenomenon (see or hear something everywhere after initial contact) can be used to reinforce certain concepts within different contexts which can strengthen the recollection and application ability of students
- **S2.4:** The Industrial Engineering community works in various environments. Sharing insights and resources from the different environments (which are currently dispersed) can help in strengthening relationships throughout the profession
- **Conclusion 2 [Desirable Systemic Change]:** In the knowledge era, it becomes vital for professional communities to create knowledge & resource sharing platforms that act as incubators and places to congregate for initiatives that can further develop the profession and attract the next generation of entrants into IE

7.4. Article 2 Manuscript

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Abstract

An age-old problem facing higher education institutes is the verification that the knowledge taught in class was actually learnt and internalized. Many consider that the quality of education is to be measured on this basis. Historically, institutions have developed knowledge assessment mechanisms and resources which are aligned with the type of knowledge being transferred. Yet, in many cases, the time-bound nature of these assessments, the broader applicability of available resources, as well as the lack of appropriate opportunities (to learn from failure) can result in certain knowledge retention abilities instead of genuine understanding and life-long learning. The importance of dealing with this problem is further highlighted when considering generation Y and Z students who, unlike most of their lecturers, have spent most their life exposed to the internet, mobile applications and other technologies. Although several literature resources and commercial software packages deal with elements of this problem through gamification and education dashboards, a holistic system is yet to be proposed. This article consolidates the various needs of high school students, undergraduate students, lecturers and industry sponsors using system analysis and Engineering tools. These inputs were used to prototype a gamified web based platform providing work & networking opportunities and linked mobile application that help provide continuous learning & assessment. A small-scale prototype was developed ahead of the SAIIE 27 conference to solicit feedback.

Keywords
Industrial Engineering, Gamification, Generation Z, Degree of Attainment

Available Online: ieomsociety.org/ieom2017/papers/347.pdf

[1] Introduction

[1.1] Holistic Overview

The work world is becoming more and more demanding in terms of transferable skills (Greenan et al., 1997: p.193-204). Part of the problem associated with teaching these types of skills is they are often seen as very personal. Additionally, changes in technology can often make it seem as if the skills taught during an entire course or semester at university are rendered 'useless'. A brief look at various Engineering curriculums/teaching methods can highlight why this this is the prevailing perception. The methods of assessment are often overly focused on recollection-based skills. Additionally, the curriculum can often limit the transferability of skills not because the skill itself is limited but because the student's perception of the usefulness of the skill is not integrated into teaching activities (Stukalina, 2010: p.75-93). Changing this on a course by course level is often deemed ineffective because changes can be short-lived if not championed. Moreover, changes in lecturers, technological forces or public regulation return the system to square 1. Also, lecturers will often have to sacrifice part of their lecture time or course content in order to focus on such skill building activities (which cannot always be expected of them). Yet, in this knowledge era, many argue the role of the lecturer should be to direct students to the appropriate and relevant knowledge/resources that can assist their development (personally and academically), especially in higher education (Stukalina, 2010: p.81).

Adding to the problem discussed above is the irrelevant or inaccurate educational content and resources that spam web searches. Some websites have done filtered data well. However, very few sites create specialization-relevant resources (especially templates) for specific professions. More importantly, the few websites that do provide such resources can often alienate users through complex interfaces/processes or create a leeching effect where some users give and others simply take. This problem is most likely shared by various professions but the focus of this article is the field of Industrial Engineering. Industrial engineers must typically find the linkage between different knowledge areas (ranging from Engineering to business to law) taught at University instead of viewing them as silo knowledge fields and very often require specialized content to do so (Darwish & van Dyk, 2016: p1-6). To date, however, there is no prominent and dedicated Industrial Engineering (IE) platform for resource and content sharing. There is no doubt that some content is available on LinkedIn and other sources. However, it remains somewhat disconnected and inaccessible to some. Moreover, IE knowledge, data and the application of IE tools remains infrequently visualized in an appealing and user- friendly manner. Simple bar charts and graphs do not give students as much information as one might think. Advanced visual interactive dashboards, charts and documents hold better promise amongst the younger generation (Bertagni, 2015: p.201).

The lack of such a platform can be said to have hindered the could-be value of Industrial Engineering students who could have attained and retained more applicable knowledge (Darwish & van Dyk, 2016: p1-6). The idea is that students need to understand how to conceptualize their Industrial Engineering as well as general strengths, skills and abilities (Darwish & van Dyk, 2016: p.14). This can help them create skill development plans and evaluate themselves against a benchmark of real individuals in industry. The potential lies in providing IE with resources and connections that can assist them in keeping up to date, continuously improving their knowledge and learning from the best in each industry.

[1.2] Stakeholders

Due to the complicated nature of this problem, it can only be resolved by understanding and satisfying the relevant stakeholders. After all, without their engagement and buy-in, any potential solution is destined to failure from the start. The stakeholders for the problem identified above are:

Table 1. Needs of Different Stakeholders

Stakeholder	**Need**	**Comments**
High School Student	A platform to learn more about Industrial Engineering	The main objective with this group is to raise awareness and attract talented individuals into the field by providing them access to relevant and realistic views of their expected work environments.
Undergraduate University Student	A comprehensive platform to enhance learning	Existing learning/resource platforms used by institutions vary in quality and functions. Thus, a national or international platform that looks beyond university and company borders is required. This platform will not replace the students' traditional learning environment, but rather merely supplement it.
Recent Graduate	A link and opportunity to contribute to academia	Many recent graduates are in search for relevant topics for their postgraduate studies. A unified platform can give them access to a community to share and improve ideas with. Additionally, various recent graduates often package parts of the workplace problems they face in industry in the form of projects to allocated to final year students and can use such a platform for recruitment.
University Staff Member	A less resource consuming method to provide students with experiential learning	Many lecturers require the help of the broader community (including fellow lecturers, their own students and professionals) in transforming their courses to be more industry relevant and transferable-skills focused. This can be done through gamification and experiential learning activities.
Industry Sponsor	A more transparent method to select and sponsor talent	Industry sponsors are constantly searching for a better way to select the right candidates for graduate programmes, improvement projects or scholarship/sponsorship opportunities. Since most universities make it mandatory to get practical experience, these needs can be made to be mutually beneficial relationships.

[1.3] The Problem

In short, the problem is that while various resources and content are available; they are not coordinated and leveraged appropriately in a consolidated platform. An evaluation of stakeholders' needs highlights that an intuitive system that better reflects the relationships in the real world and provides more relevant content is an absolute necessity.

[2] Surrounding Literature

[2.1] Engineering Education

The first major area to consider is the nature of education and knowledge. Knowledge can be expanded to the set of skills, experiences, information and capabilities individuals apply to solve problems (Hanisch et al., 2009: p.148-160). Knowledge is something universally true but needs to be acknowledged by a person's belief system or his aspiration to seek the truth. Bratianu (2010: p.194) quotes Nonaka's works by describing "knowledge as being 'justified true belief" and as 'a dynamic human process of justifying personal beliefs as part of an aspiration for the truth' (Nonaka, 1994, p.15). Thus, knowledge becomes a relative concept as personal belief, a view which limits very much its status of objectivity and its role in science". Although education and learning are often seen as coming hand in hand, providing education does not necessarily mean anything has been learnt and learning does not only come through education. Education is "The process of receiving or giving systematic instruction and information about a body knowledge, especially at a school or university" (Oxford, 2014). It is commonly accepted that this role (at least until secondary level) is the responsibility of government. Learning, however, is "the acquisition of knowledge or skills through study, experience, or being taught" (Oxford, 2014). This is commonly viewed as the responsibility of the individual. Various research seems to suggest that the core issue at play is the lack in continuity and difficulty in teaching reflection skills to Engineering students (to increase their ability in conceptualize abstract concepts and apply them to problems) (Burke et al., 2005: p.132-144). Yet, this is not at all because of a lecturer's poor understanding of the concept taught in class. In fact most students, upon consulting 1 on 1 with the lecturer, will praise the way they guided them through understanding the concepts and highlight the depth of the lecturer's subject specific knowledge. Rather, it is the product of an ineffective knowledge transfer methodology that limits the perception of the value of that knowledge (Burke et al., 2005: p.132-144). This is much like transporting 200 tons of goods between warehouses with a motorcycle; it can be done (in theory) but would unimaginably ineffective.

Modern society needs more 'complete' Engineers and this needs a shift in our Engineering education system. This means that Engineers should develop social skills and develop the capability to thinking about ethics and sustainability. This will serve as a better response to the

increasing complexity of Engineering problems. Also, this needs to take place at a middle and high school development age (De Graaff and Ravesteijn, 2001: p.419-427). This is not to diminish Engineering problem solving skills but to rather propose that Engineers "will have to understand some of the non-technical concepts in order to become more complete Engineers" (De Graaff and Ravesteijn, 2001: p.419-427). Gattie (2011: p.521) argues that "the traditional Engineering education model, while analytically rigorous, is characterized by properties that, although necessary, are insufficient for preparing students to address complex issues of the twenty-first century". He believes that Engineering education needs to be analyzed as a complex system. He argues that the traditional course structure on problem solving fails to immerse its recipients in the complex aspects of Engineering problems and the holistic nature of human condition. Many pedagogies exist on how to approach this issue. Some argue that peer evaluation is the best way, while others insist on the role of projects or task- based learning. Most of these methods have yielded positive results; they were all able to resolve a problem bigger than the issue at hand by convincing students of the value of the learning taking place. This broke down perception barriers and allowed the students to receive quality learning by absorbing the entire activities.

However, when these activities become mundane and are done solely as part of meeting, marking or other criteria the quality would drop. This is because "holistic education [should] encourage a cooperative, egalitarian, mutually respectful relationship between adults and young people…. The education environment should be a community of cooperative inquiry, discovery and learning" (Miller, 2000: p.382-393). After all, teaching a thought process requires more than lecture slides and an exam; it requires an experience. This is especially true for complex concepts which require a developed trained eye. Industrial Engineering has various examples that mix between the method and the abstract. Concepts like TOC, Lean, and Optimization…etc can take on very different meanings depending on the environment. Additionally, the way in which the concept is taught can sometimes place mental barriers on applicability. In addition to the above, communication amongst Industrial Engineers needs to be improved. Industrial engineers apply the concepts differently and place different limitations based on their perception or point of view. Thus, a tool that would allow to them to debate, share, discuss and develop concepts can help show the broad applicability of such concepts. The problem lies in the fact that Industrial Engineers require more practice on some of the concepts taught in class and their broad applicability.

[2.2] Generation Y & Z

A second major area considers whom is receiving the knowledge. Misunderstanding the type of student can yield the same negative results as teaching the wrong material. The upcoming generation entering higher education is often classified as Generation Y or Z since "researchers and others who have written about Generation Z have found it difficult to classify this generation precisely. Some say that it began [with people born] as early as 1991… Others argue the generation began as late as 2001" (Brotheim, 2014: p.16). While "Generation Y, known for its widespread civic involvement and lack of independence compared to previous generations" it is commonly thought that "Generation Z employees come from a generation accustomed to entitlements" (Brotheim, 2014: p.16). It is not unlikely for them to "e-mail or text the agency head directly to opt out of an assignment or question a policy… The Z Generation is highly connected. Many have had lifelong use of such communications and media technologies as the Internet, instant messaging, text messaging, MP3 players, mobile phones, and YouTube" (Brotheim, 2014: p.16). These factors show the need for a different method of interaction.

The two key areas of relevance to this article, however, is the relationship this generation will have in relation to their workplace as well as the education institution. For this generation, it would seem a more appropriate educational conception is that "learning is a process not of knowledge transmission but of meaning making… learning is a dialogue, a process of internal and social negotiation, a socio-dialogical process" (Jaleniauskienė, 2015: p.40). Adding to this is the fact Generation Z students "are all 'native speakers' of the digital language of computers, video games and the Internet…. [that some hypothesize caused] a change in the brain structure that means young people think and process information in fundamentally different ways compared to older generations" (Helsper & Enyon, 2009: p. 1). These disruptions are being felt by educational institutions and have started rippling into the workplace. It is important to mention that these waves affect different countries, sectors and institutions differently but this does not mean that the waves will not reach virtually these systems in time.

[2.3] The Modern Workplace

Recruiting talent and providing an appropriate environment to grow is at the heart of concern of the modern workplace. Generation Z individuals have a different perception of work which requires special attention since it simultaneously facilitates and complicates the conception of a workplace. For Generation Z "The effect of social environment is an important factor… [it is] the duty of employers is to target setting up more chatty and hearty relations out of the business culture… This generation is self-confident and wants to guarantee their future. They know that working has an important role to make true their dreams, and if it doesn't become they would

be unhappy. Happiness is very important on the business area" (Ozkan & Solmaz, 2015: p.479-480). Yet, this can have both positive and negative effects. On the positive, "internet usage by generations Y and Z will assist them to perform searching, researching, and completing their tasks rapidly in a professional way. Via the Internet, generations Y and Z can communicate, collaborate, become involved, and gain new knowledge to become more aware of global and local issues" (Issa & Isaias, 2016: p.595). Predictably, the negative is that this generation can also be seen as 'attached' or even 'addicted' to their mobile phones and see it as an extension of their social life and would predictably want it to form part of the workplace (Ozkan & Solmaz, 2015, p.95-96) (Issa & Isaias, 2016: p.595). This can be a problem when considering the fact that different generations work in the classroom or workplace and this can create sensitivities if the culture is not adapted to understand/mitigate these effects and creating collaboration out of them (Srinivasan, 2012: p.48-66). There is a "differences in work values among employees from different generations exists. Awareness of those differences among generations can help managers to create a more pleasant and productive workplace… Boomers live to work; Millennials work to live. Boomers are willing to wait their turn for promotions and rewards, and they are very loyal. On the other hand, younger generations want immediate recognition through title, praise, promotion, and pay" (Gursoy et al, 2013: p.47).

[2.4] Gamification

A source of hope in resolving the above complexity comes in an unlikely form: Games. Historically, games have proven to be one of the few methods that truly consolidates social interaction and skills development. "Learning practices in the form of games between teacher and students or trainer and trainees can be traced back to ancient Greece" (Markopoulos et al, 2015: p.118). Yet, modern understanding has differentiated between Game Based Learning (GBL) and gamification as a means of implementing games. Gamification is "using game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning and solve problems" (Spina, 2013: p.7). Whilst "GBL provides students with games that have an educational objective that are achieved through the game play… These games can supplement direct teaching or replace it, but it is clearly a game. The essence of gamification is that it occurs in a non-game context; therefore, it would be applied in such a way that would not change the existing practice of learning and instead focus on making it more engaging and challenging for students" (Codish & Ravid, 2014: p.132). The worry is that increasing the playfulness too high can result in a system where there is no perceived link to responsibility and thus would render activities being seen by generation Y and Z individuals as merely a consequence-free game (Codish & Ravid, 2014: p.132-144). It is also important to mention that creating a point system can create problems of its own where "rather than improving outcomes, gamification runs the risk of actually decreasing motivation if it solely on

a rewards system to encourage participation" (Spina, 2013: p.7). Thus, when considering higher education and recruitment activities it is important to balance the playfulness of the system as well as the level of engagement.

The suggested platform must consider specific applications of gamification since the platform aims to be a mix between an electronic resource library, opportunity posting area and social network. Research conducted found that the gamification method has gained traction in public libraries, recruitment processes, business processes and Engineering education. For example, libraries are using gamification "to highlight library features or services… [which] helps libraries understand how patrons use the library and allow patrons to more easily share their library experience with their friends" (Spina, 2013: p.8). Whilst recruitment uses gamification to "stir people's interest in job openings, project an innovative image of an employer and deliver accurate previews of applicant's future job performance" (Zielinski, 2015: p.59). Although it requires massive investment in resources and thought, it has the potential to create a true micro environment that can change behavior, create unique experiences that assist with Engineering education and improve transferable skills (Perryer et al, 2016) (Rodrigues, et al, 2016) (Scoech et al, 2013) (Sosa-Vieira, 2016). These can help a certain group of similar minded knowledge seekers (professionals and individuals) to create a small world that caters to their discplines specific needs (de-Marcos et al, 2016: p.320).

[3] Concept Development/Design Methodology

Given that designing the proposed platform can be seen as a mix of a software and societal project, a mix between the spiral iterative model and v model were used in consolidating the requirements into the design. Section 3.1 decomposes the problem identified in section 1 further using the insight from literature while section 3.2 as well as consultations with Industrial Engineering professionals. The scope identified at the North-West University and from the South African Institute for Industrial Engineers was merely to develop a concept system based on the identified needs. Thereafter it can be developed into a full solution.

[3.1] Needs Analysis

In order for the system to develop social meaningfulness and quality content there needs to be a balance between what the stakeholder receives (output) for their contributions (input) while maintaining transparency in the process. Table 2 below explores the requirements [R] stemming from needs [N] arising from the different user types [UT] and their roles [UR]:

Table 2. Input and Output of Different Users

Stakeholder	Input	Output	System Process [Platform]
User Type 1: *High School Student*	Is expected to fill in surveys (to gauge perception) and participate in simple IE games [UR1.1]	Would receive personalized feedback on whether IE is appropriate for them from quizzes [N1.1], consultations [N1.2] and interaction [N1.3]	The system will thus be required to automate certain responses [R1.1] and suggest relevant content [R1.2]
User Type 2: *Undergraduate University Student*	Is expected to be an active participant in networking [UR2.1] and partake in relevant activities [UR2.2]	Higher quality networking interactions [N2.1], IE relevant templates [N2.2] and educational content [N2.3] to develop one's self [N2.4]	The system will thus be required to provide relevant resource databases [R2.1-2.3], a networking portals [R2.4] and personal profile [R2.5]
User Type 3: *Recent Graduate*	Is expected to post relevant opportunities (research, work or experiential) [UR3.1-3.3]	Will receive relevant recognition for contribution [N3.1] and ability to gather relevant data [N3.2] or resources [N3.3] to solve research or workplace problems [N3.4] and develop themselves [N3.5]	The system must provide a transparent posting of opportunity [R3.1] and recruitment process to facilitate selection of appropriate candidates [R3.2]
User Type 4: *University Staff Member*	Is expected to use the platform as an enhancement to class based learning [UR4.1] and contribute to available content [UR4.2]	Will receive automated assessment feedback [N4.1] as well as access to other educators' content [N4.2] which reduces workload on lecturer and shares creative perspectives [N4.3]	The system must provide templates that suit various types of educational content [R4.1] that can be easily integrated with existing content on different universities knowledge platforms [R4.2]
User Type 5: *Industry Sponsor*	Is expected to post relevant sponsorship, reward and career opportunities [UR5.1-5.3] as well as professional templates used in industry [UR5.4]	Will receive shortlists of relevant candidates from the system based on given criteria [N5.1] or achievements [N5.2] and promote their industry relevant template contents [N5.3]	The system must provide a way to distinguish and filter candidates through IE relevant metrics [R5.1] as well as a resource sharing functionality [R5.2]

Upon review of the formal requirements listed in table 2, it was found that an additional hidden requirement of kick- starting this platform would be necessary [R6.1]. The idea is that having a platform without a critical mass of users will create less meaningful interaction and reduce the perceived value.

[3.2] Prototype System Design

[3.2.1] Design Inspiration

Perhaps one of the best gamification methods uncovered during the research was by using the Baader-Meinhof Phenomenon. The Baader-Meinhof Phenomenon is the familiar phenomenon of “when you hear something for first time it seems to appear everywhere”. It can be used in strengthening the student’s ability to identify and understand the concept. Although it is quite a simple concept, its essence can be used for the benefit of experiential learning. It triggers the development of transferable skills in teaching students to learn about a phenomenon or piece of knowledge, to keep an eye out for phenomenon, to experience it in various environments and lastly to record that experience in a way that matures over time. Two important things to consider when designing a platform is that “straightforward mechanics of leaderboards and points work well for introverts, but can have negative effects on extraverts. Similarly, rewards work well for extraverts and less well for introverts. To achieve overall increased playfulness, a correct combination of mechanics should be used and, if needed, changed throughout the course, to ensure success” (Codish & Ravid, 2014: p.132). Additionally, two points highlighted by de-Marcos et al (2016: p.320) are that “(1) Social gamification tools driven by motivational affordances promote the creation of meaningful learning communities in terms of the overall structure of the network. (2) Student's position in the network seems to influence learning performance”.

[3.2.2] Concept Design

Upon relevant consultation with a sample of stakeholders, the proposed concept was two interlinked systems. The system description along with the requirement and need they answer along with the user type they require are discussed below:

1 - Eye for Industrial Engineering: The first is social media game (to be used on linkedin and twitter) codenamed I-4-IE. This is a simple game that requests users to take a picture or data of a relevant IE concept, term or idea in action and then label it according to the discplines/sub discipline of IE and post it to a common social media platform. A variation of this is weekly challenges where followers are requested to find the IE idea in a posted picture or data on social media platforms. This would be developed to answer the requirement [R6.1] while fulfilling needs [N1.1,1.3,2.1, 6.1] with most input coming from [UT1,2,3].

2 – IE Res-Base Platform: The second system is a networking portal specialized to **Res**ound IE interested individuals and professionals. This portal caters for the various educational, **Res**earch and **Res**ource requirements of the IE community on it. The system is made of the following key portals and pages:

Key Portals

P1 - Personal Portal: Accessible to all user types [UT1-5]. Aim is to provide visually acceptable dashboards for exploring IE socially and personally.

P1.1 Overview Dashboard: A page designed to provide an overview of the activity [R1.2] on the entire platform while suggesting content to user

P1.2 Social Dashboard: Several pages designed to provide a blog and discussion boards to various topics [UR2.1] [N1.3,2.1] [R2.4].

P1.3 Profile Dashboard: A page designed to explore one's personal image, badges and achievements on the platform [UR2.1] [N2.4,3.5] [R2.5].

P1.4 Mail Dashboard: A page for the receiving and sending of intra-portal mail using that follow certain processes for requesting mentors, requesting content…etc [UR2.1] [N1.3,2.1] [R2.4] to cater for need for transparency and efficiency.

P2 – Resource Portal: Accessible by user types [UT2-5]. Aim is to provide visually acceptable dashboards for exploring IE socially and personally.

P2.1 Eye for Industrial: A page designed to create a continuous update from the I-4-IE App and social media linked platforms [UR2.2] [R1.2]. Users can use this to see what others see from their perspective, broaden their horizons and discuss/debate with others regarding specific images.

P2.2 Mentors and Specialists: A directory of professionals on the platform with the relevant way to contact them (from their input) filtered by profession area, type of assistance they can offer…etc [UR2.1,2.2,3.1-3.3,5.1-5.3] [N1.2,2.1,3.1,3.3,3.5,4.2] [R3.1,2.4]

P2.3 Sub Discplines: Several pages designed to explore educational content surrounding each sub discipline of Industrial Engineering. Developed in a peer reviewed wiki format. [UR2.2,3.1-3.3,4.1] [R2.1-2.3,4.1,4.2,5.2]

P2.4 Contents & Templates: Several pages that package resources required for certain project types, initiatives…etc. Sponsored content by industry is branded [UR2.2, 3.1-3.3,4.2,5.4] [N2.2,2.3,2.4,3.3,3.4,5.3] [R2.1-2.3,4.1,4.2,5.2]

P3 – Projects Portal: Accessible by user types [UT2-5]. Aim is to provide a transparent method to share available development, work and sponsorship opportunities.

P2.1 My Project Dashboard: Several pages that highlight the team, tasks, files, calendar and metrics of projects which the user is enrolled in/manages [UR2.2,3.1-3.3,4.1] [N2.3,2.4,3.4,3.5,4.1] [R2.1-2.3,3.2,4.1,5.1]

P2.2 Surveys and Quizzes: Several pages that vary in function from knowledge testing to feedback requesting [UR1,2.2,3.1-3.3,4.1,5.1-5.3] [N1.1,3.1,3.2,3.3,3.5,4.1,4.2,5.1] [R1.1,2.5,3.2,4.1,5.1]

P2.3 Current Project List: Several pages where available opportunities and projects are posted by [UR3.1-3.5,4.2,5.1-5.3] [N2.4,3.2,3.4,4.2].

P2.4 Completed Projects: A gallery of achievements of platform members that highlights what is possible with collaboration [N3.1,4.3,5.3]

[3.2.3] Available Design Tools

Given that the request was a conceptual system design, prototyping tools were used to develop the concept. Bootstrap was found to be an excellent tool for rapidly prototyping and designing dashboard application. Admin platform templates available online were customized using the pine grow software package to develop the relevant platforms identified in table 2. The memento database android app was used to prototype the Eye 4 IE mobile application.

[4] System Concept

[4.1] Eye 4 IE Application

[4.1.1] Description of System

The solution encourages the student to identify and record data from the world around them when they see a link to a concept taught in class. In many ways, it is methodologically the same as giving mathematics exercises to encourage practice. However, in this case, since some IE concepts can be quite complicated and not objectively solvable like mathematics problems, the aim is to train the eye in identifying problems and the brain in resolving them. Even if the solution is not implemented, the student gains the ability to go through the motions of problem resolution. That is why the app will be called “Eye for Industrial”. The idea is to train the undergraduate students to develop this specific “eye” to capture real-world manifestations. This will, in turn, support their theoretical knowledge. The application itself will have a collection of templates that can record certain types of data. For example, one of the templates might simply require students to take a picture of an event which reminded them of a specific concept. Lecturers can update the concepts on the template and see how much feedback they can obtain after teaching a certain concept. Other templates might be more course specific or complex. For example, a template can require students to record number of people in queues and perform time studies

[4.2.1] Eye 4 IE Application

Figures 1-3 showcase the proposed application. As can be seen, a strong focus was placed on visual appeal. Figure 1 displays the homepage of the app showing the IE-Spy social media game along with several sub-discplines specific templates for queuing times and statistical process control. Additional mini portals for connecting with IE professionals are included. An additional dashboard for the mobile application is shown in Figure 2. On this page, helpful

reflection tools are given to the user to reflect on their experience. Figure 3 shows a sample form for the IE Spy game where a simple survey allows the user to record a picture that relates to an IE idea or upload a visual representation of collected data.

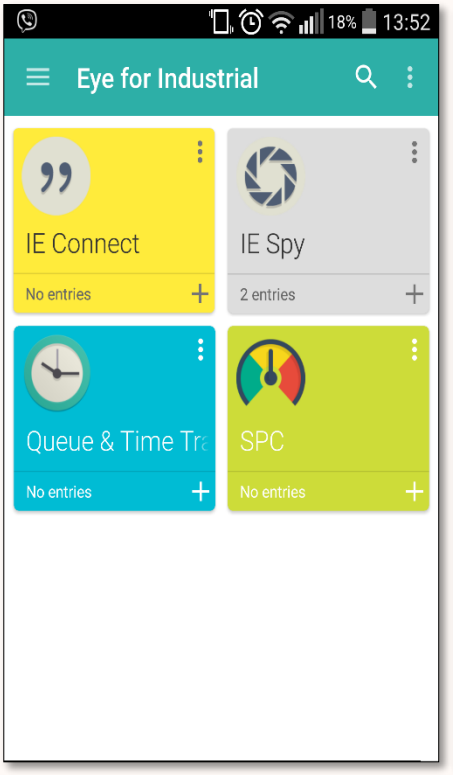
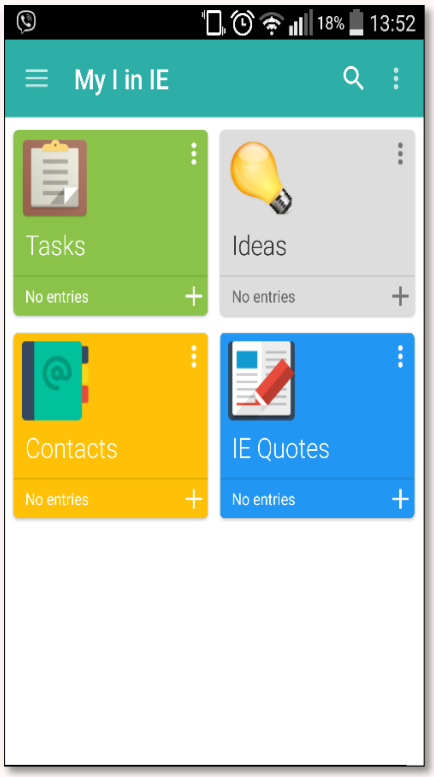


Figure 1: Main Dashboard Eye-4-IE App



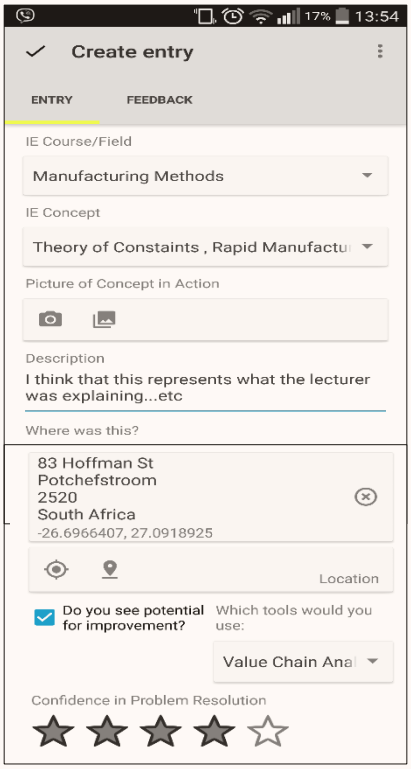


Figure 2: Personal View Eye-4-IE App

[4. 2] IE Res-Base

[4.2.1] Description of System

The platform is a multifunctional resource-sharing solution. It takes the meaning of resource in the broadest sense (time, networking, template resources, content…etc). The proposed final solution aim is collect data from surveys posted on the website, interaction between members and content posted. Industry might also be kind enough to share IE relevant data within their companies. Additionally, it can potentially provide resources and templates suited for IE use. Additionally, customizations of these will be available on the website for different Industries or cases. Educational content can be packaged into courses for strengthening certain skills, specialties or capabilities in a standard video or text format. A strong focus is needed on visualize Industrial Engineering knowledge, specializations and spread in Industry. Also, the interface with other bodies of knowledge can be depicted. Final solution should be a fun and interactive place where students can spend some of their time. Alumni of undergrad programmes will be encouraged to participate. Lastly, it should promote postgraduate research for IE in Industry by removing some perceptions about academia. This is primarily done by creating collaborative efforts that mix between the positives of the private sector and education sector.

[4.2.2] Visual Design

Figures 4-10 below showcases the most important pages/portals of the platform. Pictures are marked with maroon boxes with a unique ID to enclose certain app objects. Descriptions of app objects are provided below the figure.

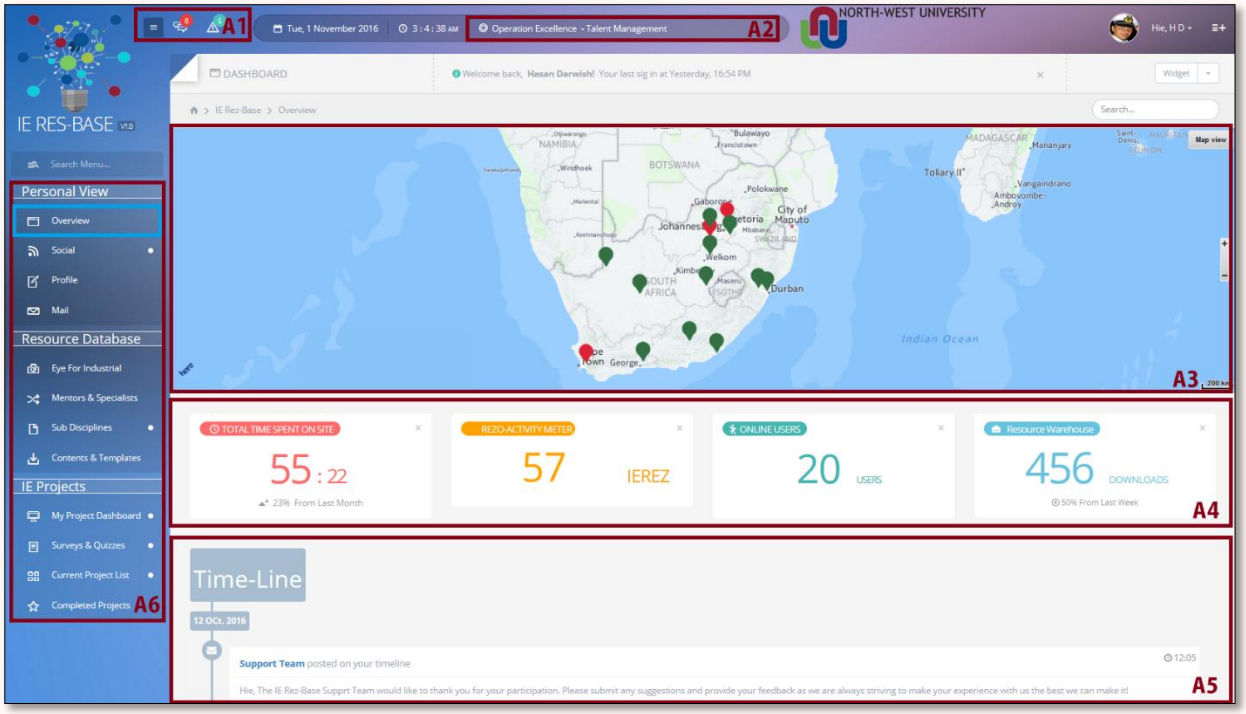


Figure 4: IE Res-Base Main Dashboard (Overview) [Own Work] ***A1:*** Notification and messaging applet. ***A2:*** Randomized IE term (on click will direct to wiki page) ***A3:*** Map of active and inactive users (red and green) ***A4****:* Website activity statistics and resource availability ***A5:*** Timeline of user relevant activity on platform ***A6:*** Navigation panel between 3 sub portals

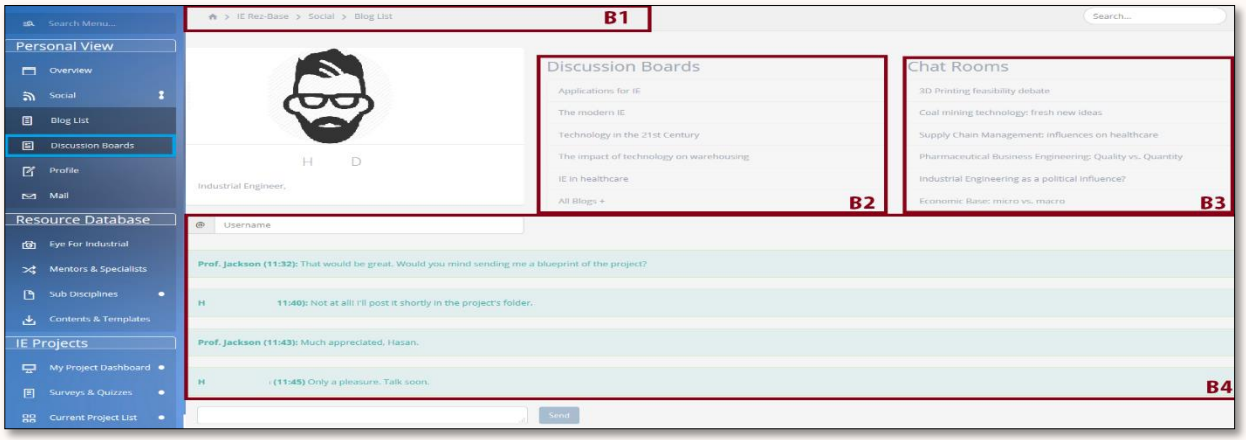


Figure 5: IE Res-Base Social Page (Blog List) [Own Work] ***B1:*** Navigation Bar ***B2:*** Available Discussion Boards ***B3:*** Available Chat Rooms ***B4****:* Chat with IE platform user

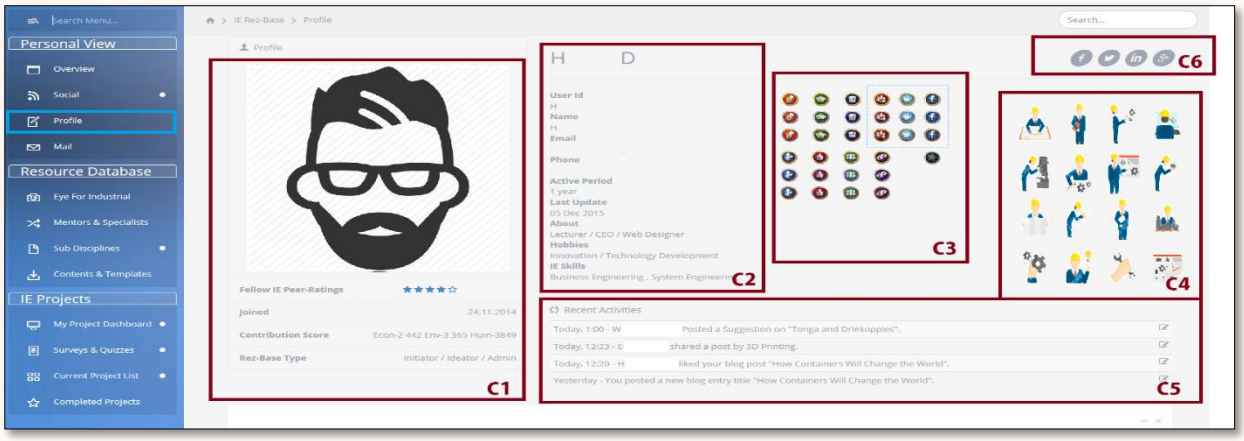


Figure 6: IE Res-Base Profile [Own Work] ***C1:*** Profile overview and picture ***C2:*** Profile information and contact details ***C3:*** Unlocked badges and rewards ***C4****:* IE Lifetime achievements/Type of IE ***C5:*** Recent activities ***C6:*** Social media links

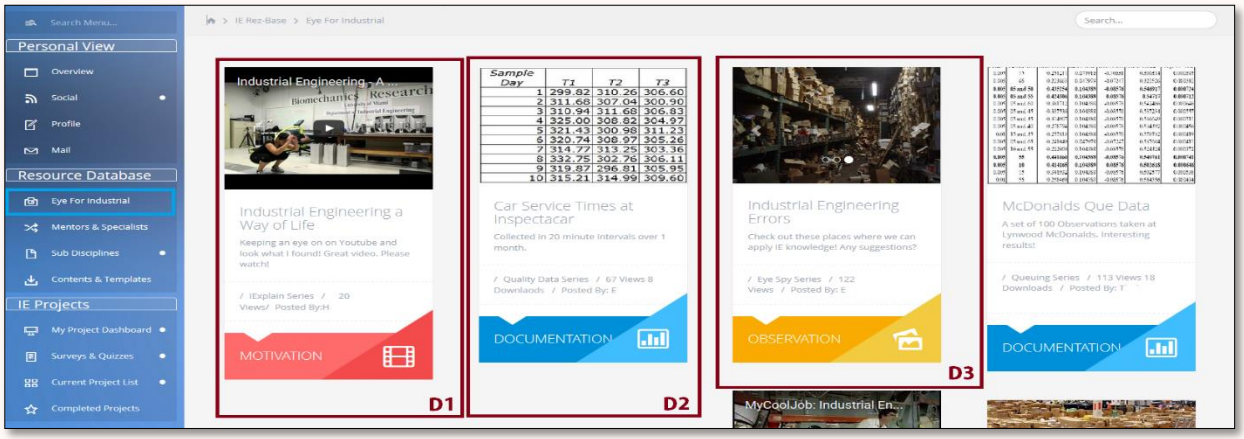


Figure 7: Eye 4 IE Page [Own Work] ***D1:*** Motivation video content post ***D2:*** Documentation data content post ***D3:*** Observation picture content post



Figure 8: IE Res-Base Sub Discplines Knowledge [Own Work] ***E1:*** Definition from multiple sources ***E2:*** Sub-field terminology and related concepts ***E3:*** Academic resources (journal articles) ***E4****:* Textbooks relating to sub-field ***E5:*** Websites and tools used in sub-discplines

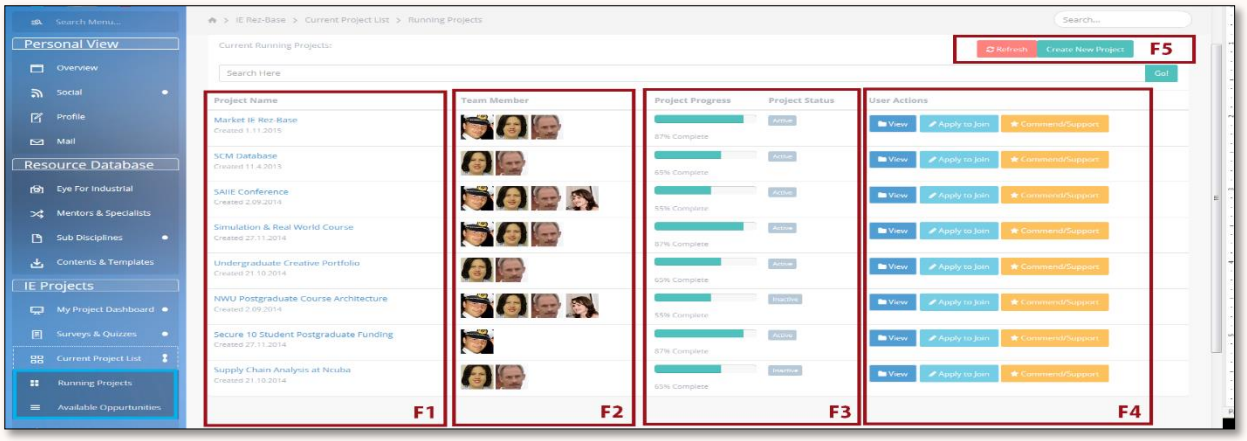


Figure 9: IE Res-Base Available and Running Projects [Own Work] ***F1:*** Project name ***F2:*** Team members involved in project ***F3:*** Project progress and status ***F4****:* User Actions with regards to project (Apply to join, view details, comment/commend. Etc) ***F5:*** Create a new opportunity (project/research project/concept)



Figure 10: Eye 4 IE Completed Projects [Own Work] ***G1:*** Completed project overview ***G2:*** Economic focus achievement bar ***G3:*** Environmental focus achievement bar ***G4:*** Social focus achievement bar ***G5:*** View project details **G6:** Share project on social media ***G7:*** View project team/contact team ***G8:*** Comment/comment project

[5] Conclusions and Recommendations

[5.1] Conclusions

This article proposes a comprehensive platform concept which is, in many countries, a massive improvement on existing professional development and recruitment platforms. The concept recognizes the importance of considering literature surrounding both the actual problem associated with education (from high school through to the workplace) as well as surrounding technological and generation forces which naturally impact the final solution. A preliminary pilot of the Eye-4-IE application was performed with preliminary feedback indicating a positive outlook. It also provided valuable improvement opportunity in the form of simplifying the forms and getting started process.

[5.2] Recommendations

It is recommended that collaboration amongst various international student and professional Industrial Engineering societies be conducted to roll this system out as a global initiative that links IE professionals worldwide. This would allow for a truly diverse small world community that can share valuable insight into the differences of IE academics and application in practice.

[5.3] Future Research

A full system development is currently underway after concluding formal requirements analysis with relevant stakeholders at SAIIE, the NWU and with students and young professionals at various educational institutions and workplaces.

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8. Article 3 – Economic Level: Impact of Major Environmental, Social and Economic Forces on the Field of Industrial Engineering

8.1. Details of Article 3

All relevant administrative details of this research output were submitted on the NWU system and are available in Appendix D3.1. This conference paper was submitted for the 27th annual conference of the Southern African Institute for Industrial Engineering (SAIIE), held from 27-29 October 2016 at Stonehenge in Africa, North West, South Africa. The article was completed using the author guidelines for the South African Journal for Industrial Engineering (SAJIE) available in Appendix D3.2. The conference paper underwent a single round of a triple blind peer review (feedback available in Appendix D3.3). The conference paper was first available online on November 2016 in the NWU research repository. The paper received the award for best poster presentation at SAIIE 27. There are no statistics on the paper access from the proceedings, however, the article was accessed 20+ times on ResearchGate.

8.2. PhD Golden Thread in Article 3

This paper addresses the third identified area of concern which deals with the role of the Industrial Engineer in the economy. This specific article explores the role of all macro-disruptors (economic, environmental and social), however, it shows how the locus of control is significantly greater in the economic sphere and thus change should perhaps come from this area. More importantly, the article shows how adaptation to macro forces is similar to walking a long road… once the first few steps are taken a momentum builds up which allows for more changes to be made. For the overall PhD, this article took a genuine effort to develop a cohesive argument for why it is important to change the thinking process and how misevaluating macro-disruptors can result in a field, even as progressive as Industrial Engineering, lagging in its development.

8.3. Extracted Insights from Article 3

- **S3.1:** Means of production are becoming decentralized and simpler due to 3D printing & additive manufacturing
- **S3.2:** Employment mechanisms, corporate structures and customer behavior are becoming more network like due to the sharing and knowledge economy
- **S3.3:** Supply chains are becoming shorter due to transport technologies creating radically different supply/demand relationships
- **S3.4:** Human concerns and values relating to education, health and other concerns are becoming more conscious
- **Conclusion 3 [Desirable Systemic Change]:** Since Industrial Engineering is deeply rooted in designing and managing the above socio-technical systems, transdisciplinary frameworks need to be created using Industrial Thinking to correctly evaluate the impact of macro-disruptors and successfully react to them.

8.4. Article 3 Manuscript

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Abstract

Every profession is bound to adapt in response to changes in the macro environments. Industrial Engineering is especially affected due to its broad application across various fields, i.e. manufacturing, customer service design, consulting and more. This article argues that the need for change is envisaged to be radical due the deep-rootedness of Industrial Engineering in specific areas where environmental, social and economic (ESE) forces are prompting fundamental transformation. This transformation often manifests itself in an evolving technology. The argument of this article is that 1) Means of production are changing due to 3D printing and additive manufacturing 2) Employees work arrangements and corporate structures are changing 3) Customer behaviour is changing due to sharing and knowledge economy 4) Supply chains are changing (supply/demand) due to drones and radically different supply/demand relationships 5) Human concerns/values (such as education, health and other concerns) are changing. Therefore, Industrial Engineering must adapt to these changes due to its connection with these fields. This article further addresses the major forces impacting Industrial Engineering from 3 starting points: top down (macro-landscape challenge view), bottom-up (technology impact view) and middle ground (IE sub-discipline point of view).

Keywords: Industrial Engineering, Economic Forces, Social Forces, Environmental Forces, Impact Analysis

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[1] Introduction

The world is changing and so is Industrial Engineering. A Coldwell Banker Richard Ellis (CBRE) report finds that "50% of occupations in corporations today will no longer exist by 2025" [1, pp.6]. Yet, this does not mean the other 50% are safe. Although they will not become obsolete, their occupations are most likely to change dramatically. The simple fact of the matter is, in the knowledge era, the inability to pick up on relevant forces shaping the context or work of a field of study can result in misalignment, outmodedness and deterioration of that field or its tools and techniques. "The next 15 years will see a revolution in how we work, and a corresponding revolution will necessarily take place on how we plan and think about workplaces" - Peter Andrew [2]. Technology is perhaps the greatest force that requires consideration. A failure to adjust and integrate technology into practice results in ineffective, minimally applicable and obsolete practices. It is important to remember, though, that technology development is often instigated by economic, social or environmental factors.

The topic of interest for this article is the occupation of Industrial Engineering. After rising to a high standard and developing capabilities that are seen as immensely valuable by industry, it would be disappointing to see that some of methodologies, tools and skills are no longer seen as useful (especially since it is possible to adapt them). The concern here is that creating something of value without the perception that it is valuable often results in similar effects as something not being valuable at all. Much like the companies that Industrial Engineers work in have contingency, human capability and risk plans; the Industrial academic and work departments have to be structured in a way that integrates and caters for all potential changes to macro environments. After all, the tools for change management and integration are being taught in those same departments; it would be unwise not to use them to do a self-analysis. In summary, in the words of Sperotto [3, pp. 8]:

> *Rapid changes in the social and industrial environment continue unabated, driven by accelerating technological developments, availability of information, networking, and globalization. Developments in polymers and new materials from nanotechnology, for example; the variety of energy sources; new manufacturing processes and paradigms, such as additive manufacturing and distributed manufacturing; aerial and robotic networking; neuromorphic technology and predictive intelligence; the Internet of Things (IoT); the spread of integrating techniques, technologies and systems throughout the whole supply chain and its parallel, waste flow management; the increasing value-adding applications in the service industries; and the blossoming world of virtual reality; will extend the complexity of integrated systems and change the focus of industrial Engineering,*

the needs of industry, the nature of work, the human-machine relationship, and the culture and lifestyle of people. Inevitably, the industrial Engineering profession and its institutions will need to embrace these changes in order to remain relevant and to contribute meaningfully to industry and society.

[1.1] Background and Summary of Argument

The Industrial Engineering profession faces many challenges in the 21st century. Yet, one can still argue that these forces are unlikely to completely change Industrial Engineering and the need for Industrial Engineers. Especially since, in many countries, it is considered a scarce skill (8th in South Africa) [4]. However, this does not change the fact that IE can remain ahead by conducting self-assessment and improvement studies. Additionally, doing so would be keeping true to the vision and core values of Industrial Engineering. There are, however, challenges arising from specific economic, social and environmental forces. Perhaps the most pressing issue is that the 21st century is experiencing the evolution of a new macro-economic system that is better suited for the needs of society and the environment. Many have labelled this new economic system as the "knowledge economy" and the "sharing economy" [5-6].

Although one cannot neglect the immense impact of the latter 2 macro-systems on the economy, it would seem that the economy is the one where humans have the most direct control. Therefore, it makes them the preferred option to influence change and actually 'do' something. This is mainly because participating in the economy is almost fully mandatory and virtually everything seems to be linked to it in some way or another [6]. Simple day to day reference to global warming, income inequality and employment wellbeing all have deep social and environmental instigators [6]. However, they seem to attract much more attention when one finds a way to display them on a balance sheet and show their link to the economy (carbon taxes, knowledge accounting, intangible accounting, talent capital…etc).

The problem of dealing with massive technological, social and economic changes is not unique to Industrial departments. "Rapid changes inevitably destabilise established institutions, and cause misunderstandings and stresses between conservative and progressive groups and individuals" [3, pp. 8]. The beauty of the field of Industrial Engineering is that it understands "that adapting to the new economic regime would require philosophies and methods tailored to the forms of work that defined the new mode of production" [7, pp. 737]. However, technological forces of the 21st century (reinforced by social and environmental forces of awareness) have completely changed the meaning of key words like 'supply chain', 'work', 'production', 'system' and even 'value'. Arguably, though, it is a key responsibility of Industrial departments to provide the frameworks, connections and strategies

to deal with such rapid changes (since there is an implicit claim to understand this complexity best and since Industrial Engineers are often in management positions and are well known for designing the systems that deal with these changes). This is also partially due the broadness of IE sub-disciplines. These sub-disciplines can be defined as: “management information systems; systems engineering; modelling and simulation; mechatronics and automation; robotics and artificial intelligence; operations research and operations management; facilities management and maintenance systems; quality management systems; project management; logistics and supply chain management” [3, pp. 6].

The solution, however, must not simply focus on future graduates (most likely from generation Y and Z). The Industrial Engineering department has to embrace a transformative role which develops existing graduates already in industry, similar minded professions in other disciplines and interested individuals willing to progresses their holistic abilities (both privately and at universities). Yet, the most valuable network to an Industrial Engineer might be fellow Industrial Engineers (and their networks within other industries) who have mastery over some skills and can further one’s own connections. The common understanding between Industrial Engineers allows for ease of communication, while the clear distinction in specialty allows for a wide influence. This also requires understanding the perception of Industrial Engineers, both in academia and in industry, on the forces changing the environmental, economic and social landscape. The overall aim of this article is to suggest developmental areas for Industrial Engineering knowledge. This will help adapt, reform, integrate and promote sustainable and healthy changes, whilst opposing, eliminating and transforming obsolete theories and technology. In short the focus of the argument in this article is as follows:

1) Means of production are changing due to 3D printing & additive manufacturing
2) Employees and corporate structures are changing, and customer behaviour is changing due to sharing and knowledge economy
3) Supply chains are changing (supply/demand) due to drones and radically different supply/demand Relationships
4) Human concerns/values (such as education, health and other concerns) are changing
5) Industrial Engineering is deep-rooted in above systems

∴ **Industrial Engineering must develop to adapt to these changes**

Section 2 review the impact of major forces in the economic, social and environmental spheres. Section 3 further explores a specific technology (additive manufacturing) as a case study to show how specific research projects can contribute to adapting to these changes. Lastly, section 4 aims to classify the challenges into relevant IE disciplines.

[2] Macro Challenges on the Industrial Engineering Discipline

[2.1] Economic Specific Challenges

The rise of drone delivery, 3D printing, EBay, Airbnb, Fiverr and even Uber will challenge every conceivable industry. This is not only because they add complexity to the network, but also because they change the rules of the game with regards to supply and demand. This has led to the rise of supply networks (example shown in Fig. 1) which "should visually depict all the linkages between buyers and suppliers throughout the world" [8]. For example, large organizations offering services and products have very high overheads with shareholder expectations as well as big boss bonuses built into their pricing might be replaced by decentralized producers. The local 3D printer/Uber driver/Airbnb room simply have their capital repayment of their hardware, living costs and some savings built in. Additionally, there might be an interpersonal relationship between the producer and supplier of goods and services. Yet, they are producing the same product or offering virtually the same core service. In fact, these applications are going a step further in truly answering the customers need because they are offering only what the customer is willing to pay for. This in itself is an excellent display of value offering design, minimum viable product thinking and system thinking. The sharing economy is a result of complex socio-economic forces with some very positive environmental effects (due to less resources being used and more being shared). Part of the forces shaping this new idea are a disillusionment with consumption, need to connect, requirement for more specialized/customized service and a lack of opportunity in the mainstream economy [1]. Additionally, a CBRE report notes that "a growing proportion of jobs in the future will require creative intelligence, social and emotional intelligence and the ability to leverage artificial intelligence. And for most people that will be a route to happiness and fulfilment." [1, pp.33].

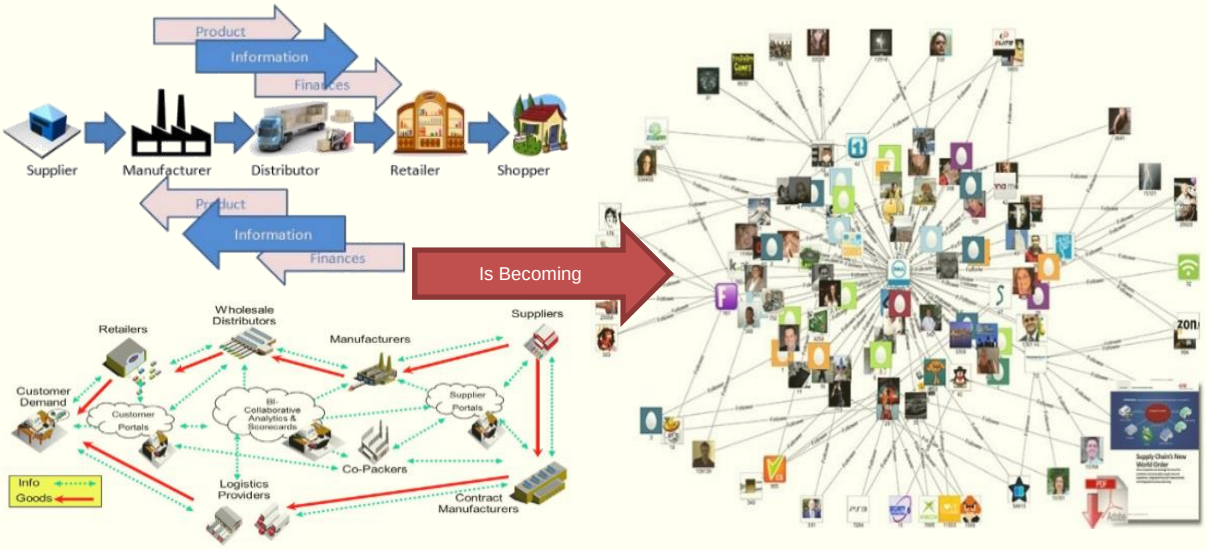


Figure 1: Supply Chain to Supply Network [8-10]

Additionally, the sharing economy seems determined to eliminate traditional hierarchical structures. It is also commonly referred to as 'collaborative consumption', "which is a trending business concept that highlights the ability (and perhaps the preference) for individuals to rent or borrow goods rather than buy and own them" [11]. Part of the reasons this shift is occurring are that traditional capitalistic and consumption models (idea that 'more' consumption holds the solution) did not create value for the overwhelming majority of agents participating in them [12]. For some, it showed a shift towards an inhumane way of living, especially since a large part of the assumptions of the previous model depend on less knowledgeable consumers who do not question as much. Additionally, the previous model resulted in more than half of the world's wealth being owned by 1% of the population [13]. Even though one might debate whether humanity has reached the sharing economy stage, it is commonly agreed that the knowledge economy is in play. The sharing economy is a natural progression stemming from the sharing of knowledge, experience and ideas. More often than not, this content has been freely available on the internet. The knowledge economy recognizes 'intellectual capital' and with that change "a significant part of a company's value may consist of intangible assets, such as the value of its workers' knowledge (intellectual capital)" [14]. The fact that more knowledge is freely available and attainable will naturally lead to more wealth distribution since wealth is no longer viewed merely as capital assets.

[2.2] Social Specific Challenges

The concern for human well-being, health, ethics and culture is not just a passing concern in Industrial Engineering. It is a fundamental pillar of the Engineering profession [15-16]. In the words of Nelson Mandela "like the gardener, a leader must take responsibility for what he cultivates" [17]. Engineers, in general, face a similar responsibility especially since the products, services, technologies and processes they design affect virtually every human being on earth [16]. Industrial Engineering are especially responsible since most of the time they are specifically responsible for the designs of the interfaces with society at large of Engineering products (or at the very least, they are responsible for coordinating efforts with those who do). This is what makes humanity/society the second anchor of IE focus [15-16].

Industrial Engineering is not only capable of providing relevant approaches to managing the facilities, infrastructure and systems governing urban life; it can setup the collaborative approaches, adoption strategies and decentralization necessary to avert unhealthy effects. One of the key specialties in Industrial Engineering is the ability to adapt to scaling up and scaling down. This is why Industrials should naturally work with city planners to "modify the design and use of our cities [and] develop approaches to allow us to live in high-density ''urban villages'' separated by parklands, recreation facilities and garden plots, and connected by light-rail transport" [18, pp.1123]. In addition to traditional IE tasks, several vigilant IE postgraduates

and professionals have noticed the immense benefits that IE can have in developing the systems necessary for governance and providing services (especially health and education). Uzosoy in Christensen discusses that “like industrial supply chains, the health care ‘supply chain’ consists of multiple independent agents, such as insurance companies, hospitals, doctors, employers and regulatory agencies” [19, pp.143] and “the task is complicated because demand for service is determined by both available technology and financial considerations (such as whether or not certain treatments are covered)” [19, pp.143].

Government services (education, health and voting) face similar challenges and have had some benefit from Industrial Engineering intervention [20]. Although IE is still in very early stages of intervention in the public sector, one can only wonder how much benefit can arise from IE using systems principles to restructure government services to be more transparent, effective and consistent [20]. The most relevant point here is that humans naturally interact with systems. There is no doubt these systems are complex, but IE tools can extract relevant factors. Additionally, they can participate in designing systems which best reflect the virtues of its agents. Whether this system is education, healthcare or something else is not the issue. Industrial engineers will naturally work with the available professionals and specialists in that field to develop a system which answers a principle need [15]. Part of answering a need requires Industrial Engineers to review some theory from industrial psychology and organizational behaviour. The increasing connectedness of the world has resulted in people’s voice being better heard [8]. Social media is a great example of how each person can create an online presence which represents them as an agent [8]. The communication between these agents, their exchange of culture and mail has created an effect that converted this once disperse world into a small village. Another effect of this is rapid urbanization as more people try to find more opportunity, interact with similar minded people and experience new things as they setup their lives [1].

The most pressing issue, however, remains that modern human psyche is different and the impact of perception greater. Part of this lies in the fact that “evolutionary emergence of advanced symbolizing capacity enabled humans to transcend the dictates of their immediate environment and made them unique in their power to shape their life circumstances and the courses their lives take. In this conception, people are contributors to their life circumstances, not just products of them” [21, pp.164]. The prime role of an Industrial Engineer, with regards to the above, is aligning perception with reality. An additional focus can be on finding a way to “balance between the individual and collective aspirations” [15, pp.6]. Lastly, perhaps the Industrial Engineer should adopt a clear focus on application. There is no shortage of people creating knowledge/technologies, so Industrials would be perceived better if they focused on applying it for the benefit of society.

A good place to start benefiting society is radically changing the idea of work. When asked about work, the perception of an 8-5 workday comes to mind (with 1-2 hours each side for traffic) [1-2]. This is unfortunate and perhaps the reason flexible hours and deliverable based pay work systems came to be. The idea of work was largely developed to suit the needs of a previous century where it was believed that the 8-5 model provided the best productivity and health. When this pre-21st century idea is applied in the 21st century, family relations are strained (since working parents have less time to interact), time is actually wasted at work (due to an imbalance between pay and expectation) and so on [1]. Thus, overall productivity is lower and the perception is self-defeating. However, work, in the broadest sense, is a physical or mental effort directed towards the production or accomplishment of something. Due to the fact that this creates value, one can naturally expect a share of the value in the form of a salary, benefits…etc. Ironically, even in the definition, physics arguably reaches better results than the perception of fixed hours. The definition in physics is the transfer of energy from one system to another. If IE works on converting this definition to accurately account for work/energy coming from individuals and collectives, then Industrial Engineers will have something better to base a “work” theory on (which will determine remuneration).

[2.3] Environmental Specific Challenges

The 21st century has seen a rise in environmental regulation. Interestingly, this is only partially due to government efforts. The devastating cycle of consumption has lead scientists, sociologists, Engineers and others to seek alternative technologies. Customers all around the world are becoming more aware of the effects of their actions and consumer choices [15]. Additionally, a larger focus is being placed on sustainability, preservation and conversation of the resources that allow us to live our lifestyles. Although some of these technologies have existed for a long time, the reason they fall under the environmental section is because the rising interest in them as a true alternative only grew in response to environmental problems [15]. The technologies that will be discussed share a common idea in that they aim to be wasteless (in doing so, they are also sustainable and environmentally friendly). For Industrials, a wasteless process is an ideal process. Theoretically it is impossible to produce no waste at all; yet, when one studies nature, one finds that the idea is more about creating waste which is usable by another system as a resource.

Environmentally-driven technologies are striving to provide the closest thing to wastelessness and symbiotic relationships humanity has known. They might hold the key to a healthier environment with less polluting chemicals and better sustainability [12]. If an Industrial Engineer is asked what an ideal manufacturing process would look like, there is no doubt that the definition will include eliminating the waste. Additive manufacturing and 3D printing not only

do this, but they also simplify a production process which used to take 12 machines in a 100m line into a 3 by 3m build area. These developments are constantly brought to light in the media world. However, there is a need to understand how additive manufacturing affects the entire world around us. Beyond reviewing what techniques are available and what design processes are used today, a deeper understanding must be developed on how these developments affect our supply chains, facilities, customizability, quality of and even the way companies will design our products. The rapid destruction of our natural resources prompted a revision of our energy production [12]. Some countries were fast to convert fully to alternative energy while others remain sceptic. Whether there is direct links to global warming and natural catastrophes, it is no secret that the chemicals involved and created by non-renewables are harmful to the environment and everything living in it, both directly and indirectly. It also simplifies the energy conversion process immensely (from raw potential energy into usable energy). Alternative energy technologies include geothermal, solar, wind and various others. Yet, the problem does not seem to be with the technology, but rather it seems to be an inability to see the true financial benefit of alternative energy. Industrial engineers naturally need to take a proactive part in resolving this problem by utilizing skills learnt in management accounting, Engineering economics and other courses to accurately reflect the financial and non-financial benefits of alternative energy to companies and decision makers [15]. Accounting for the right things might lead to very different decisions and will facilitate a swifter transition to more sustainable energies.

Energy and products are definitely important, but they are not nearly as important and vital as food to human survival. Food security is a growing concern across the globe. “Eating is the most important act of human existence” – Bob Cat [22]. The ability of the planet to produce food sustainably for 7 billion people has decreased due to environmental decay [12]. What adds more complexity to the issue of the food supply chain is the nature of its variability in the supply demand relationship. Different cultures have different diets and different people demand different types of food daily (which is perhaps one of the most unpredictable sources of demand). The question here is how does one provide demand locally (to ensure high quality), whilst ensuring rapid response times to demand (keeping low stock which also increases quality), and ensuring that minimal resources are used in the process?

Hydroponic and aeroponic faming might provide the answer since they utilize a water or air based medium to give plants the exact nutrients the need [22-23]. This is often done in a controlled environment, requires virtually no soil and produces high quality good consistently due to the lack of severe environmental changes typically encountered in normal farming [23]. The idea itself was largely conceived by recognizing that soil is merely a transfer agent. The

actual nutrients are what is really required by the plants (differentiating perceived need from true need). Additionally, business cases can be made for both small scale decentralized production and large scale centralized production.

Sustainable food cycles recognise and utilize the waste of one organism to feed another until a complete cycle is achieved (forming symbiotic relationships) [24]. This naturally occurs in nature, but restaurants and businesses are starting to notice its positive impacts. A great example of this is a symbiotic relationship between beer, fish and plants which several restaurants have taken advantage of on [24]. The fish produce waste used to grow the beer, the fish eat some of the vegetation to grow and both of them are served at a restaurant which provides the funds to run the entire operation [24]. This shows that these methods can be applied to the business environment as well to create more sustainable and healthy competition less focused on the 'dog eat dog' metaphor. Drawing parallels between the natural world and business world can create for some very interesting answers.

[3] Technology Impact Review: Additive Manufacturing as a Case Study

During the past decade humanity saw the rise of consumer electronics due to the rise of the micro-processor. Moore's law predicted that processing power will double every 1-2 years with components becoming more affordable, reliable, usable and widespread; and he was correct. However, a new buzzword has hit the technology world: Additive Manufacturing. Additive manufacturing is a process by which components are built, altered or repaired using a variety of processes [25-27]. This concept mainly focusses on the addition of material rather than subtraction; thus creating less waste whilst saving time, money and ensuring top quality. Processes vary from laser manufacturing to cold spraying. Some processes (mainly known as 3D printing) only require heating and placing certain polymers into the preferred form. However, one thing is clear from the scientific literature and technology markets: Additive Manufacturing is here to stay [25, 26]. Additive manufacturing by nature is a superior process capable of very advanced designs. In the past 3-4 years there has been a trend developing within this technology and it is expected that the next decade will see the same effect as the processor (shown in Fig. 2).

Printing a pizza at your local shop or having an old piston rebuilt like new with metal powder were topics mentioned solely in science fiction only a couple of years ago. However, developments in the additive manufacturing world have led to a new production method which is not restricted by tolerances, geometries or complexities [25, 26]. Although somewhat expensive at this point in time, it is argued that additive manufacturing will be the way we produce any product in the future [26]. Whether it be our food, metallic service parts or even

our organs; scientists have found a way to use additive manufacturing techniques to use raw powders to create an endless possibility of products [26]. These developments are constantly brought to light in the media world, however, there is a need to understand how additive manufacturing affects the entire world around us. Beyond reviewing what techniques are available and what design processes are used today, a deeper understanding must be developed on how these developments affect our supply chains, quality of our products and even the way companies will design our products [26].

With any growth of this kind it is natural to see problem areas such as: inefficiency, quality, process and other multidimensional problems. Since this technology deals with aspects of man, money and machine; it is vital that an Industrial Engineering perspective is developed to help save millions in future and assist in advancing this fantastic technology. Additionally, the simplified supply chain and facilities can be a research area on their own within IE. Perhaps due to the smaller facility sizes and improved power efficiency, alternative energy can be used.

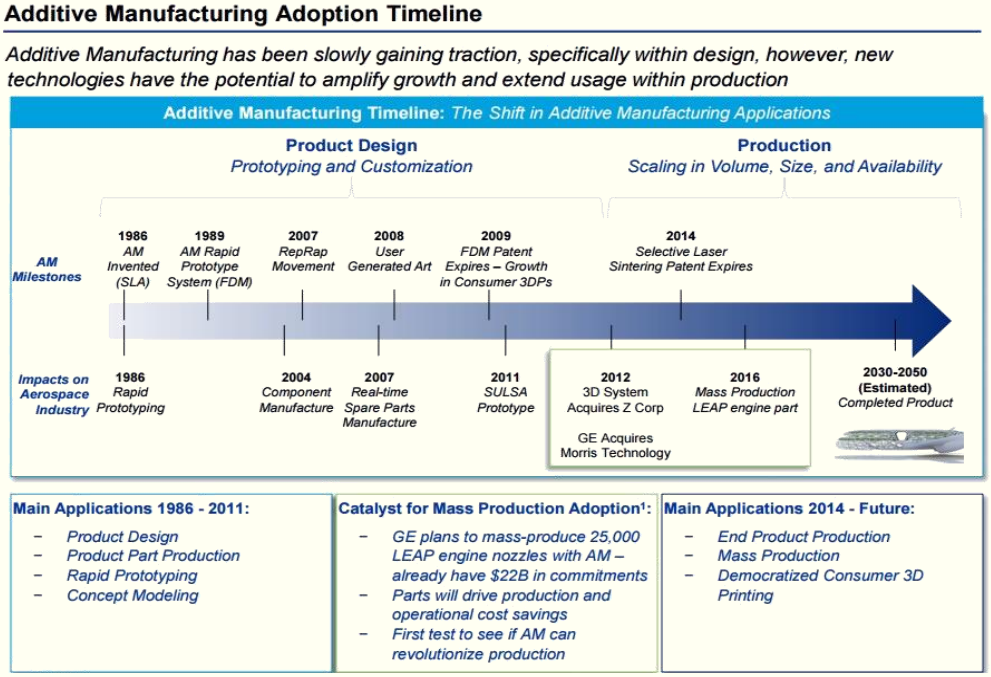


Figure 2: Growth and Maturity of Additive Manufacturing [25]

[3.1] Potential IE Research Topics in Response to Additive Manufacturing Technology

[3.1.1] Quality Standards & Decision Support Data for Additive Manufacturing

A potential idea is to create a universal test jig/board, using quality management and design of experiment tools, to be able compare different additive manufacturing technologies to each other and thus be able to understand to what industry they can be used in. The aim is to test one powder material at a time on the base given below with different scenarios such as different base materials and conditions to create a variety of shapes and figures designed to test the full capabilities of the technology.

Each technology will be compared on the basis of 3 aspects: Cost, Quality and Time. Each of these aspects has sub qualities indicated in the table below to show the exact area where technologies surpass each other. Such a deliverable will provide a very good platform for analysing the different technologies. Different "boards" can be developed by experts for different test fields and material however the concept must test a variety of operating conditions, materials and builds while ensuring that accurate data is recorded about the time, cost and quality. This can help create a way to compare apples with apples. Overall this would provide an excellent platform for companies to test machines, technologies, materials or suppliers. This will give them an excellent test before commencing production with that specific supplier and will ensure that their criteria are met. A visual representation is shown in Fig. 3.

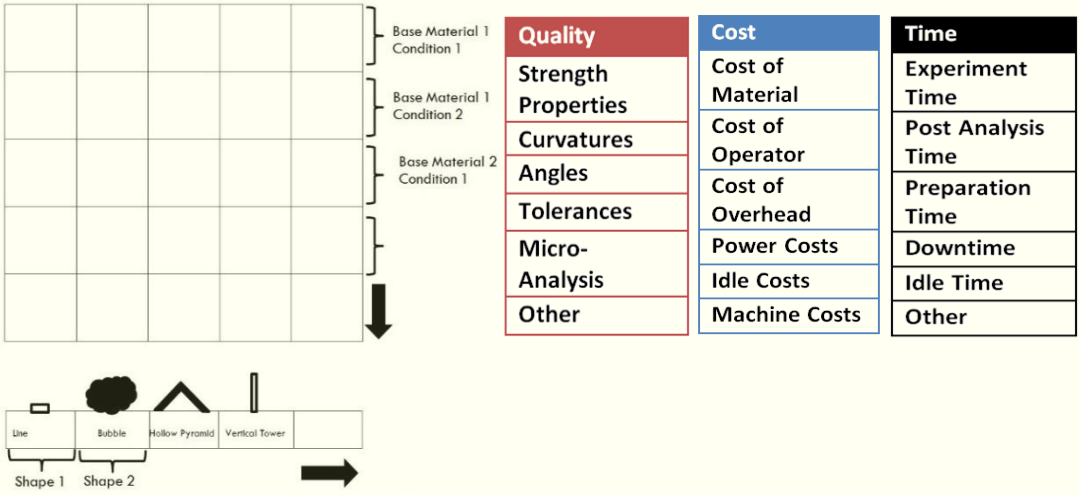


Figure 3: Universal Additive Technology Test Jig/Boards [Own Work]

[3.1.2] Production and Manufacturing Requirements & Specifications

From this above it can easily be seen how specific requirements can arise for different industries. Industries will most likely be grouped by product size and complexity; changing the way in which production and manufacturing requirements are classified and communicated (shown in Fig. 4 below).

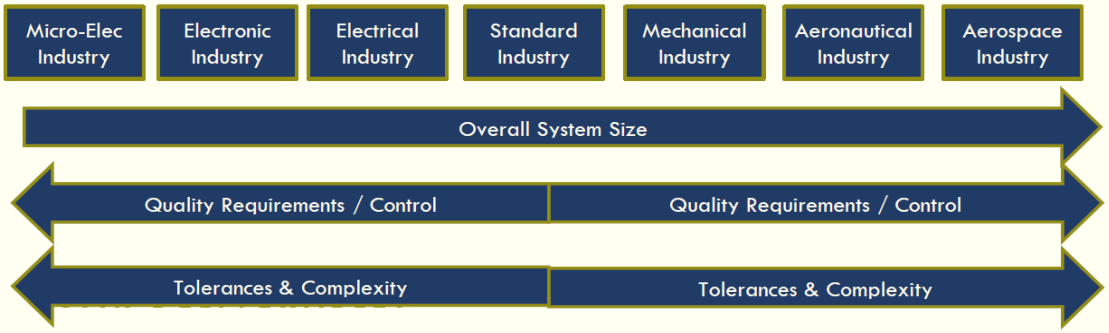


Figure 4: Production and Manufacturing Industry Classification [Own Work]

[3.1.3] Wasteless Design Methodology

The development of this new hardware will naturally require a new industrial design methodology. The design processes available today are somewhat lacking if we try to apply them to additive manufacturing. The main problem is that they do not take the full spectrum of possibility when it comes to additive manufacturing. There are modern techniques on how to define and design a product which allow rapid prototyping and testing. In addition to this most design processes do not consider the ability to refine designs in real time. Additive manufacturing allows easy additions to designs as well as reconstructions. There is much less waste involved and designs are modified relatively quickly. Even manufacturing errors can be corrected easily without creating unnecessary waste. If the product has already reached the customer, a simply process can allow them to get their product fixed on site without scrapping or returning the product. Products can be upgraded in this manner as well. This is why a define-design-refine and manufacture technique should be considered when designing products for the 21st century.



Figure 5: Design Process [Own Work]

[3.1.4] Supply Chains, Facilities Planning and other Considerations

In addition to having immense impact on our products, the additive manufacturing technique has major impacts on the way we source our products, produce and store raw material (powder in this case) and even on the facilities that will produce products. Some argue this might be decentralized but some products will have to be proceed in centralized facilities (for intellectual property, legal and health reasons). Designing a future manufacturing facility, as well as the considerations that need to be taken, can form the basis of many studies. These facilities can be decentralized or centralized, multi-product group focused or single product group focused, produced on order or customized from stock. More importantly, traditional location models, production scheduling, inventory management (which has to adapt to powder based inventory) would have to adapt massively to these changes.

[4] Impact on Specific Industrial Engineering Sub Disciplines

Without context on where the literature and case study (from sections 2 and 3) fit within the broader structure of the Industrial Engineering body of knowledge; several vital questions and connections can be missed or overlooked. This section explores the impact of some of the developments and arguments discussed above on specific sub disciplines of Industrial Engineering in dialogue format.

System Engineering/ Project Management: It would seem the forces above will definitely result in more and more projects becoming available to Industrial Engineers. Although some of them will be large scale, it is likely that a large proportion will be small scale development and management projects. However, traditional project management and system Engineering tools and methodologies simply do not cater for these types of projects. Industrial Engineering must be proactive in finding ways to distil the core of the theories and tools and develop appropriate module based models to assist in implementing successful project management and system Engineering regardless of scale. The focus, then, will be on adapting theory to the specific scopes and requirements of each respective project.

Logistics and Supply Chain: The fact that most additive technologies are powder/particle /nutrient based will most likely radically change the technology, vehicles and methods of warehousing and delivery of products. The biggest question with regards to the above is: will supply chains be reduced to a simple 5 step process that: 1) converts ores/raw materials into powers 2) transfers them to appropriate warehousing facilities for storage 3) delivers them to relevant AM technologies for conversion to parts 4) assembles them into final products and 5) ships them to clients? Will returns management be a corrective process where a 3D printer is taken to client site to correct product? Is the carbon footprint for this activity significantly less than existing supply chains? The interesting thing here is hydroponic farming is very similar to additive technologies in that it simply adds what is required by the plant (natural machine in this case) in order to produce the final product. Does this make the future of everything we eat and use (accounting for most products) additive based?

Information System Design: Advances in payment, booking and tracking technologies is forcing traditional information systems out of their comfort zones due to a significant difference in user interaction available (arising due to new supply-demand relationships). Additionally, the sheer amount of data required to understand this complexity is engulfing. Yet, the widespread use of smartphones as a data collecting tool is becoming a reality. The concerning questions are: how will the data be collected? How can it be stored effectively? How does one best make use of this data for competitiveness? And, most importantly, how does this data transition to information and then knowledge and perhaps artificial intelligence in the near future? The customer is most likely going to want answers to these questions especially because of rising concerns on privacy.

Simulation/Automation: The ability to simulate this uncertainty and adapt automation technologies to react appropriately is most definitely a challenge. With so many factors to test for sensitivity, is it even practical to conduct simulations? Or is there a way to simplify the chaos

into specific agent based characteristics? Can this be done proactively or is it destined to be reactive? Additionally, simulations models will most likely have to develop a way of simulating generational human culture and ethics, especially if this sub-field hopes to create convincing models/arguments for government services.

Business Engineering: With the rise of the sharing economy comes the reality that many business Engineering tools will have to be restructured to cater for the individual instead of the corporate structure. The biggest impact of the forces above is that money that is used to flow to traditional business hierarchies will now go directly to individuals. Thus, traditional strategy development, process modelling and business models need to adapt. The question is: does each individual then become his own business or do they follow the business model of the app which brings them customers? If they are unique and are not app reliant, how will these individual 'businesses' differentiate their processes/value offering? Will the sharing economy find symbiotic relationships with the traditional economy or remain competitive?

Operations Research: The algorithms in the code of every application are constantly determining the most effective 'route', 'producer' and more broadly 'connection'. These optimization algorithms are essentially the decision makers. Yet, with this continuously changing environment, a static decision maker will result in tremendous waste. Dynamic decision making and optimization is the most likely the future of operations research. Whether it is a que, production or infrastructure problem: optimality is based on dynamic factors and thus will have a dynamic answer. The question remains, however: is it possible to truly get the optimal answer in these scenarios or will optimization radically change to accept certain confined area as 'optimal'? What if this confined area radically changes in the solution space? Does that mean the introduction of sensitivity as a core element in operations research problems?

Operations/ Facilities Management: The sharing economy will perhaps more accurately reveal the meaning of the word 'facility' and 'operation'. In a nutshell, the facility will become the encompassing structure that facilitates business operations to take place. People are most likely to convert their garages, gardens and bedrooms to facilities (production, servicing and other). However, with this comes massive facilities designs and safety regulation problems. Are there realistic methods to properly oversee such operations?

Quality Management: Perhaps the biggest question for quality management going forward into the knowledge economy is how one assesses the quality of intangible assets (mainly knowledge, human capability and talent). As for the sharing economy, will new standards for

decentralized producers come to existence? Will perception play a bigger role in quality? Or will technology facilitate a way to create more accurate quantitative measures for perception?

General IE: The sharing economy and knowledge economy are most definitely challenging legal and business regulations both nationally and internationally. The simple fact of the matter is they create interactions and assets that governments and lawmakers are not traditionally accustom to deal with or account for. More worryingly though, some sharing economy transactions are not even trackable by most governments and some knowledge assets require a whole set of new depreciation and taxation laws.

[5] Conclusion

It would seem, at some level that adopting and adapting to even a few macro ESE trends will naturally lead to the others. Maybe this is because once a new ideology of wastelessness, equality and humanity comes into operation they indicate and make us realize (individuals and collectives) how bad the previous ideology was; which can naturally result in a continuous cycle of reconsideration and improvement. There is no doubt in the Industrial Engineers ability to deal with economic changes. However, environmental and social changes are unfortunately more difficult to adapt to and require an authentic focus. This paper recommends, for example, that Industrial Engineers naturally need to take a proactive stance in resolving environmental problem by utilizing skills learnt in management accounting, Engineering economics and other sub-disciplines to accurately reflect the financial and non-financial benefits of alternative energy to companies and decision makers. Accounting for the right things might lead to very different decisions and will facilitate a swifter transition to more sustainable energies. Additionally, although there is no doubt that humanitarian Engineering projects exist, yet, they represent a minority of projects. This is not to say that projects don't take human concerns into consideration, but, it does show that most projects have a different central focus: money, enormity or competition. Over time this can lead to human factors being disregarded and left to satisfy the minimum. Industrial Engineering should be the champion of the humanitarian Engineering movement. After all, the roots of IE are so intertwined with workers, their rights, their health and balancing or superseding it over financial considerations.

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9. Article 4 – Societal Level: Bottom of Pyramid 4.0: Modularising and Assimilating Industrial Revolution Cognition into a 4-Tiered Social Entrepreneurship Upliftment Model

9.1. Details of Article 4

This article was submitted to the Journal of Industrial Integration and Management: Innovation and Entrepreneurship (JIIM) on the 28th of January 2018 and will undergo a double-blind peer review. Initial feedback is expected within 4-8 Weeks which will be in March-April 2018. The author guidelines and proof of submission can be found in Appendix D4.1 & D4.2 respectively.

9.2. PhD Golden Thread in Article 4

This paper addresses the fourth identified area of concern which deals with the role of the Industrial Engineer in society. This specific article explores, specifically, how Industrial Engineering can help in developing Bottom of Pyramid (BoP) economies. For the overall PhD, this article took a genuine effort to develop a cohesive argument for why it is fundamental for Industrial Engineers to be more actively involved in social equality.

9.3. Extracted Insights from Article 4

- **S4.1:** The societal type currently existing in the knowledge era and experiencing the fourth industrial revolution is not post-industrial but post-post-industrial
- **S4.2:** This society is better named the network society; its extraction of value mainly stems from an ability to be connected, collaborate and leverage networks (which has evolved as a cognitive function over 4 industrial revolutions)
- **S4.3:** What was previously known as the bottom of the pyramid society is, in this scenario, the outer network society and rarely experience the full benefit and value added by Industry 4.0 and the knowledge era due to a lack of appropriate systems in place
- **S4.4:** Industrial Engineering was founded on ensuring that all of society (from employees to customers) have a voice in shaping the products and systems that ultimately service them
- **Conclusion 4 [Desirable Systemic Change]:** Since the majority of society (80%) lives in the outer network, it is fundamental for Industrial Engineers to design new systems that connect them to resources (in the broadest sense) that can help them develop socio-economically and cognitively to be able integrate to global network society

9.4. Article 4 Manuscript

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ABSTRACT

Developing a sociopreneurial (social-entrepreneurship) ecosystem is a substantial long-term investment. Much like natural ecosystems, there are a multitude of support systems needed to maintain balance and diversity in sociopreneurial ecosystems and their interactions are complex in nature. Yet, the various benefits that arise from such ecosystems make them a worthwhile investment. Examples of this come from global universities and private companies who have succeeded in creating hubs of innovation and creativity in different cities around the world. These hubs have achieved commendable results and produced quality initiatives. Yet, there is little success beyond the walls of cities, especially in low income communities. Typically, Bottom of Pyramid (BoP) Entrepreneurs must either move to cities to make their entrepreneurial ambitions come true or settle for small business status. This is especially troubling given that their communities are often the ones that need their skills most. The article begins by discussing the concept of Bottom of the Pyramid (BoP) society. It argues that in the context of the knowledge era and the rise of the network society, the BoP is better named “the outer network society”. Using Industrial Engineering principles and systems thinking, the researcher designed a product range and upliftment model (collectively known as the ModulaRISE) that helps resolve most of the structural issues with developing a sustainable sociopreneurial ecosystem. The ModulaRISE model provides 3 core support structures that can assist in reversing this unfortunate brain drain: Education, Operation and Finance. Moreover, an overarching concern resolved with the model is the tiered system that helps bridge cognitive challenges of being exposed to Industry 4.0 futuristic technologies without the proper incentivized build up. The model has already been launched on a small scale with preliminary case studies showing significant promise. The vision is to develop a fully turn-key upliftment in a box model for BoP communities which connects them to the world and allows them to collaborate to mutually enrich their society and the global society. In concluding, it is discussed that since the majority of society (80%) lives in the outer network, it is fundamental for Industrial Engineers to help design new systems that connect these societies to resources (in the broadest sense) that can help them develop socio-economically and cognitively to be able integrate to the global network society.

Keywords: Social Entrepreneurship, Upliftment Model, Industry Development, Learnership, Micro Franchise, Bottom of Pyramid

[1] FROM BOTTOM OF PYRAMID TO THE OUTER NETWORK

"Entrepreneurship is present in all societies, but it manifests itself differently depending on the context." – Philip E. Auerswald

When one imagines a thriving entrepreneurial ecosystem, the setting is rarely in a rural African village or a disconnected farming community in central Asia. Typically, a picture of a thriving metropolis is envisaged in a first world country with big investors backing the next 'big thing' with substantial finances and connections to help entrepreneurs establish new businesses. This is not necessarily in itself a negative thing. Yet it shows an inherent bias towards expecting radical and large-scale innovation from locations which are better connected or have better support networks – the silicone valleys of the world.

To a certain extent, the definition of entrepreneurial ecosystems plays a role in this since they can be defined as "communities of agents, social structures, institutions, and cultural values that produce entrepreneurial activity" (Roundy et al., 2017:99). These important foundations and features are often missing in Bottom of Pyramid (BoP) ecosystems, which often leads well-meaning entrepreneurs to search for other ecosystems to grow their entrepreneurial nature. Otherwise, their ambitions tend to fade as they are unable to realize success in the overarching conditions of their current ecosystem.

The economic effects of migration of entrepreneurs from BoP ecosystems to mainstream entrepreneurial ecosystems is part of the larger 'brain drain' which has "cost the African continent over $4billion in the employment of 150,000 expatriate professionals annually... Ethiopia had lost 75 percent of its skilled workforce between 1980 and 1991, affecting the ability of such nations to get out of poverty… [Whilst countries accepting immigrants give] preferences for people who arrive with sufficient capital [Financial and Human] to start new businesses" (Mba & Ekeopara, 2012:42).

This article explores whether the status quo can be challenged using the disruptive developments of the knowledge era and the concept of the sharing economy. In the knowledge era, the economic base has shifted towards viewing intellect as a resource (Gorey & Dobat, 1996). This presents a golden opportunity to use highly skilled economic migrants (within a country, region and internationally) to help establish low-income entrepreneurial ecosystems which can lead to a 'brain circulation' phenomena in those regions. Saxenian (2005) explains that 'brain recirculation' is the effect of highly skilled individuals who originally left their country for a better life returning to their home countries to establish companies whilst maintaining ties with the country they migrated to.

The case study for this article is the sub-continent of Southern Africa with specific focus on regional economic migrants. It is assumed in the above context (to be successful) that the home location "are politically and economically stable enough that immigrants will consider returning home" (Saxenian, 2005:56). As mentioned in Saxenian (2005:35), this model has worked well for India and China which have reaped the benefits of "these engineers and entrepreneurs, aided by the lowered transaction costs associated with digitization, are transferring technical and institutional know-how between distant regional economies faster and more flexibly than most large corporations".

The scenario described above might work for some countries and regions but as explained in Saxenian (2005:56) not "all developing economies are positioned to reap the benefits of brain circulation and peripheral entrepreneurship". The South African scenario creates special considerations which need to be catered for. For example, one of the problems is the existence of a dual economic and social system. Another is the history of apartheid which purposefully created poverty traps (through policies) in township and homeland areas where economic migrants came from. These policies still hinder the growth of entrepreneurial ecosystems until today. Yet, some of these challenges to the development of sustainable entrepreneurial ecosystems can be alleviated by utilizing modern developments in the field of Industrial Engineering. The developed conceptual model is known as ModulaRISE.

[1.1] Bottom of Pyramid (BoP)

"The problem of poverty must force us to innovate, not claim 'rights to impose our solutions'… BOP problems cannot be solved with old technologies" — C.K. Prahalad

The Bottom of the Pyramid (BoP) can be defined as the segment of the global population (almost 4 billion people) living on less than 2$ a day (Prahalad, 2006). The concept was introduced by C.K Prahalad in his argument that companies should focus significant effort on trying to reach and grow in these underserved markets (Prahalad, 2006). Notably, the idea was that the 4 billion individuals in the BoP formed the world's largest untapped market of potential consumers. Many argue that this view, although well-meaning and relevant at the time of its research, is both outdated and value-laden with neoliberal capitalism (Faria & Hemais, 2017).

Faria and Hemais (2017) point out that, unfortunately, even though some scholars and initiatives studying the BoP may mean well; it is very much possible that their approach led to more negative than positive impact due to an inherent colonization mentality built into their initiatives. Faria and Hemais (2017:271) explain that "rather than a future-oriented cosmopolitan business design aimed to overcome poverty challenges in the developing

world… the [current] BoP approach rearticulates, within an era of neoliberal capitalism, the rhetoric of salvation and progress, which was inaugurated by the darker side of modernity over five centuries ago with the discovery/conquest of America".

Some of the dark sides of the traditional BoP approach were overcome by a newer iteration, namely BoP 3.0. What BoP 3.0 proposed amongst other things was open innovation, innovative ecosystems, sustainable development and innovation for the last mile which can help rectify some of the negative connotations and applications of the previous paradigm (Cañeque & Hart, 2015). Yet, modern developments surrounding Industry 4.0 and the rise of network society suggests even further room for improvement to form BoP 4.0.

[1.2] Network Society

"The future is already here — it's just not very evenly distributed" – William Gibson

Sociologists typically distinguish between 3 types of societies: pre-industrial, industrial and post-industrial Each era of human development had a unique organizational structure worth exploring. Staron (2006:23) states that "an era is a particular period of historical time having distinctive characteristics. Every era has a signature (or preferred) style of organization". Figure 1 summarizes the insights in Staron (2006). It is notable that in the knowledge era, all previous structures are present simultaneously (in the form of an ecology) which adds to the complexity of designing solutions for the knowledge era.

Some modern accounts cite a 4th type of developing society, the network society, which is currently being investigated (Castells & Cardoso, 2005). The biggest concern with regards to the network society is that only a small percent of global society exhibits its expected behavior and benefit from the ability to extract value from being connected, collaborating and leveraging networks (Castells & Cardoso, 2005). This has led to unequal and unjust access to the benefits of being connected, collaborating and leveraging networks.

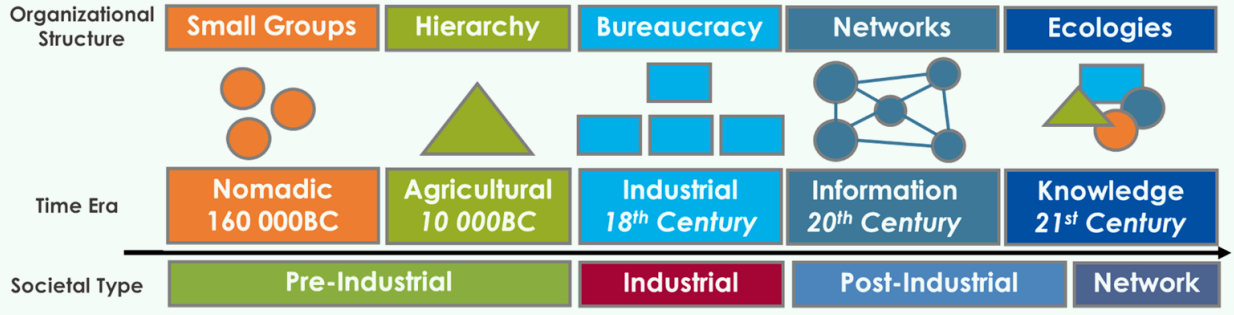


Figure 1: Evolution of Human Organization – Adapted from (Staron, 2006:23)

[1.3] Opportunity for an Sociopreneurial Ecosystem for Outer Network Society (BoP 4.0)

"When we want to help the poor, we usually offer them charity. Most often we use charity to avoid recognizing the problem and finding the solution for it. Charity becomes a way to shrug off our responsibility. But charity is no solution to poverty. Charity only perpetuates poverty by taking the initiative away from the poor" — Muhammad Yunus

Although we live in the 21st century, starting a business is still very costly and personal initiative driven (Darwish, 2015; Darwish, 2016b). Expanding markets into underserved markets is challenging. Additionally, ensuring social and environmental sustainability requires special consideration. This is further complicated in the outer network due to a lack of appropriate systems in place to connect entrepreneurs in these areas to resources and support (Darwish, 2017a).

In order to successfully start business or social initiatives in the 21st century, appropriate payment, power and support infrastructure is vital (Darwish, 2017a) (Darwish, 2014). Thus, potential solutions require a truly turn key offering that includes the necessary groundwork and training content. Moreover, the rise of electronic management platforms and dashboards (in the form of enterprise resource planning software) can help visualize business operations and establish key performance indicators for business owners (Darwish, 2017a) (Darwish, 2014).

More importantly, given the history of the Southern African region, a special focus is needed on skills development and resolving the entitlement mentality (in South Africa specifically) (Darwish, 2017a). Thus, to develop skills and encourage autonomy, a structured learnership-type model which follows a tiered approach to growth based on accountability is suggested (Darwish, 2017a).

Additionally, the strategic sequence of building business models for the BoP must follow to ensure that the correct value proposition is generated (ver Loren van Themaat et al., 2013). ver Loren van Themaat et al. (2013:199) highlights how Capitec, in the South African context, successfully disproved various assumptions regarding the BoP namely that they "[1] have no purchasing power; [2] They are not brand conscious; [3] Are hard to reach and are unable to use technology". The sequence of elements used in the case study that helped overcome the barriers is shown in Figure 2.

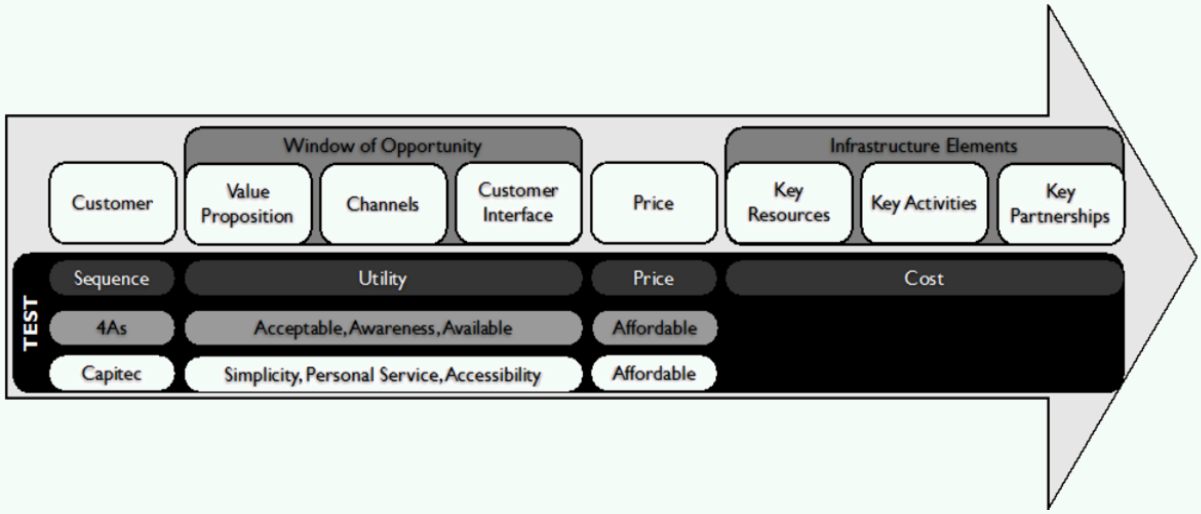


Figure 2: Framework for BoP [Capitec Case Study] (ver Loren van Themaat et al., 2013:198)

Identified Opportunity: By considering the BoP communities as merely a segment of the network society that lies in the outer network (disconnected from resources), it became apparent for the Southern African context that a sociopreneurial solution can be designed to suit the needs of the BoP communities. The suggested solution takes the form of a tiered turn-key sociopreneurial solution (social upliftment business in a box) which houses the necessary hardware, software and educational content (leveraging Industry 4.0 innovations) to successfully sustain the business. The initiative holds promise in resolving many of the challenges facing charity and social investment-based initiatives of the sort in BoP communities.

The solution would need to be designed using industrial and cognitive engineering principles to help these communities develop socio-economically with the necessary industrial revolution cognition.

[2] INDUSTRIAL REVOLUTIONS & INDUSTRIAL ENGINEERING

"Engineering is all about using the power of science to make life better for people" – N.R. Narayana

A brief historical exploration of Industrial Engineering activity uncovers that an imbalance exists in its benefactors (Bowen, 2009). For the most part, Industrial Engineering activity appears to contribute a majority of solutions to the top of the pyramid of most industries. In the colonial era, engineering (in the broadest sense of the term) was recorded as being overly concentrated on creating weapons and organizing army logistics (Sperotto, 1994). The industrial era saw most engineers being caught up with the problems of mass manufacturing (Sperotto, 1994). Even a more recent account of history shows that an imbalance still exists between engineers servicing the 'top of the pyramid' as opposed to those servicing the many layers that allow that top to be supported (Lister & Donaldson, 2011). This is a major problem with immeasurable impact. The state of many bottom of pyramid communities, industries and sectors is living proof that there is a need for a more equal distribution. Only in the knowledge era are engineers opening their prospects to previously overlooked industries with needs for the solutions only engineering expertise can provide.

Although every field of the sciences and humanities contributes to human knowledge, engineering is tasked with using scientific knowledge to solve human problems in innovative ways (Kotkin, 2013). This is perhaps why there is a strong connection between engineering activity and human development (Sperotto, 1994). Joel Kotkin (2013) explains that "engineering advances drove America's quest for industrial supremacy in the 19th century…By the early 19th century, the U.S. was producing its own major inventions, including the steamboat and cotton gin. By the end of that century, the U.S. was clearly on the way to industrial preeminence". In fact, the sheer importance of engineering graduates has led to institutes such as the UNESCO evaluating economic development in countries by their number of graduates in science, engineering and technology. It is concluded that there is some correlation between the number individuals with high problem- solving capability and economic development.

As discussed in an interesting engineering (2015) article "normally, it is expected that countries such as the United States and Japan would make the cut. But what is even more interesting is that some of the developing countries are also starting to make the top 10 as well… According to the World Economic Forum, "talent will be the key factor linking innovation, competitiveness and growth in the 21st century". However, many institutions, such as the OCED (2016), decouple the number of graduates from potential growth and focus more on the % of graduates in natural sciences and engineering as an indicator. Evaluating the data reveals

a more accurate perspective. Countries such as Germany and South Korea graduate 30% of their students in fields of science and engineering and display extremely high economic prosperity whilst several countries with widespread social and economic problems rank below 10%.

It is important to note that several countries with natural science and engineering graduates falling below 10% might still have excellent programmes in engineering and technical fields (such as South Africa). Yet, the problem seems to lie in where those graduates work. In South Africa, for example, a majority of qualified graduates work for the private sector and resolve problems relating to improving the profitability of the private sector in some way or another. This happens in city centres and economic hubs such as Gauteng where up to 40% of the country's GDP is generated. Yet, the outer network communities (BoP, rural, low income, township and informal) do not get their fair share of qualified graduates assessing their problems and developing relevant low-cost solutions. This is perhaps why even 20 years after becoming a democracy in 1994 which promised to resolve many of these problems, South Africa maintains elevated levels of inequality, high reliance on subsidy income, low levels of education and elevated levels of unemployment in BoP and outer network areas.

[2.1] Field of Industrial Engineering

"Modern Industrial Engineering is concerned with the integration of resources and processes into cohesive strategies, structures and systems for the effective and efficient production of quality goods and services" – Frank Sperotto

The Instutite for Industrial and System Engineers (IISE) defines "Industrial and Systems Engineering [as the field] concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of Engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems". Furthermore, the field is fuelled "by the challenges and demands of manufacturing, government and service organizations throughout the twentieth century. It is also a profession whose future depends not only the ability of its practitioners to react and facilitate and operational change but, more important, on their ability to anticipate, and therefore lead through the change process itself" (Maynard & Zandin, 2001:13-14).

Many professionals have noted a lack of Industrial Engineers in the public sector or participating in public service in the Southern African context. A study done by Van Dyk (2014) showed that although many Industrial Engineers work for parastatal or state-owned

companies, they do not directly deal with issues of inequality or social justice. Moreover, Schutte et al. (2016:18) highlighted Black Coloured and Indian (BCI) Industrial engineers "end up in positions where they are less influential and earn less, and are therefore not clear enablers of the drive to attract more young people from disadvantaged backgrounds to become IEs. This is likely hampering the growth of the discipline in significant industry sectors such as general government services, where the IE discipline needs to have more BCI IEs of the appropriate stature to grow in this sector".

Lister and Donaldson (2011:48) explain that "current Industrial Engineering paradigms aim to improve quality and profits, and emphasise labour-reduction, specialisation, analysis and optimisation. This can be at odds with the needs in a developing country…. [In addition to this] relatively few Industrial Engineers are employed in South Africa and Kenya, and not many are produced by the educational systems in these countries. Those who are available, work in organisations such as manufacturing industries, government, parastatals and the services sector". Namibia, for example, "aspires to be an industrialized nation by 2030 facing significant challenges like poverty. (Only about 47% of households have a main source of income) … The Namibian, like the South African, economy is diversified…. [Which is why there is a] … need for Industrial Engineering tertiary education. Of course, real wealth comes from people with ingenious ideas and tenacity to make them work to the benefit of all. In the process, they change themselves, change those who work with them and will industrialize Namibia. While designing and running superior systems are at the heart of Industrial Engineering, it is the people in them who matter both consumers and producers… [And] Ethical behaviour is paramount in producing a good society" (Snaddon, 2011:1-2).

One of the things that hinders the development of more IE based initiatives in the BoP is a preconception that an Industrial Engineer's technical skill have no value in this setting. Yet, a good example of an Industrial Engineering application (without necessarily defining it as such) is the unique food delivery business endeavour Dabbawala in India. Every day, 2 million home-cooked food deliveries take place in a range of 60 to 70 km. The speed, precision and cost of doing these transactions through traditional structures would have probably been impossible (Thomke & Sinha, 2010). However, this industry has been running for more than a hundred years in India with proper structures, offices, delivery people and virtually no theft (Thomke & Sinha, 2010). Moreover, it is considered a six-sigma process (Thomke & Sinha, 2010). This success would not have been possible without excellent supply chain design and the use of quality management and process engineering principles (which form part of Industrial Engineering).

Another example in India is the production of the Indian bread Lijjat Papad where thousands of Indian women earn extra income for the family by producing as many of these breads as possible (Ramanathan, 2004). The supply chain, cash handling and international sales pipelines that those ladies have achieved are remarkable. The organisation also ensures that money is given only where value is created and the workers are motivated to produce as much as they can because the organisation has the capacity to buy all the bread produced (Ramanathan, 2004).

It is possible to successfully implement similar solutions in South Africa and other developing countries. However, that would require Industrial Engineers to take initiative and apply their minds to help solve problems faced by the largest part of the world's population. Yet, the context being entered has not undergone an industrial revolution in the traditional sense. Thus, some inspiration for designing the initiative can be drawn from the 4 industrial revolutions to design micro-versions based on similar principles.

[2.2] The 4 Industrial Revolutions

"No other revolution has made such a great impact as the Industrial Revolution has ever made" – Jwaharlal Nehru

Major developments or disruptions in the underpinning technologies that enable manufacturing and services are typically referred to as industrial revolutions. "Historically, the world has experienced three major growth periods where disruptive technology has brought about huge productivity improvements in manufacturing. More specifically, the invention and implementation of the steam engine in the 1800s, Ford's mass production model of the early 1900s and the first wave of automation with the birth of Information Technology (IT) in the 1970s" (Simio, 2017). Currently, the modern world (network society) is experiencing the fourth industrial revolution which is described "a trend towards a fully connected and automated manufacturing system, or Smart Factory [Where] all production decisions are optimized based on real time information from a fully integrated and linked set of equipment and people."

One of the problems facing the African continent, as a whole, is the lag in industrial revolution cognition. Rural regions of Africa remain disconnected and virtually unexposed to developments around the world (even in places with high mobile penetration). Any solutions developed need to cater for the historical situation facing South Africa. Thus, to avoid technological shock and ensure integration, a clear structure integrating the beneficial developments of these revolutions is required.

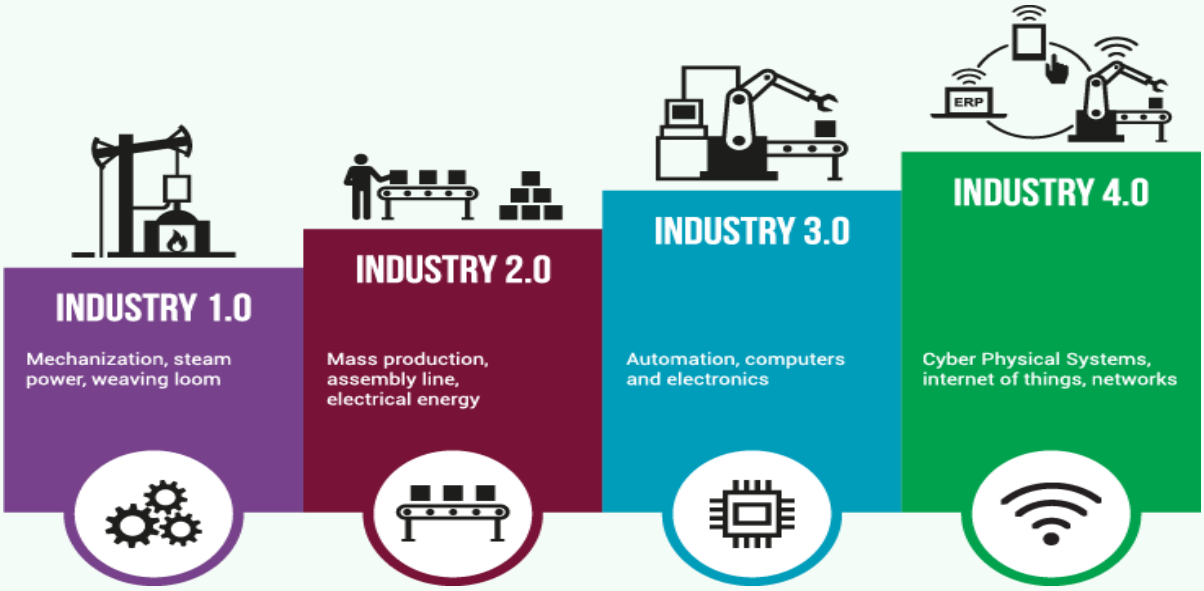


Figure 3: Four Industrial Revolutions (Simio, 2017)

[3] THE MODULARISE MODEL

"People.. were poor not because they were stupid or lazy. They worked all day long, doing complex physical tasks. They were poor because the financial institution in the country did not help them widen their economic base" — Muhammad Yunus

The Problem Context: In the South African context, the lack of participation of Industrial Engineers (and other disciplines) in bringing about major technological disruptions to outer network areas has left them economically and socially underdeveloped. This has led to most initiatives in those regions to require significant post-implementation investment, leaving them unsustainable because of their non-adherence to basic business design principles that accomodate their market. Moreover, education forms one of the biggest stumbling blocks to implementing a successful ecosystem. Insufficient education inhibits the ability of the community to communicate with external entities (which may be able to provide support in a variety of ways) and risks the potential of success to socio-economic development (due to improper education on how to manage and sustain the developmental projects).

The Opportunity: Many workers in mainstream economic sectors come from the outer network and in fact can be classified as migrant economic labour. These are hardworking, skilled and resilient human beings whose only option to gain a better life lies in entering employment, mostly, of large organizations and franchise businesses. They are well exposed to developments of the knowledge era but generally have not considered it possible to integrate these developments into their home communities. Moreover, these individuals earn minimum wages in South Africa (R3 000-R8 000) and most of their wage is spent on transport and renting accommodation which leaves very little as 'savings'. Yet, many communities have

internal savings funds known as stockvels (which were initially setup as a survival fund), get Corporate Social Investment (CSI) from nearby businesses and can potentially access government development funds.

The ModulaRISE Model: By carefully examining the context, a socio-economic upliftment learnership model was designed. Modular represents the design philosophy used in the product design and RISE stands for the 4 tiers: Rookie Toolkit, Intermediate Home Business, Servitization Center and Economic Hub. The idea was to design a simple business case that would leverage existing funding systems to help plant sociopreneurial initiatives which can integrate and grow within communities. The model uses developments in the sharing economy and the financial structure of franchise restaurants to create turn key upliftment opportunities in a box. The units and their business cases (repayment plans) are designed using Industrial Engineer principles (from supply chain, business engineering, operations management, facilities management and others). Everything from the standard processes, costing and service offering is already designed into the 4-tiered system. These kits also come with an ERP system, educational content and operational manuals to assist in bridging the gap for entrepreneurs. Moreover, the model provides 3 continuous support relationships with the outside world network society (Operational, Education and Financial).

The Process: An entrepreneur, to become a participant, simply has to go the local ModulaRISE Showroom and they will be exposed to a variety of turn key opportunities that run out of shipping containers. Once the entrepreneur has made a selection of available businesses in their area (that are determined by studying the community's integrated development plan, studying the competitive landscape and analysing the community's fundamental human needs), they will participate in training courses at the local Incubator (available in their community). The entrepreneur, after developing some basic accounting and technical skills, will then get funding from the Financing Centre which bases the decision for providing a starting toolkit on their performance rather than their ability to fill in paperwork. Moreover, this challenges the traditional learnership model which provides certificates to graduants instead of opportunity. With ModulaRISE the entrepreneur graduates with an entry level business which they must grow themselves. The entrepreneur thereafter provides services to their community and repays their 'capital'. An operator is available continuously to help advise them on how to develop their skills, repay their unit better. Once they are ready, they 'RISE' to the next tier of their selected business stream. A visual representation of the model is presented in Figure 4.

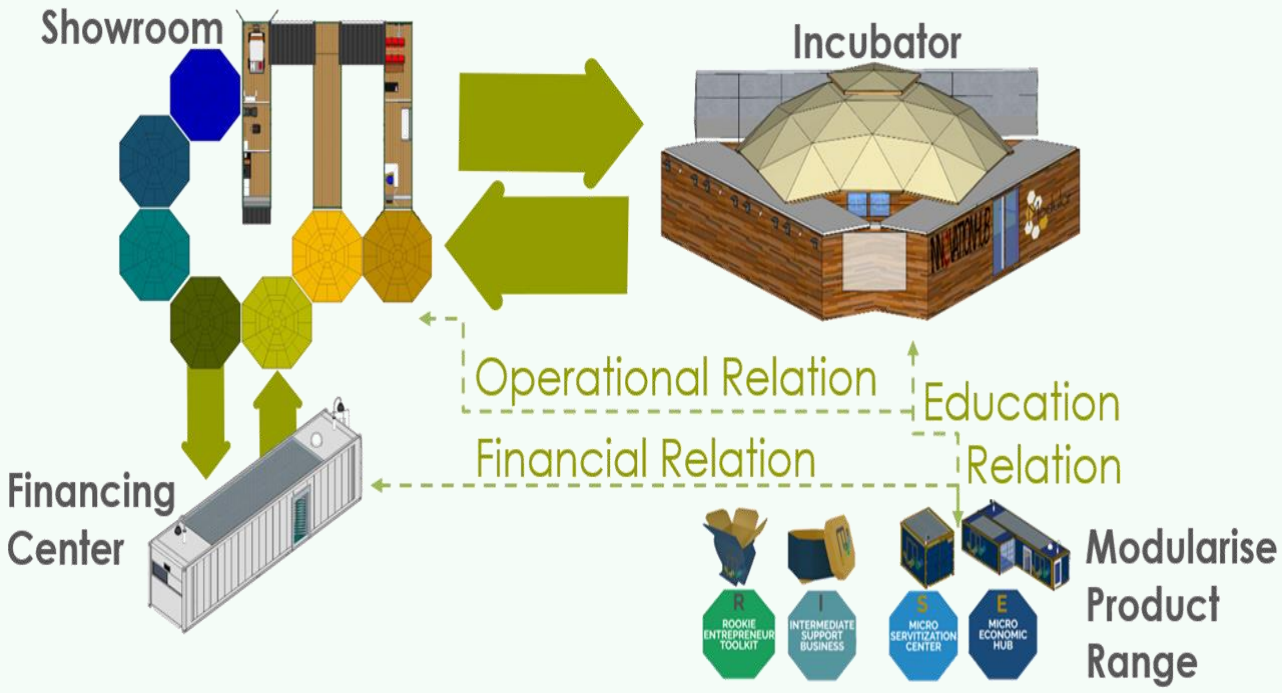


Figure 4: ModulaRISE Model [Own Work]

[3.1] Operational Relationship

The first point of contact is the Showroom. This element of the model can better be understood if one conceptualizes it like a car showroom. An entrepreneur enters and sees various turn key business model opportunities available to their region. Much like a car, these turn-key container businesses (Modular Innoboxes) come with a warranty plan which is administered centrally. The Modular Innoboxes are fully solar powered, insulated, internet connected, include an ERP system, are movable and come with business and operations manual (Darwish, 2017a). Unlike cars, however, the Modular Innoboxes come with their own repayment plan (given that the entrepreneur can use them to generate an income and repay their capital). However, in order to ensure successful transition and build accountability, the entrepreneur starts at the R level which is the entry level of that business stream. For example, if the Modular Innobox houses a clothing design and production workshop (as an E level), then the R level will be a sewing machine (Darwish, 2017a). A description of the level, The necessary Key Performance Indicators (KPI) that must be monitored and the Enterprise Resource Planning (ERP) apps that are provided are discussed in Table 1 below.

A key element of the operational relationship is the design of these packages. Given that some community members may not have access to the bigger picture and cannot distill the Integrated Development Plan (IDP) for their given community, a Modular employee will conduct these analyses using Industrial Engineering tools and design a unit which [1] satisfies a fundamental human need in the community, [2] can be funded by grants or corporate social investment (which the employee will obtain as well) and [3] caters for the local business

ecosystem and ensures that the market is not flooded with toolkits that would compete with each other and therefore hinder all of the individuals' ability to earn an income.

Table 1: Operational Relationship of ModulaRISE model (Darwish, 2017b)

Level	Description	Main Key Performance Indicators	ERP Apps Needed
[R] Rookie Entrepreneur	Single Tool – Multi Service Range – Single Person	**KPI:** Customer satisfaction **KPI:** Response time	-Customer Relationship Management -Quality Control -Accounting, Invoicing, -Purchase -Expenses -Sales -Timesheet
[I] Intermediate Support Business	Multi Tool - Multi Product Range – Partnership of Rookies	**KPI:** Customer retention **KPI:** Number of orders met on time	**R Apps &** -Manufacturing -Maintenance -Equipment -Appraisal
[S] Servitization Center	Single Facility –Service and Product Offerings – Manager + Employees	**KPI:** Number of business goals completed on time	**I Apps &** -Inventory – Events -Marketing -Leave (Vacation) -Employee Appraisal
[E] Economic Hub	Multi Facility – Complimentary Offerings – Multiple Owners	**KPI:** Return on capital	**S Apps &** -Projects - Website

[3.2] Educational Relationship

The educational relationship is the cognitive development mechanism of the model. This element was introduced to truly integrate the accountability aspect and ensure that incentive and rewards are based on success. An example of an entrepreneur's journey is: the rookie entrepreneur receives a single tool (sewing machine, camera, handyman equipment… etc) and begins with a 1-month programme focused on tool specific training as well as supportive financial and marketing training. After a 6 month on the job practical element, the recorded data obtained from the entrepreneur qualifies them to go into the next level or remain in their current level. If the individual makes it to an intermediate, they are grouped with similar minded individuals and trained for 2-3 months to run a support business offering multiple compatible services as part of a value offering. Their educational programme grows to include human resource, inventory, advanced financial and other complimentary training. After a 1 year on the practical element of the job, the individuals can qualify to receive a permanent containerized Modular Innobox site and offer formal services in the form of a Servitization center. The training component of the S tier is on the job and includes several interventions based on the collected data from the micro facility. After running the business for 1 further year, the micro facility and its owner/operators can graduate to the highest tier E where they become part of an economic hub offering various other services to compliment and cross-pollinate with their services.

The aim is to create a knowledge sharing platform that allows owners of similar business units to share their insights and continuously improve the operational model. Individuals who contribute new service or product designs would be rewarded by deducting from their capital repayments and employing them as educators in the incubator. Summary shown in Table 2.

Table 2: Educational Relationship of ModulaRISE model [Own Work]

Level	Education Timeframe	Industrial Revolution Cognition
[R] Rookie Entrepreneur	1 Months Course Followed by 6 Months in Continuous Rookie Level Monitoring & Training	Links to the cognitive elements of the first industrial revolution of replacing human activity with machines. Toolkits are simply made up of single tool that must be used by entrepreneur to generate an income.
[I] Intermediate Support Business	2-3 Months Course Followed by 1 Year in Continuous Intermediate Level Monitoring & Training	Links to the second industrial revolution of dividing labor amongst skilled workers and creating production lines. Several toolkits need to work together to make product offerings and value propositions.
[S] Servitization Center	4 Months Course Followed by 2 Years on Site Assessment and Peer to Peer Training	Links to the third industrial revolution of using data and information to make smarter business decisions
[E] Economic Hub	Teambuilding Activity followed by Continuous progress reporting	Links to the fourth industrial revolution of automating various processes and producing technical workers

[3.3] Financial Relationship

One of the key elements that is often disregarded in sociaopreneurial initiatives (and can ultimately be a cause of failure) is finances. The ModulaRISE project took note of this element and ensured that the financial model was well designed. Each tier was designed to correlated with a business type that could be registered formally. Additionally, the packages were costed reasonably to allow for suitable repayment cycles. Grant funding is the main form of funding that is used. Yet, since all entrepreneurs are expected to repay their capital, a cyclical fund was setup to ensure that grant 'repayments' help in starting new RISE initiatives and therefore contribute to ecosystem development.

Table 3: Financial Relationship of ModulaRISE model [Own Work]

Level	Capital Requirement	Repayment Timeframe	Business Registration Type
[R] Rookie Entrepreneur	R10 000 – R50 000	8 Months – 1 Year	Sole Proprietor
[I] Intermediate Support Business	R50 000 – R150 000	1 Year – 1.5 Year	Partnership
[S] Servitization Center	R150 000 – R450 000	+-2 Years	Private Company
[E] Economic Hub	R450 000 – R2 000 000	+-4 Years	Public Company

[4] PILOTING, PROTOTYPING AND FUTURE

[4.1] Prototype

The first attempt at testing the concept of the Modular Innobox was undertaken in early 2013. The concept was known at time as the Busy Box. This business concept dealt with designing a movie theatre in a shipping container for low income communities that is flexible enough to provide a multitude of services through the existing service infrastructure (Darwish, 2014). Thus, the concept was designed to perform a dual functionality as a business and educational initiative (Darwish, 2014). By day, the unit serves as a virtual, self-sustaining classroom providing learners with world class support and educational services that they would otherwise not have had access to. By night, the unit transforms into a simple, sustainable business managed by an owner-operator with the support and partnership of an external party. The Busy Box implementation site was located in Soshanguve, South Africa. The Busy Box went live on 1 August 2013 and continued until late 2014. Various lessons were learnt from the process of designing, testing and implementing the Busy Box concept. It was found that incentivized models are the most effective way to ensure good buy-in from potential owners or managers. In addition, it is important that product and services in low income communities be redesigned to give only what the community members are willing to pay for. The final, and perhaps the most important, lesson was that excess capacity in low income communities can be used to create a social and business revolution (Darwish, 2014).

[4.2] Pilot

One year later (in 2015), the first official Modular Innobox product was launched as a pilot in partnership with the South African branch of a well-known German company. This product was known as the Log Lab. The Log Lab was designed to be hi-tech multipurpose venues that fits inside a container. The unit features 15 comfortable multimedia room seats and 12 computer desk workstations (Darwish, 2015). The unit was fully solar powered, internet enabled, with CCTV and security sensors. Furthermore, fingerprint entry and exit was installed. The unit was sponsored to a school and the income generated would subsidize the school's existing programmes (Darwish, 2015). More importantly, the Log Lab provided local and world class content for education and skills development. It also helped educate communities about crime, health and other important aspects of community life. A comprehensive review of the unit was done in mid 2016 with excellent results. The school had experienced only a few days of downtime in the entire year and generated a sizable income from sponsorships and micro-transactions (Darwish, 2016a). Moreover, the community started designing their own initiatives using the tools provided to meet some of their needs (Darwish, 2016a).

[4.3] Future

Modular Innobox (Pty) ltd launched its first ModularRISE showroom to the public on the 2nd of June 2017. The aim was to market fully functional and real-life models of most of its product range. The showcase was displayed at the Innovation Hub in Pretoria until late 2017 and was moved to the North West University after developing a strategic relationship with the institute (Darwish, 2017a). To lower conceptualization costs, the showroom was designed to use VR and AR technology to facilitate conceptualizing new turn-key business designs.

Currently, the project has filed various proposals (with government and private entities) to help develop comprehensive Enterprise Resource Planning (ERP) software packages that can enhance the product offering. Additionally, this can assist outer network micro-economies in formalizing existing community services, insourcing manufacturing and developing innovative servitization value offerings for their community (Darwish, 2017a).

The overarching goal of the project going forward is to propose a scientific approach to capture and record value in these communities by formalizing and modernizing their economic activity.

[5] CONCLUDING REMARKS

"Give the Community Assets not Liabilities" — Unknown

[5.1] Results

This pilots and launches were shown on SABC, Etv, Joburg Today, Business Day live and several other media outlets and had a feature on the University of Pretoria website. The researcher also received an award from Young People in International Affairs as being one of the top 35 projects impacting Africa. Moreover, the forming of the strategic relationship with the NWU and a major South African bank will help strengthen the educational and financial aspects of the model and allow Modular Innobox to focus on the operational aspects.

The model truly presents a new take on developing sustainable entrepreneurial ecosystems by integrating industrial revolution cognition in the design and providing support in key areas. Additionally, an interesting finding was that the ModulaRISE product range is less expensive than purchasing the elements, necessary to start a business, separately (given that it makes use of economies of scales and leverages partnerships). This further adds to the appeal since many financial institutions loan out money to start small businesses but cannot necessarily guarantee that the entrepreneur will know what to purchase to start their business and manage their cashflow. This model allows financial institutions to loan a business instead of money and to continuously provide financial support to the entrepreneur by facilitating rapid repayments and financing future growth. Ideally, stockvels can participate in this, given that they are community-centered investments, and this would see wealth being captured within the community. Stockvels could become the finance house for initiatives within the community.

Currently, four project students have completing their final year Industrial Engineering projects in designing supporting systems that will further the success of the model. Darwish (2017b) determined the requirements for the performance management system for monitoring and graduating entrepreneurs. De Beer (2017) is analyzing how some units can impact food security and improve availability and quality of fresh produce by designing sustainable supply chains (using one of the Modular Innobox units). Erasmus (2017) conducted a preliminary investigation on how funding can be captured in these communities by selling some of their art products in overseas market and bringing back hard currency to the micro community. Lastly, Ferreira (2017) created a tool that assists in integrating the ModulaRISE offering to the community's IDP and fundamental human needs.

[5.2] Future Research

The current focus is on building a financial model to help scaling up on a national scale. Additionally, an appropriate ERP and performance management system is in development. The project team is currently working with existing partners to roll out a full-scale test in a

community in North West province. The idea is to start with 80-100 rookie toolkits and see how many economic hubs can be extracted at the end of the project lifecycle. Naturally, some entrepreneurs will fall away during the process, but the aim is to assess the overall impact of planting these seeds of initiative in the community.

[5.3] Conclusion

ModulaRISE is a 4-tiered entrepreneurial learnership model designed to uplift outer network micro economies. The ModulaRISE model is branded as a learnership model because it offers the educational content required for individuals with little to no formal education to RISE to business levels by owning and running their own Modular Innobox. It is entrepreneurial because a ModulaRISE participant does not graduate with a degree; they graduate with a business. It is not a perfect model as yet, but it holds significant potential to be the way initiatives are started in the Southern African area, hopefully leading to sustainable sociopreneurial ecosystems.

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10. Article 5 – Environmental Level: Analysing the Environmental and Social Awareness of Industrial Engineering Using Corpus Analysis of the Industrial Engineering Handbook

10.1. Details of Article 5

This article was submitted to the European Journal of Industrial Engineering (EJIE) on the 28th of January 2018 and will undergo a double-blind peer review. Author received feedback to review publication and resubmit in April 2018. The author guidelines and proof of submission can be found in Appendix D5.1 & D5.2 respectively.

10.2. PhD Golden Thread in Article 5

This paper addresses the fifth identified area of concern which deals with the role of the Industrial Engineer with regards to the environment including societal impacts on the environment. This specific article explores, specifically, how Industrial Engineering terminology can be adapted by using corpus analysis to integrate developments in Biomimicry and the works of Manfred-Max Neef on fundamental human needs. For the overall PhD, this article took a genuine effort to develop a cohesive argument for why it is fundamental for Industrial Engineers to truly take a genuine understanding of and incorporation social, ecological and environmental concerns.

10.3. Extracted Insights from Article 5

- **S5.1:** Beyond biological factors, various psychological factors form the identity of the modern human being which have led to the term Homo Industrialis; By virtue of being industrious, the human being wishes to adapt their environment to better suit their needs
- **S5.2:** Even though this nature has existed for centuries, its professional function was only formalized relatively recently in the IE field since Industrial Engineers display more of this industrious behavior as well as understanding the systems perspective surrounding it
- **S5.3:** However, this behavior can, if remained unchecked, lead to significant societal and environmental decay especially when the terminology used to describe it is value laden with growth as opposed to balanced measures
- **S5.4:** Yet, Industrialization is absolutely necessary for development, but its current form is environmentally and socially destructive which can be partially attributed to a slow integration of global developments into the terminology and philosophies taught in industry and educational institutes
- **Conclusion 5 [Desirable Systemic Change]:** IE is one of the fields affected by this problem which can be largely resolved by adapting some of the IE body of knowledge to reflect developments in biomimesis and a modern understanding of human needs

10.4. Article 5 Manuscript

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ABSTRACT

In his famous book 'In the footsteps of Homo Industrialis' Frank Sperotto discuss the development of Industrial Engineering, its complimentary thinking style and the industrious nature of the human being over the timespan of millennia. Undoubtedly, Industrial Thinking philosophies have served human development. Yet, the restricted boundary of consideration and value laden formulations of key industrial terminologies, concepts and thoughts has led to undesirable manifestations. Over time, this led to destructive environmental and social decay which is highly problematic for the knowledge era. This article discusses how to reformulate key philosophies of Industrial Engineering and its sub-disciplines from literature sources to be more adaptable and harmonious to knowledge era situations. A corpus analysis of the 5th edition of the 'Handbook for Industrial Engineering' is conducted for identification of terms and philosophies. It is suggested that these key terms be adapted using developments in biomimicry and Manfred-Max Neef fundamental human need. Furthermore, further research on formulating a generalizable and harmonious definitions of key IE terms and methodologies is discussed.

Keywords: Biomimicry; Industrial Engineering; Industrial Thinking; Homo Industrious; Fundamental Human Needs; Corpus Analysis; Industrial Revolution

[1] INTRODUCTION

Whilst reading 'In the footsteps of Homo Industrialis' by Frank Sperotto one cannot help but be left in awe as they uncover the simple ideas that lead to the massive economic structures we now know as industries. An industry can be defined as an economic sub-system within which homogenous processes strive toward common generalizable outputs (similar products or services). An industry comprises various economic, social and environmental activities. Centuries and centuries of investment and mastery of this industrious side of the human psyche has led to some truly remarkable developments (Sperotto, 1994). Moreover, the rise of industries is often instigated by expansion in human needs.

[1.1] Industrialization & Growth

Industrialization has become something seen as absolutely necessary to human development. Many definitions exist for industrialization but perhaps the one that best acknowledges its focus on growth comes from Fitzpatrick et al. (2013) who explains that “industrialization can be defined as the process whereby industry’s share of the labor market and/or output in a given economy or economies (local, national or global) increases of time”. In many cases the state creates the necessary groundwork for companies to industrialize and form major blocks of the economy. It can be said that Industrialization in itself is not necessarily a negative thing, however, the way in which it is done, and which areas can result in the negatives severely outweighing the positives. Moreover, a general concern is that elements ‘fueling’ it can lead to perpetual environmental and social degradation.

Chenery et al. (1986) explains that “the transformation of an underdeveloped to a developed economy can be defined by a set of structural changes required to sustain a continuing increase in income and social welfare. Although these requirements vary with the natural endowments and social objectives of each country, there are a number of factors that produce a degree of uniformity in this transition”. During the process of industrialization “countries [need to] muster the resources to do so. As this transformation takes place it necessarily entails changes in other aspects of social structure”. This change in social structure often leads to the development of a new type of human being: Homo Industrialis. Not does this change the perceived needs of this modern type of human being, it radically changes their relationship with their environment.

[1.2] Homo Industrialis]

Beyond biological factors, various psychological factors form the identity of the modern human being which have led to the term Homo Industrialis; By virtue of being industrious, the human being wishes to adapt their environment to better suit their needs (Sperotto, 1994). Homo Industrialis “represnts that considerable segments of human society intent on the development

of industry producing structures, good or services…. In a broader sense, Homo Industrialis can be interpreted as the modern man as a whole. Not that he is any different to Homo Sapiens anatomically but because of his mental and spiritual differences. Clearly [there are] differences of attitude, drive, values and lifestyle… In this sense, Homo Industrialis is characterized, not only by his ability to adapt to the environment, but by his ability to adapt the environment to suit himself. He achieves this by being industrious" (Sperotto, 1994:4).

The psyche of Homo Industralis is commendable in that it is inventive, resilient and motivated to grow. However, for the same reasons it is often viewed as one of the most disharmonious and destructive forms of the human psyche. Especially when it is granted an encompassing economic and political system which rewards this behaviour and limits accountability and responsibility (such as consumerism, neo-colonialism and oligarchies). Nagy (1972) explains that "it is with almost carnivorous ferocity that 'homo industrials' attacks… programmed destruction of… cultures are usually carried out in the name of economic, military, protective, defensive and historical 'necessity'. I will make you happy even if it kills you' and then kills him or what amounts to almost the same thing, destroys his way of life'.

Moreover, a concern more directed at the way of thinking is "disharmonious Industrial Thinking is based on monism, i.e. on the recognition of one absolute, primary origin (part), which generates and suppresses other parts and constantly causes conflict among and the parts as well as within the whole. The priority belongs, instead, to the disharmonious parts and particulars, which are at enemity with each other and which aspire to domination over the whole. An ideal of this thinking is the industrial civilization and the one-dimensional economic person – homo economicus or homo industris, whose primary target is profit rather than harmony. This way of thinking in aggregate of its attributes, progressive in due time from second half of the 20th century, shows its inconsistency in the decision of the global problems, which it only multiplies and under pressure of which its industrial society collapses. This thinking may be defined [by being synonymous by]: disharmonise, monism, and others" (Semashko, 2013:18).

For a large part of history this function of growing industries, maximizing profits and optimizing labour efficiency (often at the cost of society and the environment) was not a formal profession but was done by individuals who displayed certain abilities. Initially known as efficiency experts, these individuals eventually became known as Industrial Engineers and in many countries, they helped industrialists grow industries (who in various context formed monopolies that trampled competition) (Zinn, 2014) (Marksberry, 2012). Industrial engineers in their early days were often lower level managers who were incentivised to make localized improvements. Their abilities and focus grew with time to become more socially and environmentally aware.

[1.3] Industrial Engineering (IE)

Although the modern Industrial Engineer has overcome many of the problems pointed out by Semashko, one cannot deny the massive environmental and social degradation caused by this type of thinking by Industrialists and, to some extent, Industrial Engineers of the 18th to 20th century. In fact, some of the negative effects remain to the modern day. Yet, it is arguable that Industrial Engineering (IE) has also contributed to the problem as well; by making things faster, cheaper and better it also increases their consumption. This is not to say that all of these improvements are necessarily negative. However, negativity must be considered. In industries where customer behavior is transformed to consumer behavior, the environmental impact of efficiency needs to be studied. Efficiency does not necessarily change the current paradigm of how we use resources.

However, Schutte et al. (2016:2) explains that "industrial engineering has evolved into a major Engineering and management discipline. The effective use of IE has contributed to an enhanced standard of living through increased productivity, improved quality of work, better quality and nature of services, and improvement in working environments… Industrial engineers (IEs) are thus responsible for the optimal design, implementation, integration, operation, improvement, and management of high-level systems. Such systems typically consist of chemical, electrical, electronic, mechanical, or civil components. These high-level systems generally exist within organisations as a mixture of equipment, information, people, capital, policies, processes, etc. IEs optimise these systems to improve quality and productivity and to reduce costs. Human and physical resources are thus combined and integrated to achieve specific objectives in these organisations."

[1.3.1] Problem Context

A historical analysis does indeed show that certain parts of the IE history were affected by predominant economic ideologies which have affected the environment negatively. However, the knowledge era improved human understanding of the global impact of industrial activity. Luckily, developments in environmental, social and other fields can be used to re-think some of the IE body of knowledge. More specifically, by adapting some of the philosophies and tools used in the IE field, interdisciplinary balanced and harmonious ideals can be encouraged instead of outdated growth and profit ideals. The field of Biomimicry and the works of economist Manfred Max Neef can assist in this regard due to their focus on creating sustainable industrial ecologies.

[2] TERMINOLOGY & PHILOSOPHIES

Industrious behavior can, if remained unchecked, lead to significant societal and environmental decay especially when the terminology used to describe it is value laden with growth as opposed to balanced measures. Similarly, industrialization is necessary for development, but its current form is environmentally and socially destructive which can be partially attributed to a slow integration of global developments into the terminology and philosophies taught in industry and educational institutes.

The key concern within a western context is that terms are phrased using neo-liberal and consumeristic ideals. The problem, however, lies when these value-laden philosophies and related terms are imposed/exploit certain societies, cultures or the environment. One cannot deny that there is a misalignment in the terms that favors profit over protecting social culture, environmental ecologies and other important socio-environmental factors. Once again it is important to note that profit is important. However, merely 'considering' the social and environmental factors is not enough. A genuine rethinking of the way in which Industrial Engineers (and other disciplines) communicates about these issues needs to be undertaken. The answer, however, does not lie within Engineering… it comes from linguistics: Corpus Analysis.

[2.1] Industrial Engineering Terminology and Philosophy

[2.1.1] Handbook of Industrial Engineering

Industrial engineers use a wide variety of philosophies that have been in use for decades in various environment. The ultimate goal of most these philosophies is reducing waste and ensuring efficiency & effectiveness (Maynard & Zandin, 2001). Some of these include theory of constraints (ToC), total quality management (TQM), quality function deployment (QFD), optimization and many others. The most inclusive resource that summarizes, discusses and provides case studies for IE philosophies and their development (in the industrialization timeframe being examined) is the Handbook of Industrial Engineering by Maynard and Zandin (2001).

In their handbook on Industrial Engineering, Maynard and Zandin (most recent is the 5th edition published in 2001) provide what can be described as the most comprehensive about IE, its sub disciplines, its future and the often-forgotten intricacies surrounding the field. The 2000+ page handbook remains an important reference point and guide for the development of the profession. One of the most stimulating sections in the Handbook of Industrial Engineering is titled "Is Industrial Engineering Dead?" (Maynard & Zandin, 2001). Although the section might seem controversial at first (due to the proposed question), it is actually a forward looking

predictive analysis of what sub-disciplines can emerge and be directly attributed to IE especially since "the ability to forecast the direction of a profession is extremely difficult, if not impossible" (Maynard & Zandin, 2001:95). The authors explore what alternative terms can replace/enhance the term 'industrial' in order to more accurately reflect the work undertaken by an industrial Engineer. The authors stick to using terms beginning with 'I' in defining the alternatives and define "innovation engineering, integration engineering, information engineering, involvement engineering, instruction engineering, intellectual engineering and international engineering" (Maynard & Zandin, 2001) as possible substitutions.

Alongside the works of various scholars, IE is here to stay even if in an overarching capacity. Similarly, most scholars agree that the field to needs to incorporate a genuine understanding and respect for the macro social and environmental systems that house their activities. Bilge et al. (2016) shows how the skills and competencies that Industrial Engineers develop are built off the pool of knowledge presented to them (Bilge et al., 2016). Additionally, the field is based on the fundamentals of engineering sciences, Manufacturing sciences and economic sciences. Naturally, adapting this pool to reflect the rising environmental and social concern can lead to more sustainability.

[2.2] Corpus Analysis

Qualitative corpus analysis can be defined as "methodology for pursuing in-depth investigations of linguistic phenomena, as grounded in the context of authentic, communicative situations that are digitally stored as language corpora and made available for access, retrieval, and analysis via computer" (Hasko, 2012:1). Hasko (2012:1) further explains that "researchers using qualitative corpus analysis as the methodological basis for their investigations adopt an exploratory, inductive approach to empirically based study of how the meanings and functions of linguistic forms found in the corpus interact with diverse ecological characteristics of language used for communication… A common belief shared by all corpus linguists is that it is important to base linguistic investigations on 'real data', that is, actual instances of oral or written communication as opposed to contrived or "made-up" data. Unique goals of qualitative corpus analysis include facilitating computer-aided retrieval of authentic examples of the language phenomena under investigation, interpreting these empirical data in depth, and applying the ensuing insights to a broad range of intellectual explorations in language studies".

In corpus-based analysis there are four vital elements "the text, the language, the culture and the brain" (Scott & Tribble, 2006:VII). Scott and Tribble (2006) highlight how important it is to understand these 4 elements in order to provide an accurate context. However, different fields of linguistics deal with the boxes separately. "The lexicographer and grammarian are largely

concerned with problems within the bottom left box; the text linguist or discourse analyst to work with words in terms of their relationship with each other within the framework of text; the psycholinguist with the mental lexicon, the sociolinguist, historical and political scientist with the bottom right box [however] none of them can ignore the other boxes, for all four aspects are related" (Scott & Tribble, 2006:7). Figure 1 summarises the aspects and the expected inputs that can be extracted from each.

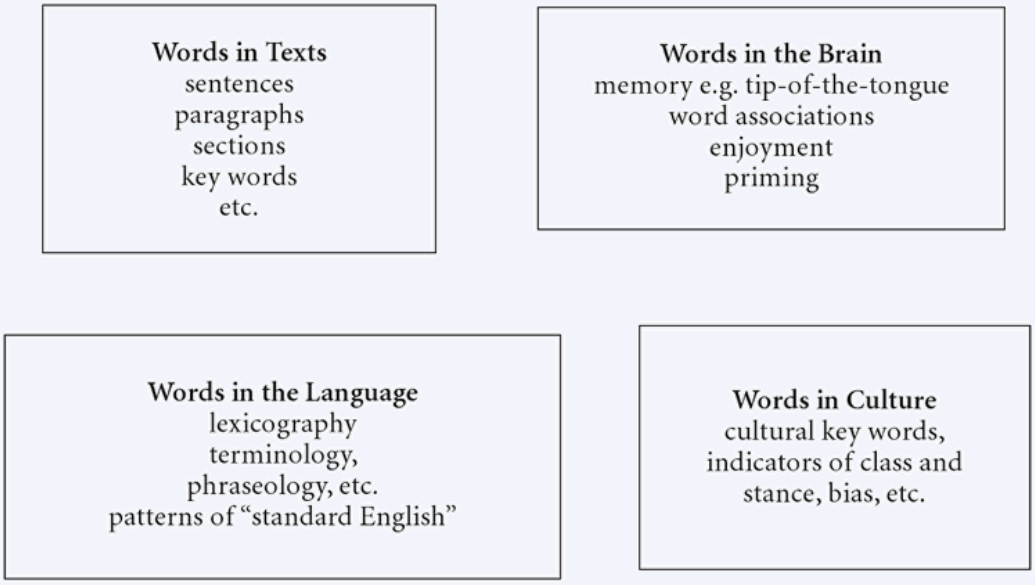


Figure 1: The 4 Elements of Corpus Analysis (Scott & Tribble, 2006:8).

[2.2.1] Corpus Analysis of IE Handbook

The corpus for Maynard and Zandin (2001) was made available on access engineering relatively recently. This allowed the researcher to conduct a corpus analysis to identify the most used terms, their relationships with each other as well as some of the overarching themes. The corpus is written by various authors and compiled by Maynard and Zandin and thus presents the ideal text to analyze for the problem at hand. It also fits in terms of the historic context of the problem (for which the effects still remain today.

The corpus was cleaned to remove repetitive tiles and non-meaningful words. Using the freely available tool Voyant Tools, the corpus analysis yielded the following:

This corpus has: 1,064,477 total words and 37,945 unique word forms.

Average Words Per Sentence: 25.9

The total number of words does not necessarily provide insight, however, the number of unique word forms and average words per sentence highlight potential complexity in the discourse which can be noted. This is quite understandable given that Industrial Engineers often draw from other knowledge fields to solve their unique problems. Naturally, the above number

include unique terms used in case studies which can inflate the number but is still an interesting finding worth noting.

The Most frequent words in the corpus and the number of times they appear in the text: time (5057); work (4733); process (3866); management (3228); industrial (3131); production (2871); engineering (2783); product (2679); design (2616); systems (2576); manufacturing (2286); cost (2213); used (2207); data (2196); new (1915); information (1854); control (1805); labor (1690); standards (1688); quality (1652); use (1634); analysis (1508); standard (1502); project (1480); based (1473); planning (1460); study (1458); company (1438); performance (1417); equipment (1414); improvement (1412); team (1375); operations (1366); number (1347); methods (1322); development (1319); percent (1290); job (1279); case (1254); figure (1221); using (1215); example (1213); total (1195); material (1190); costs (1168); required (1163); model (1159); productivity (1153); level (1140); processes (1115); parts (1096); assembly (1075); value (1054); service (1015); method (1010); products (987); important (978); inventory (977); business (976)

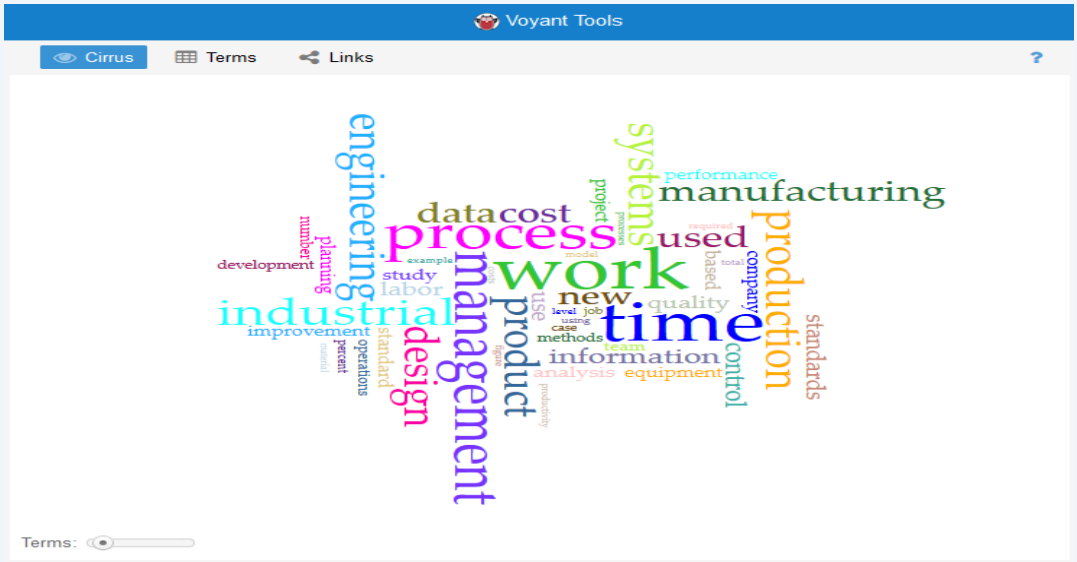


Figure 2: Word Cirrus of Maynard and Zandin (2001) Using Voyant [Own Work]

Interestingly, the term ‘time’ is the single most used term in the corpus. This is somewhat understandable given that the roots of Industrial Engineering lie in efficiency experts who started their careers with time studies and improving efficiency. Additionally, many of the other terms also correlate with some of the history of IE development into a management and engineering discipline. Interestingly, although some of the terms can be said to indirectly focus on human factors, a preliminary analysis shows there is no direct and genuine consideration for these environmental and social terms.

Two visuals that can further provide some context are provided below in Figure 3 and 4. Voyant tools allows the researcher to filter each term and explore the context within which it is being

used in order to make justifiable conclusions about the corpus. It can be seen from Figure 3 that some variation exists in the use of terms during the corpus (when divided into 10 segments). However, the top terms can be said to remain present and relevant across all segments. Figure 4 provides a sample of the context provided for each word which was reviewed. This was used in order to generate the conclusions.

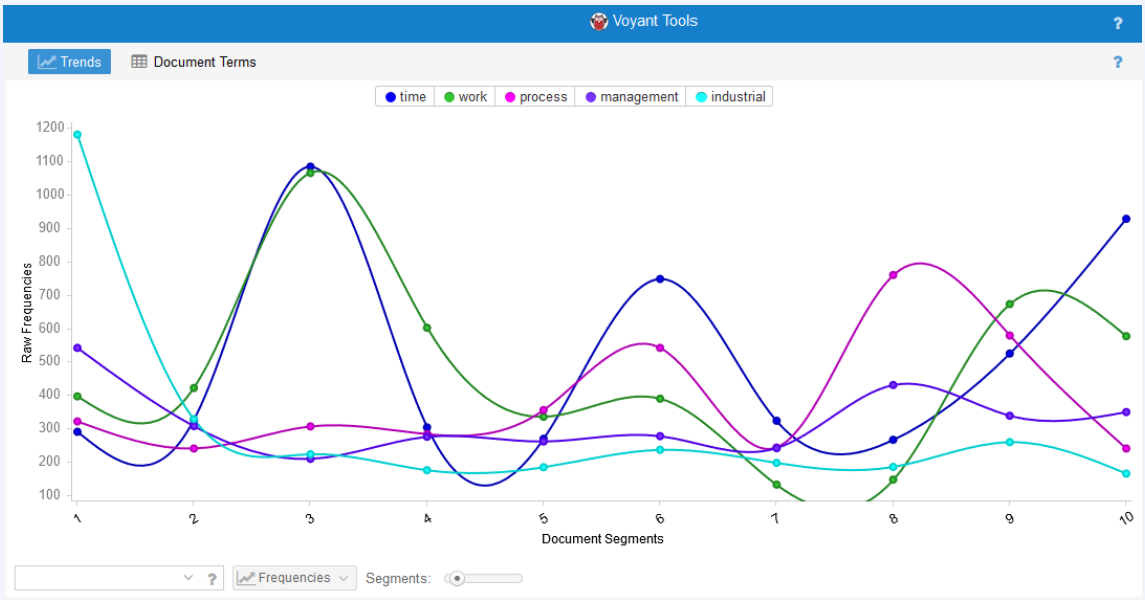
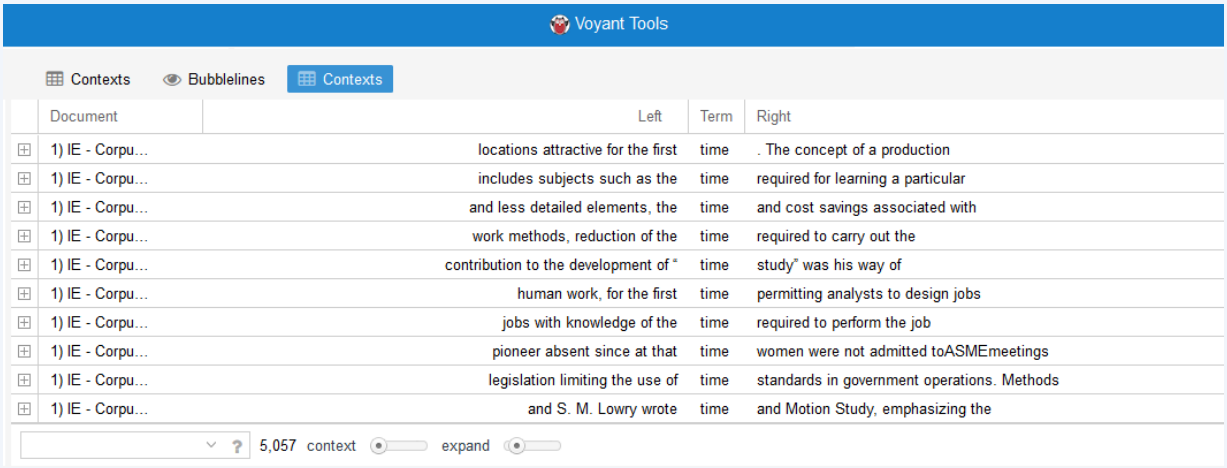


Figure 3: Word Trends (10 Segments) of Maynard and Zandin (2001) Using Voyant [Own Work]



Document	Left	Term	Right
1) IE - Corpu...	locations attractive for the first	time	. The concept of a production
1) IE - Corpu...	includes subjects such as the	time	required for learning a particular
1) IE - Corpu...	and less detailed elements, the	time	and cost savings associated with
1) IE - Corpu...	work methods, reduction of the	time	required to carry out the
1) IE - Corpu...	contribution to the development of "	time	study" was his way of
1) IE - Corpu...	human work, for the first	time	permitting analysts to design jobs
1) IE - Corpu...	jobs with knowledge of the	time	required to perform the job
1) IE - Corpu...	pioneer absent since at that	time	women were not admitted toASMEmeetings
1) IE - Corpu...	legislation limiting the use of	time	standards in government operations. Methods
1) IE - Corpu...	and S. M. Lowry wrote	time	and Motion Study, emphasizing the

Figure 4: Word Trends (10 Segments) of Maynard and Zandin (2001) Using Voyant [Own Work]

Moreover, to better understand the correlations between terms and understand how they group into clusters, two further analysis were conducted using Voyant tools (presented in Figure 5 and 6 below). Figure 5 links words, using the context and corpus trends, to analyse the strength of relationships between words with one another. Moreover, the scatterplot (in Figure 6) provides a cluster view of terms by using the above factors combined with the number of times a word was repeated in the corpus.

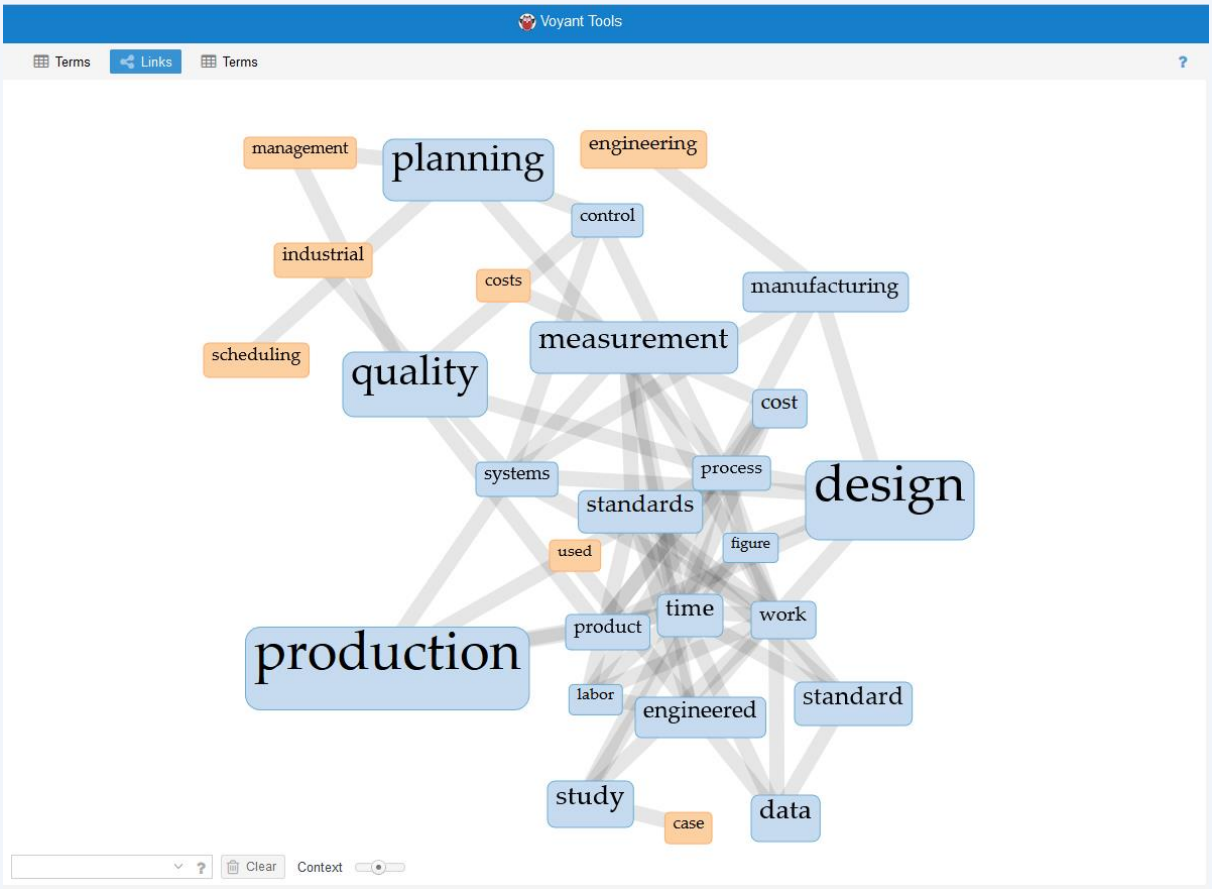


Figure 5: Word Links (Correlation Coefficient) of Maynard and Zandin (2001) Using Voyant [Own Work]

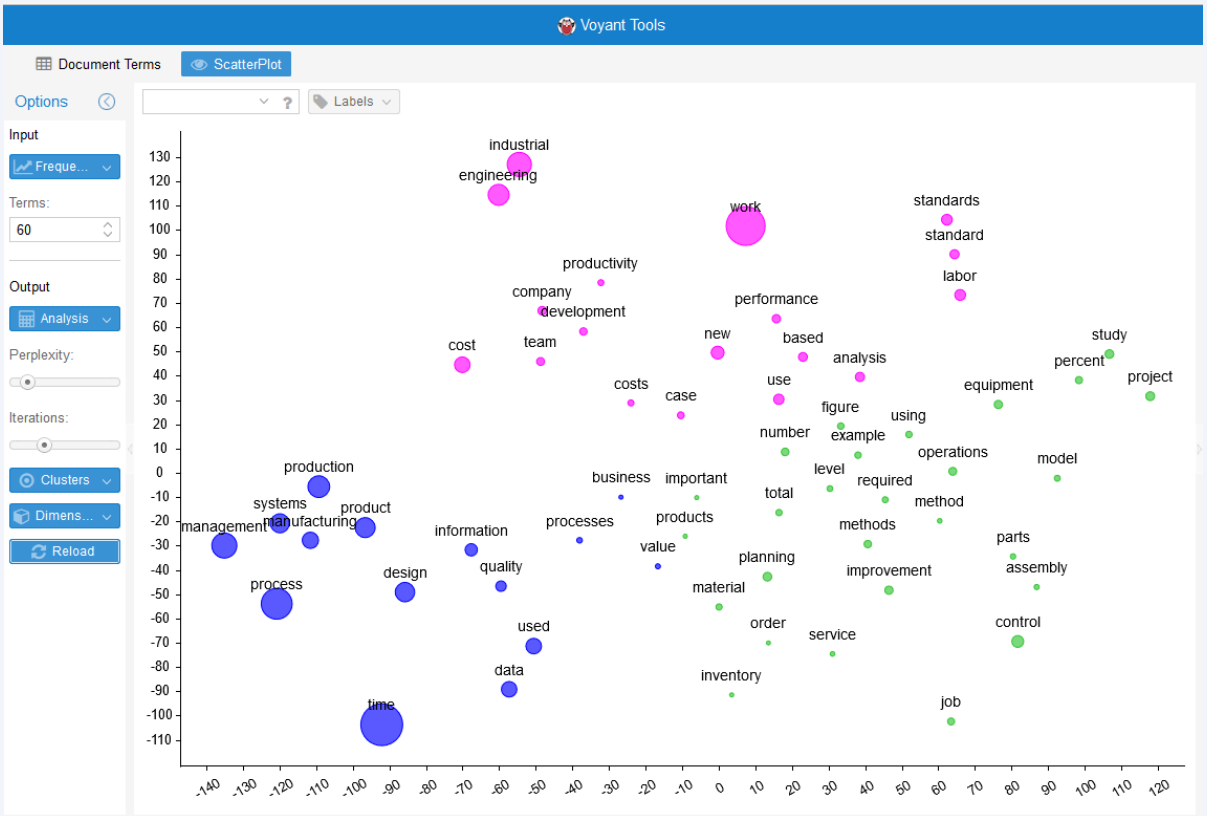


Figure 6: Word Scatter Plot (Clusters) of Maynard and Zandin (2001) Using Voyant [Own Work]

[3] INTERPRETATION AND DISCUSSION

The handbook by Maynard and Zandin (2001) represented discourse within and surrounding the profession in the 19th and 20th century. Thus, on its own it is not the best source of the current discourse of the profession. Yet, it does provide insight to the theoretical foundation for the terms in use until today. The corpus analysis was conducted in June of 2017. However, in order to extract more meaningful findings, the researcher conducted various interviews with pioneers, professionals and venturists of the field. Additionally, an international perspective was included in these interviews. Moreover, a general critical view of current discourse was conducted. The following can be concluded from the analysis:

1) Industrial Engineering as a field remains one of the most progressive fields in adapting and developing its methodology, however, given that it remains largely impacted by the macro-system of the economy; much of its terminology is aligned with that paradigm. This can be quite problematic in consumerist structures because good IE work leads to negative environmental and social impact.

2) A general analysis finds that Industrial Engineers are willing to integrate frameworks that lead to a more genuine acknowledgement and respect for social and environmental concerns as long as it does not lead to them losing their ability to design and solve problems (as engineers would). Thus, there must be a clear ability to extract plausible design requirements from these concerns.

3) Most, if not all, reviewed sources and interviews appeared to suggest that the change must begin at tertiary level in the training of Industrial Engineers. It is fundamental to continuously adapt the curriculum to keep up with modern developments.

Typically, in IE discourse, the economy is seen as more important than society and the environment. A systems perspective of this concept finds two major flaws: 1) The economy should not be equated with the above supra-systems because it creates an implicit idea that economic, social and environmental considerations should be treated the same way, and 2) Treating the system in silos is a drastic oversimplification which tends to inflate the importance of the locus of control (which typically falls within the economy) and generates unbalanced and unsustainable solution (StatsNZ, 2008, Hermes, 2011). Additionally, a variety of sources tend to treat each factor as a silo and sub-divide it further into smaller silos (OziPolitic, 2006). A venn-diagram was created to display the development in understanding which must be catered for in IE discourse. After all ““The aim of development must be neither producerism nor consumerism, but the satisfaction of fundamental human needs, which are not only needs of humanity” – Manfred Max Neef”

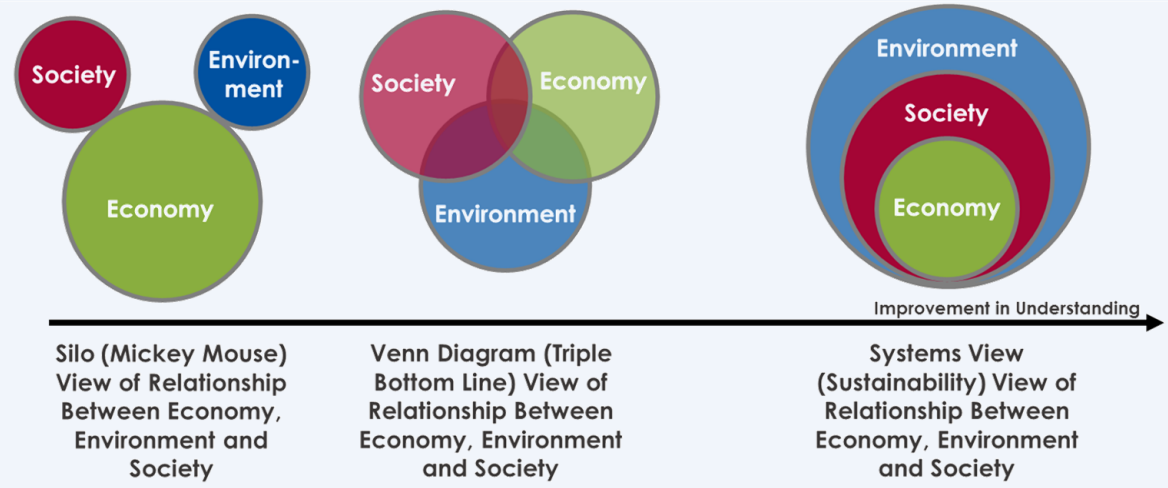


Figure 7: Evolution of Economy, Environment and Society Relationship [Own Work]

[3.1] Expanding Environmental and Social Awareness

In attempting to improve the problem context, it appears that the economic, scientific and manufacturing background of Industrial Engineers needs to be shifted away from value-laden growth terminology towards more balanced and human centred (ethical) discourse.

A simple, yet impactful, example is the idea of ***work*** and ***time*** which are the two most repeated terms. Work in many consumerist constructs means an 8-5 workday. One must truly examine whether this is still relevant today. The concern is this preconception is used, as a design consideration, in virtually all economic systems. Yet, one of the negative results is that it leads to peak traffic which in turn leads to less time socializing with family. This at the very least causes some of the social problems related to family life and yet its root cause is a perception. Taking a more 'physics' based view of work as energy being spent to create a certain output is already an improvement. This can potentially lead to output based pay as a basis for the economy.

Similarly, it can be said that the majority of IE work remains on creating efficiency. This is largely related to the perception that time is money and it is the role of an IE to artificially extend the life of organizations (their time) by performing cost saving measures. Although some cases can indeed lead to positive results, a closer exploration finds that at times it is more favourable to allow certain companies (or industrial sectors) to fade away as they have served their purpose. This allows for new industries and seeds to emerge and thus ensures continuous development of a different kind: regeneration. In this regard, some invaluable insights can be incorporated from the field of Biomimicry. This is especially helpful given it reinforces the required problem-solving approach.

Moreover, customers are often sold products and services based on the idea that they provide faster response times. Once again although in some cases this might be positive, it definitely deviates normal human behaviour and creates the problem of consumerism and the need for instant gratification. A simple exploration of industrial psychology reveals this to be both problematic and unsustainable (Max-Neef et al., 1992). Especially when it is the mass who requires it. The works of Manfred-Max Neef can be used in this regard to identity fundamental human needs and pseudo satisfiers Max-Neef et al. (1992). These too function very much like input requirements to any design process.

[3.1.1] Biomimicry

Various instances of using biomimicry to optimize human processes exist in literature. Passino (2002), for example, discusses the "potential uses of biomimicry of social foraging to develop adaptive controllers and cooperative control strategies for autonomous vehicles". These strange links between biology and manmade systems might appear strange at firsts. Yet, it becomes less confusing one considers that the aim of virtually all systems is to reach some form of equilibrium that suits their goals. Biomimicry "is a revolutionary new science that analyzes nature's best ideas -- spider silk and prairie grass, seashells and brain cells -- and adapts them for human use" (Benyus, 2009). For the larger part, it appears nature is better at this than human beings.

The concern, naturally, is that our growth behavior can lead to environmental imbalances. In order to counter this behavior, various disciplines to try to synergize environmental principles into the design process of technical disciplines (such as engineering). One such design theory is the biological design spiral which attempts to 'biologize' the problem and seek answers from nature (De Pauw et al., 2010). There are naturally many approaches that include environmental factors, but once again it is very important for Industrial Engineers to be able to design something (whether it be a process or product). Biomimicry and cradle to cradle, in this regard, hold the most promise. The design spiral that is typically associated with biomimicry is presented below. However, it must be noted that a large amount of theory from Industrial Ecology, Natural Capitalism and Cradle to Cradle must also be considered in the re-development process of IE philosophies.

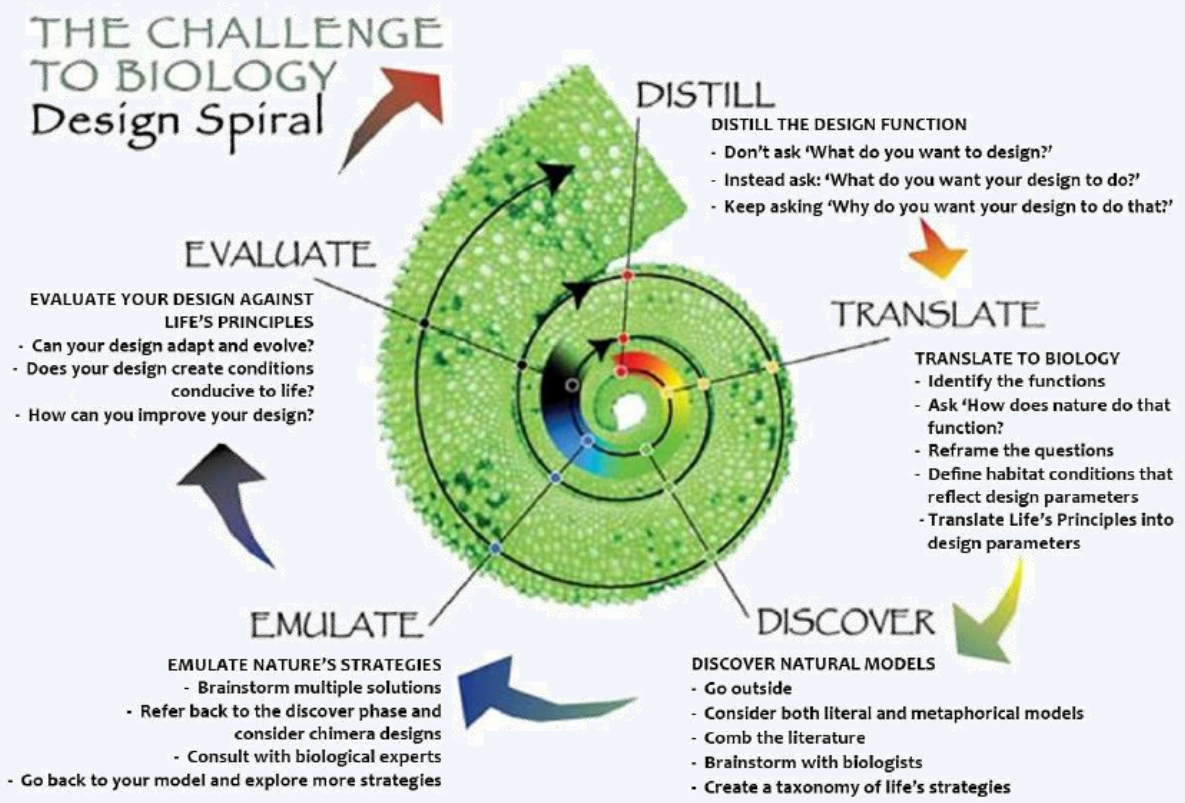


Figure 7: Biomimicry Design Spiral (De Pauw et al., 2010:9)

[3.1.2] Manfred Max Neef Fundamental Human Needs

When thinking about human needs many, if not most, individuals will refer to Maslow's hierarchy of human needs. Yet, the hierarchy has come under major criticism for not having fundamental empirical evidence to support it, looking at human beings in an animalistic manner and implying that individuals need to satisfy a certain level of needs before progressing to the other (McLeod, 2007, Wahba and Bridwell, 1976). Notably, many individuals around the world lead fulfilling and happy lives without necessarily rising up the hierarchy.

In short, what makes Maslow's hierarchy unfit for this article is that it fails to consider that human development needs are largely intertwined with their socio-economic status. A more appropriate, humane and ethical centred model can be found in the works of Manfred Max-Neef model for fundamental human needs. "Manfred Max Neef is a Chilean economist who proposed to explain the crisis of Latin America countries not only in an economic way" (Tonon, 2012). His model presents an ethical and environmentally considerate view of human needs (alongside his other works on human development, growth and quality of life). Tonon (2012) explains that Manfred Max Neef "produced a human scale approach to international development based in the idea that the development is about people not about objects. He considers that 'needs' should be understood as finite and universal, and 'satisfiers' are infinite and culturally determined".

What is particularly interesting in the works of Manfred Max Need is the classification of human needs along two axes: Existential and Axiological (Max-Neef et al., 1992). Max-Neef et al. (1992) lists the existential categories to "demonstrate the interaction of… the needs of Being, Having, Doing and Interacting". The axiological categories are defined as needs of Subsistence, Protection, Affection, Understanding, Participation, Creation, Leisure, Identity and Freedom" (Max-Neef et al., 1992). The intersection of these two axes creates a visual representation of fundamental human needs. It is important to note in this visual representation that the basic human needs are closer to the centre and should be available to all.

Yet, the aim is to reach the ultimate state of that category. For example, one might classify the basic human right of freedom as having autonomy. However, the aim of that category is to then have equal rights followed by being able to [do] choose and develop awareness followed by the ability to do this everywhere [interact]. What makes the works of Max-Neef et al. (1992) even more suitable is it lists human behaviours which are often seen as satisfiers but in fact they violate the human rights or needs of the person themselves or of society at large. These are defined in the works of Max-Neef et al. (1992) as violators, destructors, inhibiting and pseudo satisfiers. Furthermore, Max-Neef's other works give special attention to environmental sustainability in his other works (Max-Neef, 1995). This helps understand "human needs as a system; that is, all human needs are interrelated and interactive" to the immediate environment and earth's biosphere (Max-Neef, 1995, Max-Neef et al., 1992).

The main concern, with regards to Engineering, is the existence of an imbalance which tends "prioritise technical ingenuity over helping people… In some instances, appropriate technology is available but not being applied [an example being water shortages affecting 2 billion people which results in over 25 000 deaths a day] … In other instances, complex and appropriate technology is developed and applied [but for the wrong use purpose since]… peaceful and military uses of Engineering compete for the same skilled personnel" Bowen (2009). Over time, this leads to the economically prosperous getting their problems attended to by the best Engineers whilst the economically disadvantaged see their problems pile up and merge into Wicked problems (especially when 'infrastructure' problems are interrelated with health or financial need).



Figure 7: Manfred Max-Neef Fundamental Human Needs (Masha, 2016)

[4] CONCLUDING REMARKS

[4.1] Future Research

It is unfortunate that no latter versions of the comprehensive IE handbook by Maynard and Zandin (2001) have been published. However, it can be said that modern discourse of communities occurs in conferences. It would be very interesting to conduct a similar corpus analysis on the proceedings of conferences of national and international communities of Industrial Engineers and compare the results. A few particularly interesting conferences that appear to be discussing strategies to mitigate this lack of environmental and social concern are the South African Institute of Industrial Engineering's 28th annual conference (SAIIE 28) titled Taking Up Stewardship and the proceedings of the XXII International conference on Industrial Engineering and Operations Management (IIE) titled Closing the Gap Between Practice and Research in Industrial Engineering.

Additionally, it became clear that research can be done on formulating a generalizable and harmonious definitions using biomimicry. One can start with each and every course presented in the IE curriculum and create definitions based on social, biological or cultural examples of the observed phenomenon. Waste, after all, is not merely an economic term and understanding it within different contexts can truly strengthen understanding.

[4.2] Conclusion

This article will, most likely, be part of a series of articles exploring the development of the discourse within the IE field. Corpus analysis does not necessarily provide a detailed view of history and cannot explain the full story of the development of the profession. However, it can help narrow down some elements to explore further and can provide interesting visual snapshots of historical discourse as well as current discourse. There is significant adaptation that needs to take place to accommodate for developments such as Biomimicry and the works of Manfred-Max Neef in the education and training of Industrial Engineers.

Moreover, as a general tool Industrial Engineers should be actively using corpus analysis to continuously highlight and expand the broad knowledge base used by them in case studies. With a special focus on developing a genuine social and environmental concern. This can potentially be done by exploring under-researched elements that link to these factors.

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11. Research Findings & Evaluation

This section will complete stage Stage 2 of the adapted ADR-in-EE approach of the overarching methodology. It is also where the main deliverable, the Industrial Thinking Systemigram, is developed using the insights from the literature review and articles provided in Chapters 6-10.

11.1. Elements Linked to Industrial Thinking [Sub-Stage 2.1]

This sub-section aims to better understand the relationship between IE and industrial thinking, and their connections to other elements. Various academic works exist that connect a profession and its methodologies with their given thinking styles. One helpful example comes from Boardman *et al.* (2009), where the link between the abstract concept of systems theory and the applied profession of systems engineering is made clear (to create a roadmap). Moreover, the article appears to suggest that one links these two by using an intermediary system of system thinking. Boardman *et al.* (2009:1) elaborate that:

> *General Systems Theory (GST) has been with us in one form or another for more than half a century. In the minds of its originators GST was intended to be a rigorous body of knowledge that brought together the ideas associated with specific systems of interest from many disciplines; it would then evolve into a set of unified theorems under a single roof. In this way, the term system could maintain its ubiquity whilst having a precision and form per se that would permit practitioners from any discipline to better share their findings and understandings of phenomena and thereby advance the underlying theory that governed all systems. Regrettably, perhaps inevitably, GST has over time become increasingly remote and remains largely unassessed by specialists in the sciences and technology. Instead what has evolved is a collection of separate practices by which systems in their domain, e.g. Engineering, social science, and life science, are better understood and manipulated for improved performance. This in itself does not present a problem provided that these various endeavours can somehow be tied together with some cohesiveness, which, if not exactly rooted firmly in GST, gives something that at least provides pathways for a communion of systems oriented specialists.*

This extract and article summarizes the there is always a difference between the name of a profession takes during a certain period and the more abstract concept it is trying to understand or use. It does this, however, by applying a unique thinking style. This is what was being alluded to in the introduction; industrial and Engineering behavior or thinking have existed for centuries even if they were only recently formalized into an Industrial Engineering field. In Figure 21, Boardman *et al.* (2009:1) give clarity on this aspect and even show how other

thinking styles can play an important role in the development of a thinking style (paradoxical thinking in the case of system thinking).

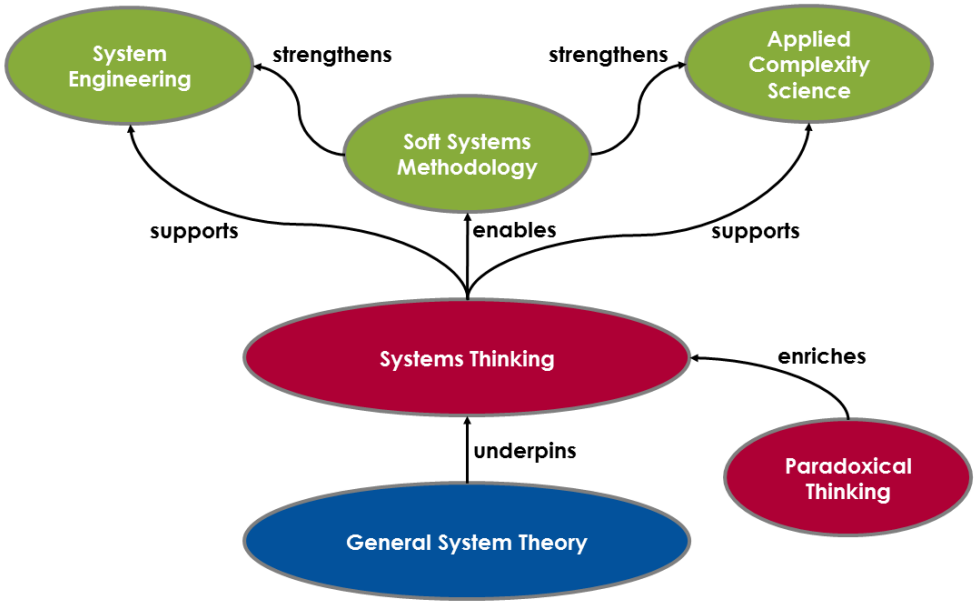


Figure 21: System Connectogram (Boardman *et al.*, 2009:1)

A similar diagram (based on the works of Boardman *et al.* (2009)) was deemed necessary for Industrial Thinking to showcase the link between elements surrounding this cognitive style. This diagram stressed that Industrial Engineers require both Systems Thinking and Industrial Thinking. In fact, many of the definitions no longer distinguish the two fields and often call the overarching field industrial and systems engineering. However, it also shows that the two fields are intertwined but have unique differences worth exploring. Figure 22 below shows the link between human development theory, industrial thinking, design thinking, industrial engineering, Industrial Thinking Systemigram, and management sciences. The introduced elements are discussed in detail in the sub-section to follow.

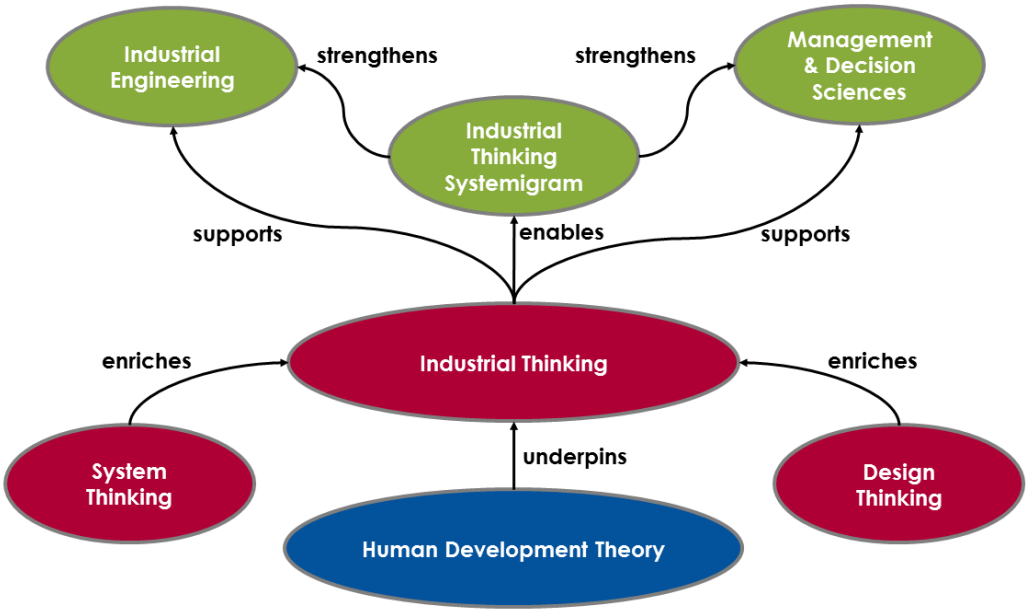


Figure 22: Industrial Connectogram [Own Work]

11.1.1. Industrial Thinking Theoretical Underpinning: Human Development

Arguably, one of the best definitions of the Industrial Thinking process is not a definition at all. Rather, it is a discussion on how the modern man developed this unique behavior and thinking style across the ages without actually being aware of it. This discussion comes from the works of Frank Sperotto (1994:3-9) in his famous book *In the Footsteps of Homo Industrialis*. A summary of the introduction section of this book gives the full picture:

> *Applying a good measure of partisan zeal may well suggest to some the naming of modern man as Homo Industrialis. In a narrow sense, Homo Industrialis represents the considerable segment of human society intent on the development of an industry, producing structures, goods or services… In a broader sense, Homo Industrialis is characterised, not only by his ability to adapt to the environment, but by his ability to adapt the environment to suit himself. He achieves this by being industrious. To be industrious requires the skills to organize concepts, materials and people in an order which strives towards constructive results. It requires more than one or two simple, reactive logical steps. And to be constructive requires foresight, imitative and an altitudinal and mental change redirects primal drive and energies. It is noteworthy that the predominant behaviour of primates is towards the destruction rather than constructive use of materials…*

Reviewing the book made clear the link between Industrial Thinking, human development, the IE profession. Much like general system theory (GST), human development theory (HDT) was developed in the minds of the original researchers to explain the phenomenon summarized by Sperotto. Human development theory is distinguished from other economic theory (such as gross domestic product) in that it seeks the development of human capabilities, wealth, and comfort rather than riches for the sake of riches or growth (HDR, 2017). Intellectually, it is based on the works of various Nobel winning economists such as Mahbub Ul Haq and links to the works of Manfred Max-Neef (which will be discussed later). Some even link it to earlier works which stressed the ideas equality, empowerment and cooperation of humans.

One may argue that the general theory underpinning of industry (using Industrial Thinking and Engineering) would be an economic one. However, a historical overview shows that "industry can provide individuals with… purpose, dignity, self-respect, self-sufficiency, economic activity and the means with which to build a life" (Sperotto, 1994:7). This, alongside the roots of IE on the shop floor of factories helping the workers to receive better working conditions, shows that at the heart, an Industrial Engineer was truly focused on achieving a balance between man, money and machine (Sperotto, 1994). This later evolved to society, economy and environment as the asymmetrical knowledge areas used by IE grew.

11.1.2. Industrial Thinking Enrichment: Design Thinking

Equally important for consideration in this section is the supporting style of Design Thinking (in addition to System Thinking). In a nutshell, there is a reason that Industrial Thinking manifested as an Engineering discipline. Design was the Industrial Engineer's practical way of contributing value to Industry. Industrial engineers designed Industry. This, at first, was undervalued due to some industrial thoughts being ahead of their time but recent developments in the world of systems classify much of what Industrial Engineers do as the design of sociotechnical systems. Banathy (2009:105-107) highlights the following about design:

> *Design is purposeful creating action, the building of a relationship between us and our world. It is the conception and creation of novel phenomena, the realization of what should be. It is the manifestation of knowledge, beliefs, values, and aspirations, translated into a great variety of what we want to bring about and make part of our lives. The design of social systems is a future-creating, collective human activity. People in social systems engage in design in order to devise and implement systems, based on their vision of what those systems should be. Or they may redesign their system in order to realize their changing aspirations and the new realities and expectations of their environments*

Banathy (2009:107-109) also explains what design is not, its difference in approach and the relevance of it the modern society:

> *Design is not speculation but knowledge- and competence-based collective disciplined inquiry. It is not planning. Planning moves out from the existing state, it produces (in a time-frame) a step-by-step progression of what to do. Design leaves behind the here and now, to create and model a new human activity system. Design is not improvement of the existing system. It transcends the existing system, envisions a new image, and—based on it—designs a new system. It is not revising or restructuring the current system. It is a process of re-visioning… Design is not future predicting but future creating… In an age when the speed and intensity of change increases exponentially, our ability to shape change, rather than be its victims or spectators of it, depends on our competence and willingness to guide the purposeful evolution of our systems, our communities, and our society.*

Although it is immensely beneficial and helpful to the IE work to collaborate with the workers in the work environment to spread a certain thinking culture. Even in an ideal environment, someone still needs to be responsible for the design of solutions. This person needs to be a professional who can technically 'Engineer' a solution with their asymmetrical knowledge and who can take responsibility for signing off on a designed sociotechnical system. That professional remains the Industrial Engineer.

11.2. Industrial Thinking Research Gaps and Extracted Insights [Sub-Stage 2.2]

Any large-scale development in human capabilities in the modern era (through use of technology) has been named an industrial revolution (currently it is claimed we are experiencing the rise of Industry 4.0). Industrial revolutions signal a change of a thinking style and a development in human industrious behavior. This shows that there is something unique and special about Industrial Thinking that is different from other forms of thought such as management, design or system. It is, however, highly influenced by them and combines them. However, the one aspect that appears repeatedly in this study is the fact that the current Industrial Thinking paradigm is simply not adapted to be harmonious with environmental and social concerns, and is lacking in some areas in order to truly match the requirements of the knowledge era. This is a sign that the thinking style requires expansion. In the words of Banathy (2009:109):

> *There are times when… We realize that our purposes are not viable anymore and we need to change them. We are becoming increasingly aware that our system is not synchronized with the environment in which it is embedded, or that it is "out-of-sync" with our desires and aspirations. We realize that we now need to change the whole system. We need a different system; we need to deviate from existing norms, we need to establish new norms. In time of massive, accelerating, and dynamic changes that characterize the current societal scene, adjustments and changes within the system will not suffice. When a gap opens up between the evolution of the system and the evolution of its environment, internal, piecemeal adjustments can no longer keep the system "in-sync" with its environment. The whole system has to change in order to make it compatible with its changing environment or with the desire of people in the system. The feedback that guides this action is called: "positive feedback". Through self-organization the system responds to positive feedback and co-evolves with its environment by transforming itself into a new state. The process by which this co-evolution and transformation comes about is systems design.*

In principle, this rethinking needs to be done for most if not all professions. However, the focus of this study is showing its necessity for the Industrial Engineering profession and its associated thinking style. Given that this study is a research, appropriate literature was used in structuring the flaws, identifying reasonable gaps and extracting insights from steps taken to resolve those gaps. Returning to the works of Checkland and Holwell (1998), it is vital to any piece of meaningful research to have a framework of ideas (F), a methodology (M) and an area of concern (A). Yet, this study showed that given the complexity of the problem, it is important to consider the system context. A custom methodology (which was built using the insight extraction ability of action research method mixed with the general structure of soft system methodology, as well as the two-stream version) yielded the extracted insights.

[What] does this study do? *Expand Industrial Thinking.* In this study, expanding takes many meanings. Expanding according to the dictionary definition means giving a fuller version or account to make more extensive. Most important to this study, is expanding the areas of concern of Industrial Thinking. This implies expanding on its philosophies and definitions that underpin this thinking style. Furthermore, an added goal is to expand the users of Industrial Thinking both within society (simplified definition) and the profession (using a procedural model). [**How] is this done?** *By Formalizing the Industrial Engineering Identity.* This proved to be an essential piece of literature that was missing and was uncovered as part of this study. **What time frame is in mind [The When]?** *For the Knowledge Era*. This study takes a futuristic view, not a retrospective one. The technologies introduced in the knowledge era radically challenge traditional knowledge areas **[The Where]** which are now required to be progressively resilient and taught in the profession **[The Why]**. The study can be summarized as follows:

S0.1: Research overview - Industrial engineers appear to share a common way of thinking and the ability to instigate it in others. Yet, unlike other fields, this seems to be largely implicit and difficult to communicate with society at large

S0.2: System context - This is a problematic situation. In order to resolve it, an interpretive systems approach (Pluralistic-Complex) must be taken to create an idealized state and take steps to realize it

S0.3: Research framework - A significant conceptual research gap exists that hinders the development of Industrial Thinking, within the IE profession, which would need to be closed in order for the thinking style to be able sensitive towards and resolve social and environmental challenges of the knowledge era.

S0.4: Research methodology - The development of an Industrial Thinking Systemigram which accurately reflects the aspirations and asymmetrical knowledge unique to the profession (by addressing cultural stream and systemic changes) is instrumental in ensuring beneficial proliferation of the thinking style necessary for progressive resilience in the face of the macro challenges of the knowledge era

S0.5: Research Area of Concern - A system of systems view reveals 2 streams: The systemic starting with the Industrial Engineer reveals 5 macro systems which deserve attention: The industrial engineer, the profession, the economy, society, the environment. These concerns can be addressed in separate articles (due to system considerations) whilst discussing the combined 'culture' stream surrounding Industrial Thinking (which is addressed collectively)

11.2.1. Insights from the Individual Level [Article 1]

Article addresses the first identified area of concern which falls within the industrial engineer him/herself. The gap found at this level was the lack of a formal Industrial Engineering identity. An appropriate article [Chapter 6] was developed to address this. The overarching argument and extracted insights that were included for consideration when developing the Industrial Thinking Systemigram are:

- **S1.1:** Historically, industrial engineers were seen as jacks of all trades but masters of none
- **S1.2:** The view above is one of the reasons that hindered the progression of a formal identity
- **S1.3:** The commonality between the thinking style and subdisciplines' tools used in Industrial Engineering is that they focus on designing balanced solution for industry
- **S1.4:** A critical review of the current state of IE finds that the modern identity is centered around being connected to various fields of knowledge whilst being masters of some
- **Conclusion 1 [Desirable Systemic Change]:** In order to hold true to their professional identity (IE-ID) of designing balanced solutions, an industrial engineer must continuously advance their interdisciplinary awareness (to connect) and cognition abilities (to master).

11.2.2. Insights from the Industrial Engineering Profession Level [Article 2]

Article 2 addresses the second identified area of concern which falls within the industrial engineering profession. The gap found at this level was the lack of a centralized way to develop the profession and train new entrants. An appropriate article [Chapter 7] was developed to address this gap. The overarching argument and extracted insights that were included for consideration when developing the Industrial Thinking Systemigram are:

- **S2.1:** Engineering education in the knowledge era (21st century) requires a significant amount of experiential learning and work-based learning to successfully transfer knowledge
- **S2.2:** Current entrants into university belong to generation Y and Z, and their exposure to technology and games since birth suggests that gamification techniques can be an effective teaching method
- **S2.3:** The Baader-Meinhof phenomenon (see or hear something everywhere after initial contact) can be used to reinforce certain concepts within different contexts which can strengthen the recollection and application ability of students
- **S2.4:** The Industrial Engineering community works in various environments. Sharing insights and resources from the different environments (which are currently dispersed) can help in strengthening relationships throughout the profession
- **Conclusion 2 [Desirable Systemic Change]:** In the knowledge era, it becomes vital for professional communities to create knowledge & resource sharing platforms that act as incubators and places to congregate for initiatives that can further develop the profession and attract the next generation of entrants into IE

11.2.3. Insights from the Profession Level [Article 3]

Article 3 addresses the third identified area of concern which can be considered as the role of the Industrial Engineering profession in relation to the encompassing system of the economy. The gap found at this level presented an opportunity to develop the profession further by successfully reacting to macro-disruptive forces shaping the knowledge and sharing economy. An appropriate article [Chapter 8] was developed to address this. The overarching argument and extracted insights that were included for consideration when developing the Industrial Thinking Systemigram are:

- **S3.1:** Means of production are becoming decentralized and simpler due to 3D printing and additive manufacturing
- **S3.2:** Employment mechanisms, corporate structures and customer behavior are becoming more network-like due to the sharing and knowledge economy
- **S3.3:** Supply chains are becoming shorter due to transport technologies creating radically different supply/demand relationships
- **S3.4:** Human concerns and values relating to education, health and other concerns are becoming more conscious
- **Conclusion 3 [Desirable Systemic Change]:** Since Industrial Engineering is deeply rooted in designing and managing the above socio-technical systems, transdisciplinary frameworks need to be created using Industrial Thinking to correctly evaluate the impact of macro-disruptors and successfully react to them.

11.2.4. Insights from the Societal Level [Article 4]

Article 4 addresses the fourth identified area of concern which can be considered the role of the Industrial Engineering profession in relation to the encompassing system of the society. The gap found at this level presented an opportunity to actively participate in ensuring social equality by using the Industrial Engineering body of knowledge to connect the Bottom of the Pyramid (referred to as outer network society) to resources. An appropriate article [Chapter 9] was developed to address this. The overarching argument and extracted insights that were included for consideration when developing the Industrial Thinking Systemigram are:

- **S4.1:** The societal type currently existing in the knowledge era and experiencing the fourth industrial revolution is not post-industrial but post-post-industrial
- **S4.2:** This society is better named the network society; its extraction of value mainly stems from an ability to be connected, collaborate and leverage networks (which has evolved as a cognitive function over four industrial revolutions)
- **S4.3:** What was previously known as the bottom-of-the-pyramid society is, in this scenario, the outer network society and rarely experiences the full benefit and value added by Industry 4.0 and the knowledge era due to a lack of appropriate systems in place

- **S4.4:** Industrial Engineering was founded on ensuring that all of society (from employees to customers) have a voice in shaping the products and systems that ultimately service them
- **Conclusion 4 [Desirable Systemic Change]:** Since the majority of society (80%) lives in the outer network, it is fundamental for industrial engineers to design new systems that connect them to resources (in the broadest sense) that can help them develop socio-economically and cognitively to be able integrate to global network society

11.2.5. Insights from the Environmental Level [Article 5]

Article 5 addresses the fifth identified area of concern which can be considered the role of the Industrial Engineering profession in relation to the encompassing system of the environment. The gap was found to be a lag in the integration of ecological developments into the terminologies and philosophies used by industrial engineers in academia and industry. An appropriate article [Chapter 10] was developed to address this. The overarching argument and extracted insights that were included for consideration when developing the Industrial Thinking Systemigram are:

- **S5.1:** Beyond biological factors, various psychological factors form the identity of the modern human being which have led to the term Homo Industrialis; By virtue of being industrious, the human being wishes to adapt their environment to better suit their needs
- **S5.2:** Even though this nature has existed for centuries, its professional function was only formalized relatively recently in the IE field since industrial engineers display more of this industrious behavior as well as understanding the systems perspective surrounding it
- **S5.3:** However, this behavior can, if remained unchecked, lead to significant societal and environmental decay especially when the terminology used to describe it is value-laden with growth as opposed to balanced measures
- **S5.4:** Yet, Industrialization is absolutely necessary for development, but its current form is environmentally and socially destructive which can be partially attributed to a slow integration of global developments into the terminology and philosophies taught in industry and educational institutes
- **Conclusion 5 [Desirable Systemic Change]:** IE is one of the fields affected by this problem, which can be largely resolved by adapting some of the IE body of knowledge to reflect developments in biomimesis and a modern understanding of human needs

Each argument above highlighted an important aspect that needs to be considered for the Industrial Thinking Systemigram. This section focused on the desirable systemic changes and thus the conclusions were phrased mostly to focus on the IE field and the role of the Industrial Engineer. However, each of them has implications for Industrial Thinking.

11.2.6. Expanding Industrial Thinking

This section concludes an intermediary cultural implication (to be considered when suggesting the feasible cultural stream conclusion) linked to each of five desirable systemic changes. The thought process for each of these is explained below:

Conclusion 1 [Desirable Systemic Change]: In order to hold true to their professional identity (IE-ID) of designing balanced solutions, an industrial engineer must continuously advance their interdisciplinary awareness (to connect) and cognition abilities (to master). **[ES-C1-IT]:** The associated thinking style of the industrial engineer must hold true to developments in the IE Identity. **Thus:** Industrial Thinking must develop to be more focused on balanced solutions rather than growth solutions.

Conclusion 2 [Desirable Systemic Change]: In the knowledge era, it becomes vital for professional communities to create knowledge and resource sharing platforms that act as incubators and places to congregate for initiatives that can further develop the profession and attract the next generation of entrants into IE. **[ES-C2-IT]:** It is important to collaboratively engage all stakeholders in shaping the future of a profession if one hopes to get their support. **Thus:** Industrial Thinking must develop strong transparent interfaces that echo the values of the profession.

Conclusion 3 [Desirable Systemic Change]: Since Industrial Engineering is deeply rooted in designing and managing the above sociotechnical systems, transdisciplinary frameworks need to be created using Industrial Thinking to correctly evaluate the impact of macro-disruptors and successfully react to them. **[ES-C3-IT]:** The diversity of macro-tech disruptions requires a lean and resilient nature. **Thus:** Industrial Thinking must entail strong management elements and abilities to leverage technologies.

Conclusion 4 [Desirable Systemic Change]: Since the majority of society (80%) lives in the outer network, it is fundamental for industrial engineers to design new systems that connect them to resources (in the broadest sense) that can help them develop socio-economically and cognitively to be able integrate to global network society. **[ES-C4-IT]:** The loss of diverse societies and ecologies is unacceptable in the knowledge era. **Thus:** Industrial Thinking demands a holistic understanding of the possible negative consequences relating to ecology and must counteract them (possibly even contributing positively to the impacted ecology).

Conclusion 5 [Desirable Systemic Change]: IE is one of the fields affected by this problem which can be largely resolved by adapting some of the IE body of knowledge to reflect developments in biomimesis and a modern understanding of human needs. **[ES-C5-IT]:** Not catering for environmental and social needs can result in devastating scenarios. **Thus:** Industrial Thinking must inherently involve mechanisms to evaluate and promote the most feasible optimal course of action.

11.3. Development of Industrial Thinking Systemigram [Sub-Stage 2.3]

In their work on defining system thinking using a system thinking approach, Arnold and Wade (2015) argue that the best way to get an objective definition of system thinking is to treat the definition as a system and apply system thinking to it due to many definitions using a reductionist approach when defining this important term. Arnold and Wade (2015:670) discuss that "if it [system thinking] is so important, then what exactly is systems thinking?... Perhaps, rooted in our own field, lies the answer to defining the elusive concept of systems thinking in a way that will allow it to be measured. To this end, proposed is a surprisingly straightforward step in defining systems thinking – the application of systems thinking to itself… Reductionist models are unable to fully depict, or to allow us to deeply understand, new complex and dynamic scenarios". The end result of their endeavor is a systemigram (system-diagram) that represents the system thinking style and process (repeated below in Figure 23 from section 2.1.3 for ease of reference). Their refined definition of System Thinking is that it "is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects. These skills work together as a system" (Arnold & Wade, 2015:675).

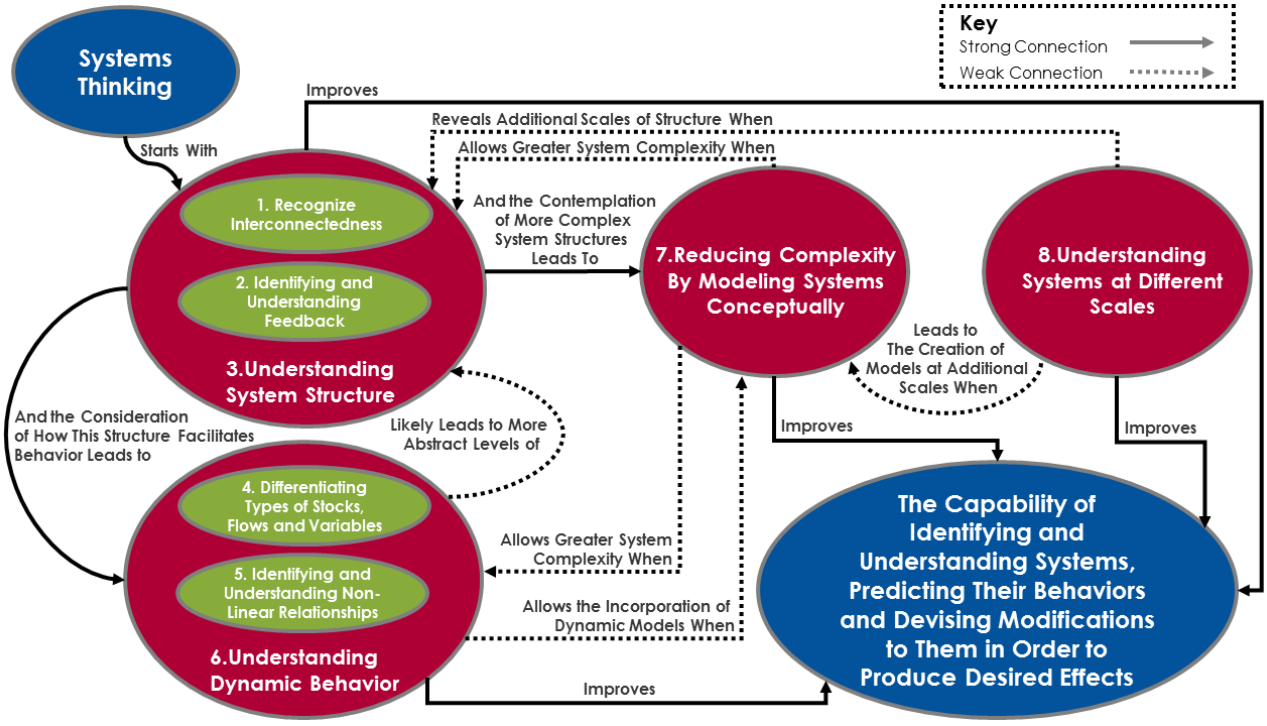


Figure 23: System Thinking Systemigram (Arnold & Wade, 2015:676)

Upon critical review of literature, it was found that the methodology used by Arnold and Wade (2015) was selected as the approach for structuring the cognitive style of Industrial Thinking. This does not lessen the importance of system thinking within the Industrial Engineering field, but the theory of this PhD is that there is a uniqueness which needs to be described and codified. System thinking, by nature, is more descriptive whilst Industrial Thinking is more prescriptive. They complement each other.

Thus, a System Thinking approach will be used by treating Industrial Thinking as a system. The process followed in Arnold and Wade (2015) can be described as follows:

1) The extraction of relevant definitions of system thinking from literature
2) Comparison of the definitions by extracting key terms and seeing which terms are most prevalent in the collective definitions
3) Development of an objective definition of system thinking based on the output of Step 2
4) The sub-definition of the key words of the objective definition
5) The development of a systemigram of the definition describing the nodes and relationships based on appropriate literature techniques

This PhD will follow a similar process. However, given the fact that Industrial Thinking is a term seldom defined or used in literature, the cognitive elements will have to be extracted from the definitions of Industrial Engineering. Thus far, what was found about Industrial Thinking is that it "must begin by differentiating value for the customer from munda — the Japanese term for waste" (Womack & Jones, 1996); it is needed "within research in academia… [due to] the obvious discrepancy between state of the art in robotics research versus actual utilized technology" (Pires *et al.*, 2005); "Prefabrication action is a good example of when building industry is utilizing industrial thinking" (Jansson & Tägtsten, 2007). Also, it was a shift that came about after industrial revolutions (White, 2010). Moreover, the review of the works Marksberry (2012) showed that true competitive advantage is achieved when industrial engineers teach others (employees and managers) to use Industrial Thinking. This allows IE solutions to be less confrontational and encourages participation of the workers. Marksberry (2012) shows how Toyota achieved this largely with their production system (TPS). Lastly, a negative prevailing view that was identified was that of disharmonious Industrial Thinking which "is based on monism, i.e. on the recognition of one absolute, primary origin (part), which generates and suppresses other parts and constantly causes conflict among and the parts as well as within the whole. An ideal of this thinking is the industrial civilization and the one-dimensional economic person – homo economicus or homo industris, whose primary target is profit rather than harmony" (Semashko, 2013).

The process used in this study is as follows:

1) The extraction of relevant definitions of Industrial Engineering from literature
2) Comparison of the results by extracting key terms
3) The distilling of relevant Industrial Thinking cognitive capabilities or thinking styles required to perform tasks described in definitions of Industrial Engineering
4) Phrasing of a systems definition of Industrial Thinking and explanation of the key-words based on the output of the process (accounting for extracted insights from articles)
5) The development of an Industrial Thinking Systemigram of the definition describing the nodes and relationships using the works of Arnold and Wade (2015)

11.3.1. Definitions of Industrial Engineering

Industrial Engineering has various definitions in literature. This section will list the most prominent and unique ones:

Sperotto (1994:6): "For centuries and particularly over the past 100 years, we have accumulated a body of knowledge on how to engineer and manage industrial undertaking successfully. This has given rise to a new discipline – industrial engineering… The discipline had its beginnings in the study of work at the shop floor level of a manufacturing enterprise but today industrial engineering finds useful applications at all organizational levels, across several functions and in many industries including the service industries. Modern industrial engineering is concerns with the integration of resources and processes into cohesive strategies, structures and systems for the effective and efficient production of quality goods and services. It draws upon specialized knowledges and skills in the mathematical, physical, behavioral, economic, and management sciences and fuses them with the principles and methods of engineering analysis and design, to find optimal and practical solutions which contribute to the success and prosperity of an industrial undertaking. Both industry and industrial engineering face many challenges together, not the least of which is the survival and prosperity of an enterprise. However, technical and business challenges must be seen in the context of broader, more general and often conflicting social and environmental challenges such as unemployment and industrial pollution. Industrial practices which disregard social and environmental consequences are self-defeating in the long term."

Salvendy (2001:5): "An industrial and systems engineer is one who is concerned with the design, installation and improvement of integrated systems of people, material, information, equipment and energy by drawing upon specialized knowledge and skills in the mathematical, physical and social sciences together with the principles and methods of engineering analysis and design to specify, predict and evaluated the results to be obtained from such systems."

Maynard and Zandin (2001:13-14): "Industrial engineering is a dynamic profession whose growth has been fueled by the challenges and demands of manufacturing, government and service organizations throughout the twentieth century. It is also a profession whose future depends not only the ability of its practitioners to react and facilitate and operational change but, more important, on their ability to anticipate, and therefore lead through the change process itself."

Schutte *et al.* (2016:2): "Industrial engineering has evolved into a major engineering and management discipline. The effective use of industrial engineering has contributed to an enhanced standard of living through increased productivity, improved quality of work, better quality and nature of services, and improvement in working environments… Industrial engineers (IEs) are thus responsible for the optimal design, implementation, integration, operation, improvement, and management of high-level systems. Such systems typically

consist of chemical, electrical, electronic, mechanical, or civil components. These high-level systems generally exist within organizations as a mixture of equipment, information, people, capital, policies, processes, etc. IEs optimize these systems to improve quality and productivity and to reduce costs. Human and physical resources are thus combined and integrated to achieve specific objectives in these organizations."

OSU (2017): "Industrial engineers (IEs) apply science, mathematics, and engineering methods to complex system integration and operations. Because these systems are so large and complex, IEs need to have knowledge and skills in a wide variety of disciplines, the ability to work well with people, and a broad, systems perspective. Industrial engineers use their knowledge and skills to improve systematic processes through the use of statistical analysis, interpersonal communication, design, planning, quality control, operations management, computer simulation, and problem solving."

IISE (2017b); (IISE, 2017c): "[Official Definition]: Industrial and Systems Engineering is concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems. [Work]: Industrial and systems engineering is about choices. Other engineering disciplines apply skills to very specific areas. As companies adopt management philosophies of continuous productivity and quality improvement to survive in the increasingly competitive world market, the need for industrial engineers is growing. Why? Industrial and systems engineers are the only engineering professionals trained specifically to be productivity and quality improvement specialists. Industrial engineers figure out how to do things better. They engineer processes and systems that improve quality and productivity. They work to eliminate waste of time, money, materials, energy and other commodities. This is why many industrial engineers end up being promoted into management positions".

BusinessDictionary (2017d): "Discipline of utilizing and coordinating humans, machines, and materials to attain a desired output rate with the optimum utilization of energy, knowledge, money, and time. It employs certain techniques (such as floor layouts, personnel organization, time standards, wage rates, incentive payment plans) to control the quantity and quality of goods and services produced."

DidacticEncyclopedia (2017): "Industrial engineering is a specialized branch of Engineering, responsible for the design and optimization of complex systems and processes. Despite what its name might indicate, the industrial engineering is not only restricted to industry but to optimizing every process, system, or organization. The aim is to achieve optimum performance when it comes to providing services or create products."

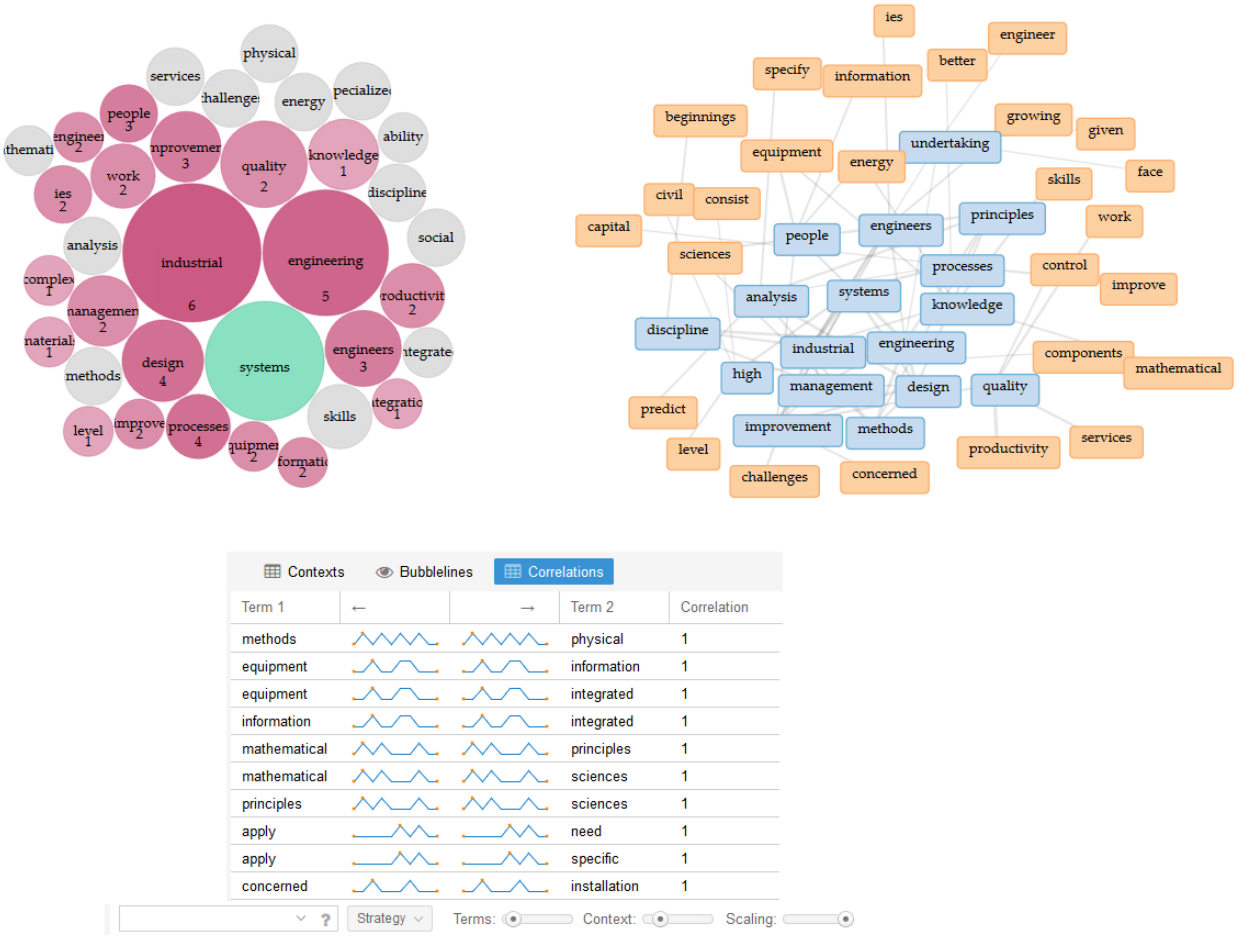
11.3.2. Systems Comparison of Key Terms

A corpus analysis, using Voyant tools, of the combined definitions reveal the following most frequently used terms [Top 50] alongside their frequency:

Industrial (23); Engineering (19); Systems (17); Quality (9); Design (8); Engineers (10); Improvement (6); Knowledge (6); Management (6); Processes (5); Productivity (5); Skills (5); Work (5); Analysis (4); Challenges (4); Discipline (4); Energy (4); Methods (4); People (4); Physical (4); Services (4); Social (4); Specialized (4); Ability (3); Complex (3); Equipment (3); Improve (3); Information (3); Integrated (3); Integration (3); Level (3); Materials (3); Mathematical (3); Principles (3); Sciences (3); Time (3); Use (3); Achieve (2); Apply (2); Better (2); Change (2); Concerned (2); Control (2); Disciplines (2); Draws (2); Effective (2); Enterprise (2); Environmental (2); Goods (2); Industries (2).

The above, however, does not provide the full picture. Other Voyant tools and a Terms Berry were used to find linkages and correlation of the definitions to get better insight on how these words connect (to distil the appropriate thinking style). Seeing the connections between terms often helps better establish the context the terms are being used in.

Chart 12: Term Correlation, TermsBerry & Linkages using Voyant [Own Work]



Contexts | Bubblelines | Correlations

Term 1	←	→	Term 2	Correlation
methods			physical	1
equipment			information	1
equipment			integrated	1
information			integrated	1
mathematical			principles	1
mathematical			sciences	1
principles			sciences	1
apply			need	1
apply			specific	1
concerned			installation	1

Strategy | Terms: | Context: | Scaling:

Given that this study is taking a systems approach, the above results from the definitions were treated as a system. Using the works of Tezu (2017) on the elements of a system, introduce in Chapter 2, the key terms were organized as follows:

Inputs: Engineers (10); Knowledge (6); Processes (5); Work (5); Challenges (4); Energy (4); Equipment (3); Information (3); Time (3); Materials (3);

***Explanation:** Inputs highlight what goes into the process in order to achieve a desired output. It was identified that the terms above represent raw inputs to virtually any IE related intervention.*

Outputs: Quality (9); Improve [ment] (9); Knowledge (6); Processes (5); Services (4); Goods (2);

***Explanation:** Outputs, on the other hand, represent what is extracted from the process after completion which can be utilized (unlike the raw input). Similarly, the terms that represented generalizable outputs of IE related interventions were listed.*

Processors: Skills (5); Methods (4); Ability (3); Control (2); Change (2); Use (3); Apply (2); Better (2);

***Explanation:** Processors are the elements that change the inputs into outputs. Within this context, these are the activities that an industrial engineer 'does' and 'uses' to transform raw inputs into meaningful outputs.*

Control: Industrial (23); Engineering (19); Analysis (4); Design (8); Management (6); Systems (17); Mathematical (3); Principles (3); Sciences (3);

***Explanation:** Controls are the decision-making mechanisms of the system. They "guide the system" (Tezu, 2017:1) and govern the processors. Within the context presented, the above terms form the key thinking approaches utilized by the industrial engineer to control the processors and are the real decision gates that must be considered.*

Feedback: Productivity (5); Integration (3); Effective (2); Achieve (2); Draws (2); Concerned (2);

***Explanation:** Feedback allows the system to assess expected performance against goals. Typically, it interfaces with control and other systems and reacts with positive or negative feedback. In this case, all elements hinting at some form of flag event that triggers an evaluation were placed under this category.*

Environment: Social (4); Environmental (2); Time (3);

[**Nature of Supra System]:** Specialized (4); Level (3); Complex (3); Integrated (3);

***Explanation:** The environment is the supra-system over which the system in question does not have direct control. Yet, the system is bounded by it. The 3 terms that were found to be supra-systems (or related to supra-systems) were listed and key terms describing the nature of supra-systems that industrial engineers work with were also listed.*

Boundaries & Interfaces: Discipline [s] (6); Enterprise (2); People (4); Physical (4); Services (4); Industries (2)

***Explanation:** Unlike the environment, the system may interface with systems at the same level or utilize them as resources (which is different than inputs). These systems have their own boundaries and shape the boundaries of the system in question. The identified terms that relate to distinct systems that the industrial engineer interacts with (such as other disciplines, physical objects, industries…etc.) were listed.*

11.3.3. Distilling Relevant Cognitive Abilities and Thinking Styles

A typical visual depiction of the works of Tezu (2017) can be found below in Figure 24. As discussed in 11.3.2, it appears that the terminology control element is the real 'thought process' that guides what an industrial engineer does in the processor part of this system. The definitions very much focused on the processors, but inherently listed how an industrial engineer ensures the proper management of their activities. Similarly, some of the definitions listed typical inputs and outputs to the process as well as how it interfaces with systems and supra-systems.

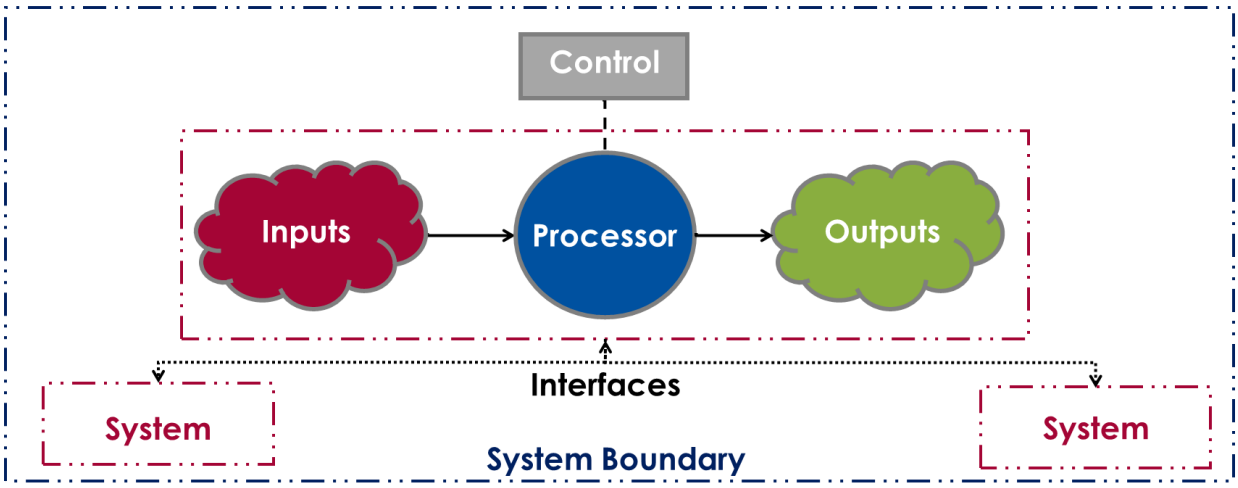


Figure 24: System Process Elements (Tezu, 2017)

Connecting the above findings with the connectogram presented in Figure 22, the distinction between 'do' and 'think' becomes clearer. Many individuals think like industrial engineers but perhaps lack some of the processors (taught at educational institutes) needed to successfully perform good IE work. Similarly, teaching an individual the processors does not necessarily guarantee that the individual possesses the necessary controls to use them as an industrial engineer should. Thus, there is a distinction between the thinking style of an industrial engineer which can be present (and instigated) in any human being and the actual activity of IE. When combined, however, quality industrious interventions are created.

By building on the insights extracted from the PhD as a whole (with special focus on 11.2.6), synergizing them with the control functions (described 11.3.2) and presenting them in a system principles casing (presented in 2.1.1), it can be concluded that:

System Cause: Industrial thinking exists to create balanced industrious solutions
System Synergy: Industrial thinking is a mix between the mathematical analysis, engineering design, management principles and systems sciences
System Structure: Industrial Thinking is an element of human development
System Continuity: Industrial Thinking is advanced by general human industrious behaviour and developments in the role and identity of the IE Profession

11.3.4. Systems Definition of Industrial Thinking

By extracting insights from the PhD document thus far and using creative facilitation to account for the gaps in the thinking style and create an ideal that can be strived towards, the Industrial Thinking style within the context of the knowledge era can be described as:

> *The cognitive ability to conceptualize balanced industrious solutions which create value for all of society in an ecologically beneficial manner. This is achieved by uncovering optimal courses of action which guide the management of resources supported by technologies. Furthermore, using sound system design processes, progress is assessed and evaluated against expected impact on society and the environment. These elements work together like an industrial ecology.*

The following key terms are further explained:

Cognitive Ability: Intrinsic mental process that is available in human beings (homo industrialis) by virtue of being industrious which prompts them to desire to change their environment to better suit their needs which may be better utilized by industrial engineers.

Balanced Industrious Solution: The ideal output of the mental process that would not result in pseudo satisfiers (socially) and non-sustainable solutions (environmentally). 'Balanced', in this context, means taking into account all available context, stakeholders and available knowledge into consideration during the design process and allocating them appropriate weight.

Value for All Society: The ideal basis of the mental process. Naturally, it is recognized that a solution must not create value for some of society at the cost of others. Moreover, an improvement for a part of society should, in theory, add value to society at large given that it causes negligible loss in value for the excluded part of society. This should not be treated as a zero-sum element where as long as the benefits outweigh the negatives then the solution can be considered.

Optimal Courses of Action: This represents the valuable outputs of the mathematical modelling, simulations and statistical analysis which need to be pre-considered before embarking on a course of action. It allows for fundamentally flawed or unmanageable paths (for practical considerations) to be ruled out from the start of the process. In many ways, this is like the development of scenarios.

Management of Resources: Resources take on various forms (knowledge, finances, subsystems…etc.). It is vital for meaningful Industrial Thinking to properly manage the allocation of resources and synchronize them to the optimal path. This includes understanding inherent risks that affect the utilization of resources which need to be predicted before initiating the management process and mitigated throughout the implementation.

Supported by Technologies: Given that the use technologies is a unique type of resource that acts more like a catalyst in this mental process, special consideration must be given to the necessity of utilization of technologies in resolving the problem (to avoid a misalignment between cost/benefit) and the maturity of the technology.

Ecologically Beneficial: In order to avoid a self-defeating course of action, industrious behaviour must adhere to limiting negative impact (of any sort) on affected ecologies. Ecologies are naturally made up of interacting environmental elements and organisms (including humans) which create unique developed 'cultures' or ecologies.

System Design Processes: The mental process must consider relevant and sound methods and processes of measuring effectiveness, impact and other KPI measures which suit the specified context that the user enters. Naturally, different environments have different 'ground rules' and unspoken ethic. Accounting for them facilitates success in introducing and measuring the conceptualized industrious solution.

Progress is Assessed and Evaluated: A vital required element is the continuous feedback required to verify that a proposed action or thought is indeed performing its function as well as validating that it is resolving the right problem. This naturally evolves over time and requires experience to properly assess, but it is not an element that can be ignored.

Industrial Ecology: Industrial ecologies are a set of industries that attempt to minimize waste by utilizing the remainder of a process as a resource in another. Similarly, the Industrial Thinking process must cycle through different elements internally to produce a well thought out idea before sharing it externally in order to minimize wasted resources in further refining the conceptual balanced industrious solution. This builds on the works of Arnold and Wade (2015).

The definition above and sub-explanations provide a synergized result which is, in itself, a starting point. Naturally, this result will be verified internally as a worthwhile output of the study and validated with the community as a valid definition (Section 11.4.2). The final generalizable definition, based off this interim result, will be presented in Chapter 12 upon considering relevant points of contention of the diverse IE community.

11.3.5. Industrial Thinking Systemigram

Although each problem area requires unique frameworks, methodologies and approaches, it is worth exploring why a unified Industrial Methodology that strengthens the unique identity of the field has not been developed. Even as a mere reference framework for how to think about the problems being faced in Industry, the development of the Industrial Thinking Systemigram can help clarify what is considered an Industrial problem and how to resolve it. The aim is to further promote the industrial engineer as a true problem solver by defining the nature. The Industrial Thinking Systemigram is believed to potentially be this catalyst.

Similar to the works of Arnold and Wade (2015), the Systemigram was purely based on the systems definition developed. However, two key differentiations were included in the development of the Industrial Thinking Systemigram:

1) Using the works of Boardman, it was decided that the Systemigram shall remain without numbering to avoid falling into the limitations with stepwise processes. Rather, a function-based Systemigram was developed which suggests an iterative process of 'calling' on mental functions in order to further refine the central goal: conceptualized balanced industrious solutions. Additionally, the external thinking styles which enrich these internal processes were mapped to reflect the synergy needed for truly balanced Industrial Thinking.

2) The visual depiction was represented as a metaphor from nature. This is an attempt hold true to some of the suggestions made in this study. The selected biological metaphor that best represented the philosophical aim of Industrial Thinking was that of the stem cell. A stem cell is an undifferentiated cell which can transform into specialized cells given a specific need. They can naturally become nerve, functional, blood or structural cells. They typically serve a repair and growth function in multicellular organisms. In initial stages of human development, stem cells are focused on growth. In their latter life, they serve regenerative functions to ensure sustainability. Additionally, they represent both a human element and environmental one.

Interestingly, STEM in many countries stands for science, technology, engineering and mathematics, which is one way of looking at Industrial Thinking; a balance between those fields. Industrial engineers, more specifically, can be said to focus on engineering design (which provides the rigorous structure), Mathematical Decision Making (which uses certain statistical functions to identify optimal scenarios), Management of Technology (to successfully manage resources) and Systems Sciences (to understand impact on supra-systems).

Even if one looks at the development of Industrial Thinking with the Industrial revolutions, it appears that each major industrial revolution introduced a new element which helped crystalize this thinking style. The first industrial revolution, centred around mechanization, initiated

industrial engineering design as a unique discipline with unique outputs. The second industrial revolution, centred around specialization of labour, introduced major management elements which helped use technology (initially very primitive such as ergonomic designs and workflow charts) to better manage resources and divide them. The third industrial revolution, centred around the growth of computing and automation, introduced the ability to develop scenarios and calculate relevant statistical measures from databases. Lastly, the fourth industrial revolution, centred around connectedness, made it vital to understand systems and their impact. The elements appear to have always existed but truly crystalized during different periods of Industrial Thinking development. Figure 25 below presents the ultimate deliverable of this study: The Industrial Thinking Systemigram.

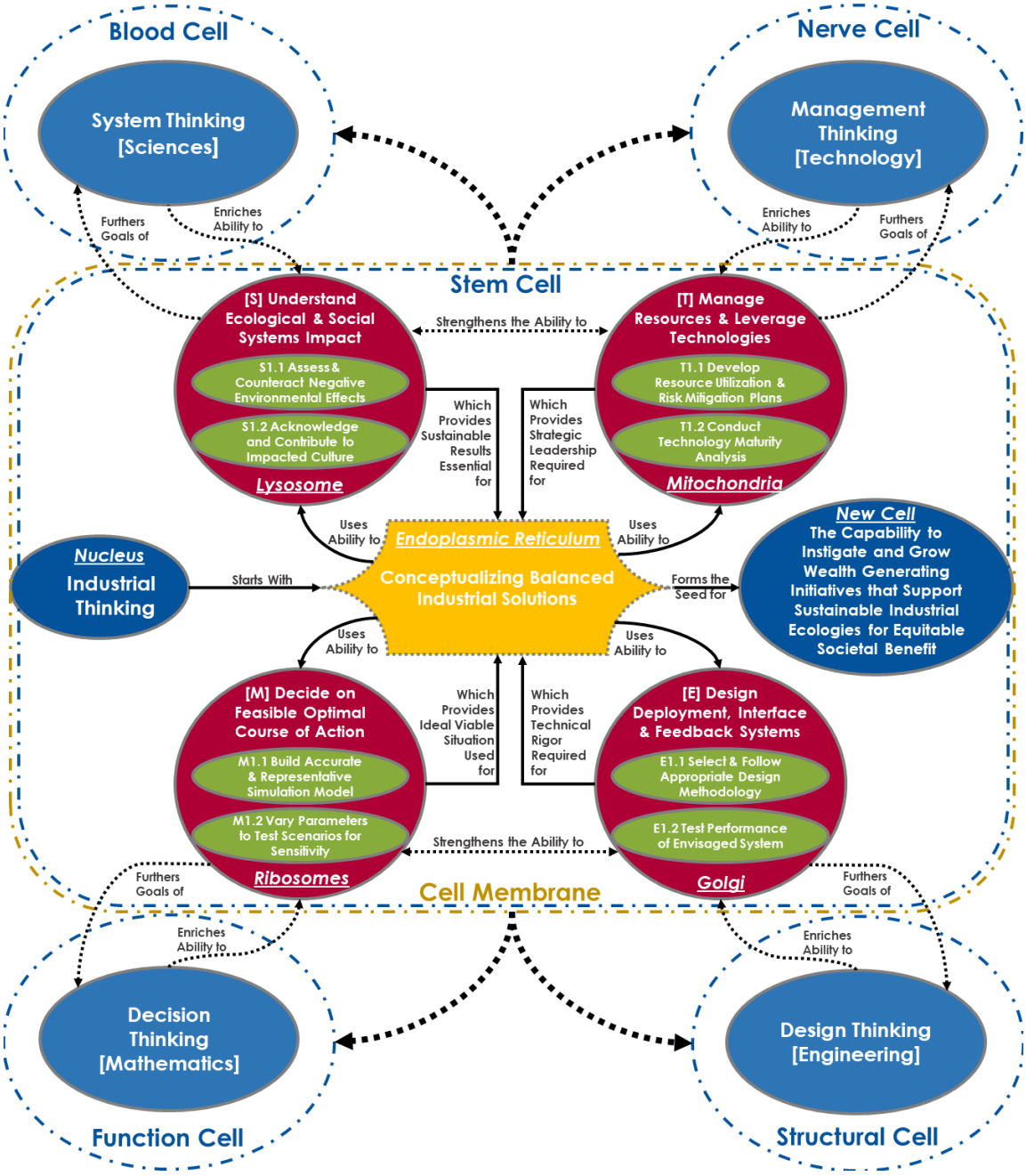


Figure 25: Industrial Thinking Systemigram [Own Work]

11.4. Evaluation of PhD Findings [Sub-Stage 2.4]

Now that the Industrial Thinking Systemigram has been developed, the evaluation (verification and validation) of it and the overall findings of the PhD can be discussed. Given that the research follows an AR process, the evaluation helps in further adapting the findings and Systemigram in order to ensure they are closest to a generalizable truth claim as they possible can be and that they are inclusive of the IE community.

11.4.1. Internal Verification

11.4.1.1. Cultural Stream Verification: PhD Framework

This section has two parts, based on the works of Van Gennip and Talmon (1995:52), to ensure verification: [1] Checking against the specification and [2] representing in a readable form for judgement concerning validity. As discussed previously, this definition is perceived through a qualitative lens, but the principle discussed above guide the qualitative view.

[1]

The first part of the cultural stream verification is ensuring that the structure of the PhD produces the expected outputs. Additionally, it must be shown that the study is of a PhD nature (as opposed to master's level). This section used the University's Manual for Master's and Doctoral students for the structuring of the document in a way that is suitable for a thesis by article publication format.

The manual further specifies the nature and role of the researcher and promoter. This was adhered to and a mutual relationship of respect was developed that includes constructive criticism with the promoter. Formatting considerations were also applied. Given that the nature of the study needs to be verified as a PhD study, the relevant evaluation questions surrounding the nature and output of the study were extracted from the manual and presented in Appendix E1. Below is the researcher's evaluation of the study according to the set criteria:

The topic: The topic was carefully selected to be one that is worthy of PhD research. Two main elements determined the worthiness: (1) The potential improvement that resolving the literature gap can bring about, and (2) the alignment with the nature of a PhD. The identified gap has not been explored and so the exploration done in this study uncovered new knowledge and created a new theory. Moreover, additional insights arise which can impact the larger domain. The study aimed to hold true to the nature of a PhD which discusses both practical and philosophical elements. This is also more aligned with the nature of Development and management engineering. With regards to the design, the research used well-accepted and scientifically-based research methods. Additionally, where appropriate, deviations were justified and explained. Furthermore, the study deviated only where necessary to produce scientific outputs.

Problem statement aims or central theoretical statement: To avoid confusing the objectives of sub-articles with the overall PhD, the key problem statement and aims were stated clearly in Chapter 3 and a visual depiction of the links between them was highlighted using a concept diagram. The aims were phrased to be as clear as possible and focused on a very specific area for improvement. Each of these aims was dealt with in a separate article whilst the overarching PhD was dedicated to resolving the main problem statement by developing an appropriate objective.

The research method:

Structure: Significant effort was invested into creating a scientifically acceptable and usable base for this study. This involved combing various research methods. Initially, it appeared that significant differences between the approaches exist. Yet, upon deeper review of the works of Checkland and Holwell (1998) and others it was determined that the selected AR and SSM approach are in fact developed from one another. Additionally, they share many similarities in their goals. Moreover, they are both qualitative. This helped structure the overall document as meaningful homogenous units with clear links to the overall structure.

Originality: The study was completed solely by the researcher and the works reflected in this study use the researcher's independent thinking. Shared authorship was only undertaken with the supervisor for her efforts in guiding the study. The chosen research method features 5 article-based research outputs (3 of which are already published). Additionally, one other research paper (not related to this study) was published. It is expected at least one other article will be written upon submission of the PhD. In order to ensure integration, the identified areas of concern were continuously referred to throughout the study. Moreover, the articles stemming from this study made an original academic and real-world contribution to improving the problem situation. The 3 published articles all received awards at their respective conferences/journals.

Research Validity: The researcher took special note of the importance of ensuring valid generalizable results from the study especially given that the AR method was used. For this reason, an intensive evaluation (verification and validation) was conducted. The researcher reviewed the necessary literature that assisted in forming the evaluation. Moreover, a genuine focus was placed on transparency to support the validation of the AR.

Study of sources: The researcher included cited available resources and literature on the subject matter (mainly from academic sources). These insights were merged with literature surrounding the context to form an appropriate theoretical foundation. Critical and argumentative insertions were included where necessary. Moreover, each unique article has its separate literature review (addressing its unique problems). This builds on the overarching literature review completed as part of the PhD the study.

Language and style, technical composition, care and finish: All technical-related provisions (font, style, order…etc.) in the manual were adhered to. In addition, guidelines for submission were used for the final formatting and technical composition. The language for the study can be described as simple and explanatory (to cater for intended audience and to make it more accessible) but special consideration was given to ensure this does not detract from the academic value.

[2]

The second part of the culture stream verification deals with representing the research in a readable form for judgement concerning validity. One of the key differentiators, to a traditional AR thesis, is the continuous sum-up of the chapters with visualized versions of the content being discussed. For ease of reference, the visualizations of the system context, framework, methodology and area of concern are available in Appendix A. The importance of these depictions is their usefulness in checking the flow of the process and how the various elements fit together. For example, the visualized framework can be used as a checklist to confirm that the researcher has indeed answered the questions initially posed in Chapter 3. Moreover, they can confirm that the findings extracted links to the objective.

Another example is the visualized methodology which highlights the boundaries between the real, system and research world. This allows a clear reference to the process followed by the researcher and their frame of mind. Moreover, it allows for illogical elements to be spotted on a high level. The researcher naturally revised these visualizations various times to ensure they are: [1] representative of the thesis and [2] achieves objectives of the study. Thus, the readable format of these visualizations allows an evaluator to verify that they are representative of the written text and make a judgement regarding their validity to the external world. After all, these visualizations are not that different from conceptual models and can be evaluated accordingly.

As alluded to previously, the element that can naturally attract the most critique is the relationship between the articles and the overall thesis. In addition to the visualizations that attempt to explain the relationship, the link can be explained when one considers the articles as themes as opposed to hypotheses. This study implicitly acknowledged the multi-perspective view necessary to achieve the objective. Moreover, it was determined that because one cannot explore an economic theme in the same way that one explores an identity theme; different methods would have to be followed in each article. However, from the viewpoint and methodology of the thesis, these explorations were done with the explicit goal of finding the elements that link back to the industrial cognitive thinking style, hence, why AR was extremely valuable in consolidating the findings. Each article was an action within a theme and the extracted ‘learning’ from that action was used in the overall thesis. Moreover, the structuring of these learnings into arguments for change (with statements and conclusions) is very common in philosophy. A PhD is, ultimately, a philosophy degree and a specialization.

11.4.1.2. Systemic Stream Verification: AR Verification Checklist

The internal verification of this systemic stream was conducted using the works of Checkland and Holwell (1998). The researcher motivates how the document adheres to the checklist defining 'good' AR research. The checklist by Checkland and Holwell (1998:20) follows:

❖ *Researcher intends to change the organization*

Although the main objective of the research was the development of the Industrial Thinking Systemigram, it is clear from the way the research was conducted that the profession was viewed as an organization or enterprise which needed alignment with some developments of the knowledge era. Significant portions of the work were dedicated to comment on both the systemic and cultural changes required for progressive resilience. Moreover, the thesis assessed the need at various levels to ensure a multi-perspective view.

❖ *There must be implications beyond the specific situation*

The aim of the developed artefacts (specifically the Industrial Thinking Systemigram) is that they have implications on most current IE activities. Not all suggestions radically change the current course of the field. However, they definitely introduce new perspectives which can help mend the road to suit the overall objective: more socially and environmentally conscious industrial engineers.

❖ *Research seeks theory as an explicit concern*

Although it was only verbalized towards the end of the research, the Industrial Thinking Systemigram represents more than just an artefact and can truly be considered as a 'theory' that explains a phenomenon. The model did indeed use creative facilitation, but the inputs were largely extracted from quantitative and qualitative analysis of the definitions of the field, identified gaps and the concerns of other academics through literature.

❖ *Any tools, techniques or models developed need to be linked to the research design*

The researcher took great care to represent any and all techniques used in the research design. The research design can be summarized in the visual representations available throughout the document (combined in 0). A thorough review of these tools and techniques was also completed in the study.

❖ *Emergent theory will emerge from both data and initial theory*

Initial definitions of Industrial Thinking were included throughout the document and summarized in Section 11.3. The emergent theory used these initial theories and data for the phrasing of the emergent text. This was important given that initial theories were disconnected and incomplete (representing only a specific context or aspect).

❖ *Triangulation is used if possible*

AR by nature depends on triangulating since many gaps exist in literature or cannot be extracted from the real world. Therefore, where necessarily, intermediary arguments were used which can be seen as a form of triangulation to pin down the overarching findings.

❖ *Theory building will be incremental and cyclical*

Although not explicitly stated in the study, the researcher designed an initial concept theory after concluding Article 1 and incrementally improved it with new insights and inputs. The presented Industrial Thinking Systemigram was the result of several iterations (design cycles) with countless minor improvements along the way until the end result was produced.

❖ *There will be an orderliness in approach*

Great care was undertaken by the researcher to combine relevant sections. The SSM assisted in achieving this goal. Four major revisions of the PhD document were developed to test the most effective way to communicate the findings. The final document follows an orderly and structured approach with each chapter focusing on a specific element (Research Overview, Framework, Methodology and Area of Concern), as suggested in Checkland and Holwell (1998). Each article was also given a chapter with an appropriate argument summary. The combined results are summarized in Chapter 11. Moreover, this is explained in the preface to clarify the structure to the reader.

❖ *Exploration of data and theory building should be explainable to others*

The study attempted to explain the theory-building and thought process preceding each major milestone to the reader by providing appropriate context. Given that some elements, however, use metaphors, some additional viewpoints may arise given the background of the reader.

❖ *Later reporting is part of theory exploration and development*

Upon completing the semi-structured interview, the researcher reported on the findings and further developed the Systemigram based on the new insights (Chapter 12).

❖ *i-x are necessary but not sufficient for valid AR*

This was initially found to be a problem which is why the latter works of Checkland and Holwell on SSM and the ADR-in-EE method (discussed in detail in Section 4.3) were used to properly structure the given problem into something workable and maintain a record of the process.

❖ *It is used where other methods are not appropriate*

This complexity and intertwinement of element in this research truly required an AR approach. Moreover, the goal of creating a large body of knowledge was also considered.

❖ *History and context are given due weight*

The overall PhD reviews and considers the available history in both the overarching document and articles. Chapter 5 gives appropriate context to each of the areas of the concern in order to understand some of the intricacies that are associated with historical developments.

❖ *The dissemination of findings goes beyond those involved in a study*

The goal of the PhD is that the insights and findings are shared and used to develop the profession. The Industrial Engineering department at the NWU is already making use of some of the findings. Additionally, individuals from other universities and some private sector professionals indicated their interest in using the conceptual models from this study.

11.4.2. External Validation

11.4.2.1. Systemic Stream Validation: AR Validation Principles

Since the thesis is heavily reliant on AR (especially the extracted knowledge from the systemic stream), it is important to further validate this process. In their work on validating AR Heikkinen *et al.* (2007) provide 5 principles to evaluate the quality and 'validity' of the AR research process.

Heikkinen *et al.* (2007:6) concludes that "action research reports are often narrative in nature, regardless of whether or not the researcher recognizes this. An action research process can easily be reported in the form of a story". Although this thesis is naturally structured differently for academic purposes, there is some truth to the comparison drawn above. However, the comparison above naturally begs the question on validity with regards to AR. Heikkinen *et al.* (2007:6) explains that this type of research "has challenged the traditional terms of validity… Many writers of qualitative reports, however, claim that these tools are no longer useful because of their lack of semantic rigor in qualitative research… Although it is no longer necessary to rely on the traditional reliability terminology in action research, we certainly should not take lightly the question of quality assessment". Heikkinen *et al.* (2007:8-9) list the give principles as:

- *Principles of Historical Continuity*

Heikkinen *et al.* (2007:9) describes this principle by discussing that "good action research recognizes the historical evolution of action both as a general macro-level phenomenon and as micro-level continuity of historical action. Within this principle, we focus on the broader historical, political and ideological trends that shape and constrain the human activity at both the local level and even globally. The development of action does not begin in a vacuum, and action never ends, and the researcher should therefore pay enough attention to the different contexts and traditions". The queries that can help evaluate the adherence to this principle are posed as:

Analysis of the history of action: *how has the action evolved historically?*

Where necessary, the researcher provided historical context. This was used to explain why features of the cognitive style of Industrial Thinking, both negative and positive, appeared over time. Moreover, it helped identify some of the value-laden problems linking Industrial Thinking to Capitalism. These needed to be addressed in order to motivate for change. This query was best addressed in Chapter 5 and in the literature review of Articles 1,4 and 5.

Emplotment: *how logically and coherently does the narrative proceed?*

A dedicated effort was placed on ensuring that the divisions and sub divisions of the PhD proceed as both a thesis and narrative would. Four revisions of the document ensured that segments of this study are coherent, link to each other and flow logically from start to end.

❖ *Principles of Reflexivity*

Heikkinen *et al.* (2007:11-13) describes this principle by stating that "the principle of reflexivity is based on the idea of action research as philosophy… An action researcher as a philosopher consciously reflects on his or her pre-insights… The principle of reflexivity also means that the research should be transparent… This will help the reader to better evaluate how the ideas have been generated and to what kind of empirical evidence they are attributable". The queries that can help evaluate the adherence to this principle are posed as:

Transparency: *how does the researcher describe his/her material and methods?*

Some AR reports reviewed by the researcher indeed faced major problems with this query. However, from the thesis, it is clear that appropriate controls were put in place to ensure that an accurate description of the methods and literature is provided. Naturally, this may be imperfect but where this was the case, it was acknowledged as such. Moreover, the visual depictions were continuously updated to accurately reflect the thesis. Lastly, the semi-structured validation process was done in a way that was transparent with the interviewees (on the goals of the study) and was described as accurately as possible.

Subjective adequacy: *what is the researcher's relationship with his/her object of research like?*

The researcher is naturally deeply involved in the research process given their role as the prime investigator. Moreover, the researcher can be seen as the one taking the actions in the real world. However, the researcher did engage with various members of the IE community both during and before the semi-structured interview phase. This can be said to have created an involved but reflective role and relationship between the researcher and the object of research.

Ontologic and epistemological presumptions: *what are the researcher's presumptions of knowledge and reality?*

Similar to the above, the researcher stated the preferred ontological presumptions. This is apparent from Chapter 2 where the preferred approach in viewing systems was discussed. Moreover, Chapter 5 included a review of available literature and choosing a specific viewpoint over another was justified. The overarching view of the researcher can be defined as pluralistic in that it approaches the problem from various viewpoints, believing in the value of each one, yet it does believe there is some form of central truth that can be uncovered. This is opposed to relativistic or monistic views. This is also what made AR valuable to the process.

❖ *Principles of Dialectics*

Heikkinen *et al.* (2007:13-14) describes this principle by discussing that the researcher must consider multiple perspectives. "This principle means, in practice, that the researcher does not base his/her research text on his/her own monologous voice, but combines in the text different

interpretations and voices—even dissonant ones… The credibility of narrative research is based on how well the informants' voices are heard in the report" (Heikkinen *et al.*, 2007:13-14). The queries that can help evaluate the adherence to this principle are posed as:

Dialogue: *how has the researcher's insight developed in dialogue with others?*

From the engagement with members of the IE community and the semi-structured interviews, it was clear that dialogue was developing on certain issues. The researcher acknowledges that some of this dialogue has happened between individuals, but a sizeable portion of this research aimed to bring these issues to the surface.

Polyphony: *how does the report present different voices and interpretations?*

In the upcoming evaluation using semi-structured interviews, the opposing and relevant voices were included to highlight different interpretations of the presented arguments. Moreover, interesting and meaningful viewpoints were incorporated in the final chapter.

Authenticity: *how authentic and genuine are the protagonists of the narrative?*

this is not particularly relevant in this research report given that the traditional AR context. However, the ADR-in-EE process and validation via semi-structured interviews aimed to create a genuine reflection of reality in the narrative.

❖ *Principles of Workability*

Heikkinen et al. (2007:14-15) describes this principle by stating that "the principle of workability means that the evaluators of the quality of action research must pay attention to whether it has given rise to changes in social actions… Sometimes the main consequence might be a critical public discussion or debate… the principle of workability brings action research back to its deepest roots: pragmatism. For a pragmatist, the thing that works is 'true'…Based on critical change criteria, the effectiveness of research is evaluated for its ability to disclose the mechanisms of power". It is also vital to take great care with regards to the ethical consequences of action (Heikkinen et al., 2007). The queries that can help evaluate the adherence to this principle are posed as:

Ethics: *how are ethical problems dealt with?*

This is not particularly relevant in this research report given that the traditional AR context deals with vulnerable people. However, where relevant, the necessary disclosures and ethical processes were followed to ensure that ethical problems are dealt with in a professional and transparent manner. Moreover, privacy was greatly respected.

Criticality: *what kind of discussion does the research provoke?*

It is in the opinion of the researcher that this thesis has and ideally will provoke a rethinking of what Industrial Thinking represents, how it can be expanded to be more socially and environmentally aware to prevent mistakes of the past, how industrial engineers are taught,

how to include colleagues from other disciplines who wish to change over to IE (through some form of postgraduate program) and more importantly how to develop this as an identity. In snippets posted to professional networking sites it was apparent that the community is willing and excited to participate in these discussions. All of these could lead future research on the many topics, eventually leading to some form of quantitative understanding.

Pragmatic quality: *how well does the research succeed in creating workable practices?*

Although the overarching thesis appears to be largely theoretical, the produced models can be instrumental in educating young industrial engineers. Moreover, an extremely pragmatic approach was taken when taking the steps. Rather than focusing on immovable boundaries, the researcher attempted to identify a few doors which need opening to create more room for interaction. This often involved researching pragmatic approaches from other disciplines due to many hard system methods being too limiting.

Empowerment: *does the research make people believe in their own capabilities and possibilities to act and thereby encourage new practices and actions?*

Once again, this is not particularly relevant in this research report given that the traditional AR context deals with vulnerable people. Where applicable, however, there was a focus on motivating the IE community (in conferences, interviews, and professional networking) to make positive actions of change, embrace new practices and the formalized IE identity.

❖ *Principles of Evocativeness*

Heikkinen et al. (2007) describes this principle by discussing that “good [AR] research awakens and provokes a person to think about things in a new and different way. The evocativeness of a research report is not based exclusively on cognitive-rational thinking, but only touches the readers at an emotional level. The most significant learning experiences are always both cognitive and affective in nature. In the narrative framework, science comes close to art. Research can also be evaluated based on the aesthetic experiences, feelings or emotions evoked by it”. The query that can help evaluate the adherence to this principle is posed as:

Evocativeness: *how well does the research narrative evoke mental images, memories or emotions related to the theme?*

If there is one thing this research can confirm it is its evocative nature. The overlay of natural phenomena on conceptual models, the descriptions of historical development and the argument to return to a more human nature ensure that the reader reflects on what is being discussed. Some disagreement may arise, but that is naturally part of evoking thoughts. Moreover, the rising emotion can bring about collective action. The themes, of this study, developed during the course of the thesis. Moreover, the objective was indeed identified early on as being a complex one, but one worth exploring. Although this thesis is not a story, per se, it aimed to be as evocative and engaging as possible for a PhD.

11.4.2.2. Cultural Stream Validation: Semi Structured Interviews

This final sub-section of the PhD evaluation discusses the interaction with the IE community which was necessary to validate the Industrial Thinking Systemigram and its associated findings. Three potential techniques were reviewed as possible methods of validation: The Delphi technique, a questionnaire and semi-structure interviews. After considerable deliberation and consultation, it was found that a semi-structured interview is the best way to evaluate this study. Given that the evaluation is taking place on well researched findings, a semi-structured interview can simply help validate the study and provide open ended feedback by the interviewees. A questionnaire could, theoretically, be targeted at the same group but given that some insight might better be extracted from interaction, an impersonal questionnaire was dismissed. Similarly, the Delphi technique can be used but perhaps is better reserved for a standalone article using interested respondents from the semi-structured interview process refining the proposed Systemigram (and its implications) through iteration after publication of the thesis.

Structure

The semi-structured interview was designed to make up of 7 sections. Initially, the interviewer simply collected non-personally identifying data about the interviewee. Sections 1 starts with the interviewer exposing the interviewee to the problem at hand and providing an overview of the research. The interviewee would first provide open ended feedback and then assess statements: S0.1,S0.2,S0.3,S0.4 and S0.5 provided in Section 11.2 using the Kaner gradient of agreement. Open-ended feedback or suggestions for improving the statements were also be recoded in an open-ended section. Sections 2-6 of the semi structured interview represent the articles of this study (Areas of Concern 1-5 respectively). The process described below was repeated for each of the articles (focusing on their extracted insights and arguments). The interviewer first gave an overview of the connection seen between IE and the identified system. The interviewee was given some time to share some insights on their perception of the connection. Following that, the interviewee evaluated the overarching argument extracted from the article (4 statements representing insights [E.g. S1.1-S1.4] and conclusion [C1]). Open ended feedback or suggestions for improvement were also be recorded in a separate open-ended question. Following this, a description of the step undertaken by the researcher to improve the problem situation was provided (using the abstract of that article and main deliverable/artefact). The interviewee will then be given space to share their opinions regarding the step and their personal experience relating to the system being analyzed. Section 7 will start with evaluating extracted insights using the Kaner gradient rephrased to reflect their impact on Industrial Thinking (marked as ES-C^{x}-IT) from each of the 5 conclusions. The interviewer then presented the Industrial Thinking Systemigram and discussed it with the interviewee. Suggestions and insights were added to the open-ended feedback section.

Kaner Gradient

The Kaner gradient was selected (as opposed to the traditional approach of using 'seriously disagree' to 'seriously agree') since it provides more room for discussion during the interview. Additionally, in the post-discussion analysis, the general support of the community can be assessed for each and every statement and towards the overall PhD. More importantly, this method is more suitable for team decision making since it represents a wider variety of attitudes that a team (or in this case community) has towards proposed changes (TRG, 2017).

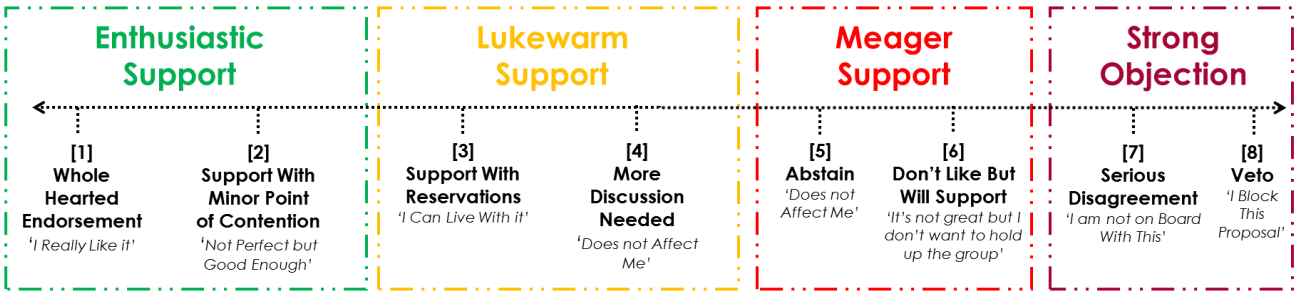


Figure 26: Kaner Gradient of Agreement – Adapted (TRG, 2017) and (Hughes, 2017)

Interviewees & Invitation Process

The process of preparing semi-structured interviews is energy-consuming and requires significant effort from the researcher (Keller, 2017). Determining the number of interviewees is a particular challenge but various sources state that the interviewer should conduct interviews until no new knowledge can be gained from the process. Given that the semi structured interview evaluation includes both qualitative and quantitive elements, it was preliminarily decided that a minimum of 15 interviews would need to be conducted for meaningful results to be extracted. A genuine focus was placed on selecting a diverse set of respondents. The interviewer classified 5 groups of IE that can provide diversity to the inputs as well as an internal factor that can ensure internal diversity within the groups. The groups and the diversity factor are listed below:

IE Academic: An individual who is currently lecturing in an IE academic department in South Africa. To ensure diversity, no 2 individuals from the same department were included as potential candidates.

IE Pioneer: An individual who has contributed extensively to the field (either academically or in practice) for more than 30 years of their life. Typical candidates might be founders of the field within South Africa and notable alumni. To ensure diversity, industrial engineers who took different paths during their professional lifetime were included as potential candidates.

IE Professional: An individual who is currently employed by the private sector and performing IE-related work. Experience can range from 4-20 years. To ensure diversity, individuals from different sectors of the economy were included as potential candidates. Some of which are professionally registered.

IE Venturist: An individual who has started an entrepreneurial venture (preferably after involvement with the private sector) or is heavily involved in consulting new ventures. This also includes industrial engineers who became business owners. To ensure diversity, individuals with different types of ventures were included in this category.

IE International: An individual who can be described as a professional or academic but has obtained their IE equivalent qualification from overseas. Typical candidates might be academic staff in international IE departments and professionals in international firms working outside South Africa. To ensure diversity, individuals from different countries were included in this category.

A list of 38 candidates was created and invitations were sent via email and Linkedin. Out of the total 38: 7 were classified as pioneers, 9 as professionals, 5 academics, 6 venturists and 11 international potential respondents. They potential respondents were sent the following email:

Dear XXXXX - Fellow industrial engineer,

Trust you are in good health and spirits. My name is Hasan Darwish, an Industrial Engineering lecturer at NWU and current PhD candidate. My doctorate degree is titled: Expanding Industrial Thinking by Formalizing the Industrial Engineering Identity for the Knowledge Era. In this PhD I have linked many articles in which I explore the nature of IE and its associated thinking style.

As part of my validation, I will be conducting semi-structured interviews of 30-45 minutes with members of the IE community (Lecturers, Consultants, Entrepreneurs and Professionals). I have selected you to be one of the 40 individuals interviewed. It would be an honor to get your insights on some of my findings. I would also appreciate your open-ended feedback on your view about the field, its state and future.

I will codify your inputs from our discussion and afterwards send them to you for checking and record keeping. All data is handled confidentially and is secured. No personally identifying information will be used in the report, merely your insights and feedback. Your participation would be highly valued but participation is optional. Should you wish to participate kindly fill in the google form below and I will contact you shortly with a calendar invite to suit your busy schedule and time zone:

https://goo.gl/forms/zxzOiIZDdI90mU5x1

Kindly note that this research project has been submitted for ethics approval and has received the following a minimal risk rating with ethics number: NWU-HS-2017-0162

Sincerely,

Mr. Hasan Darwish
Lecturer - Industrial Engineering
Faculty of Engineering
North-West University
Tel: +27(0)18 299 4025
Hasan.Darwish@nwu.ac.za

The dates for the semi-structured interviews ran from 16 October until 7 November (3 weeks). In total, 25 out of 38 respondents participated, which makes the participation rate for the evaluation (validation) 65.8%. Some of the semi-structured interviews were conducted in person and others were conducted over Skype. Notably, due to some constraints, 18 interviewees completed the full interview as set out in Appendix E2 – Semi Structured Interview Questions. Some interviews became less structured and focused more on extracting the valuable insight of the interviewee. Table 3 below summarize the statistics involving the participants and Table 4 shows descriptions of the interviewees (listed using alias and numerically on interview date).

Table 3: Potential Interviewee Statistics

Detail/Type	IE Academic	IE Pioneer	IE Professional	IE Venturist	IE International
Number Invited	**5**	**7**	**9**	**6**	**11**
Number Who Did Not Respond	1	0	2	0	6
Number Who Did Not Participate (But Responded)	0	1	0	1	2
Number Accepted and Participated in Full Interview	4	4	4	4	2
Number Accepted and Participated in Abridged Interview	0	2	3	1	1
Percentage Total Participation	**80%**	**85.7%**	**83.3%**	**77.8%**	**27%**

Table 4: Interviewee Details

Alias	Years of Experience	Interview Type	Description of Interviewee
(IE-Academic1)	3 Years	Skype/ Full	The interviewee is a developing researcher. He is involved in various fields such as healthcare, mergers and acquisitions. However, his main focus is on industrial policy. He currently lectures at one of the 4 South African universities offering IE.
(IE-Academic2)	10-20 Years	In Person/ Full	The interviewee is a lecturer and PhD student. He has extensive industry consulting experience. He is currently doing a research project in supplier development in the aviation industry. He lectures at the second of the 4 South African universities offering IE.
(IE-Academic3)	10-20 Years	Skype/ Full	The interviewee holds a Master's degree in Mechanical but is passionate about the Industrial Engineering field and has researched in the field for a few years. She currently lectures at the third of the 4 South African universities offering IE.
(IE-Academic4)	8-10 Years	In Person/ Full	The interviewee is a lecturer and researcher. She previously had experience using IE to help humanitarian causes using modelling. Her current focus is on developing modelling techniques to assess supply chain vulnerability. She currently lectures at the fourth of the 4 South African universities offering IE.

Alias	Years of Experience	Interview Type	Description of Interviewee
(IE-International1)	10-20 Years	Skype/ Full	The interviewee is a lecturer in Industrial Engineering at a prominent university in the Middle East. He is a prominent researcher, with over 75 articles and 55 in international journals.
(IE-International2)	10-20 Years	Skype/ Full	The interviewee is an international academic from the Europe. He has been involved with the IE department at a leading European University and was responsible for the transformation of the department into world renowned status.
(IE-International3)	10-20 Years	In Person/ Abridged	The interviewee is an international IE academic from Europe. She studied IE and worked most of her professional life in Europe.
(IE-Pioneer1)	30+ Years	In Person/ Full	The interviewee is prominent author, industry professional and business owner. Although he started as a mechanical engineer, he quickly found himself in management positions where he developed himself as an 'Industrial Engineering manager'. He has spent over 40 years in the field with many publications and contributions to the profession.
(IE-Pioneer2)	30+ Years	In Person/ Full	The interviewee has more than 50 years of experience in the field of Industrial Engineering and its progression in South Africa. He is an academic and leader in simulation, operations research and statistics. He is also a retired Professor Emeritus.
(IE-Pioneer3)	30+ Years	Skype/ Full	The interviewee is involved in both academia and industry. Academically, he is an extraordinary professor and is involved externally in the academic programmes. However, his main focus is in consulting and project management. Currently, he is involved in a mega project in the automotive industry.
(IE-Pioneer4)	30+ Years	In Person/ Full	The interviewee is a pioneer of the field who was one the first females globally to obtain a PhD in Industrial Engineering.
(IE-Pioneer5)	30+ Years	Call/ Abridged	The interviewee is one of the original founders of the field in South Africa. He has immense knowledge on the history and development of the profession. He has been involved with everything from consulting to education since the early days of IE in South Africa.
(IE-Pioneer6)	30+ Years	Call/ Abridged	The interviewee is a dynamic pioneer of the profession (40+ years) who has worked in industry and started various ventures throughout the years. His current focus is on IE projects in manufacturing. He is also involved in management consulting as a chairman in various institutes and involved in productivity studies in industry and teaching it at various universities.

Alias	Years of Experience	Interview Type	Description of Interviewee
(IE-Professional1)	6-8 Years	In Person/ Full	The interviewee is a young Industrial Engineer with experience in multiple industries, working for a leading turn-key engineering and technology company.
(IE-Professional2)	4-5 Years	In Person/ Full	The interviewee is an industrial engineer at a large manufacturing company. She has 5 years of experience in continuous improvement. Additionally, she focuses on compliance with government regulations: safety, health and social.
(IE-Professional3)	4-5 Years	In Person/ Full	The interviewee is an emerging industrial engineer. He is currently working for a major airline company in South Africa. The majority of his work is centered around business analysis (Re-engineering processes), enterprise architecture and traditional IE optimization.
(IE-Professional4)	8-10 Years	In Person/ Full	The interviewee leads a team of graduate industrial engineers at a major consulting firm. Her main role is business development and training.
(IE-Professional5)	4-5 Years	Skype/ Abridged	The interviewee is an Industrial Engineering professional who built her experience in the mining industry and then moved over to the insurance industry.
(IE-Professional6)	4-5 Years	Skype/ Abridged	The interviewee is a developing Industrial Engineering professional. He is currently working on rolling out fast transit systems in townships for the public sector. This entails working with various stakeholders (Taxis, Consumers and others).
(IE-Professional7)	4-5 Years	In Person/ Abridged	The interviewee is an Industrial Engineering has built his professional career in the aerospace industry thus far. He was part of the South African team that went to the global Fresh Connection supply chain challenge.
(IE-Venturist1)	10-20 Years	In Person/ Full	The interviewee is a fin-tech and health tech enthusiast currently working at a major consulting company as a manager and starting his own health venture.
(IE-Venturist2)	6-8 Years	Skype/ Full	The interviewee is an industrial engineer by training who has gained significant experience in consulting for various sectors and now runs his own initiative.
(IE-Venturist3)	10-20 Years	Skype/ Full	The interviewee is leading industrial engineer in business optimization from a planning perspective. She is involved in international training as well as local training and consulting. She owns her own consulting and training business but has worked for various companies before venturing.
(IE-Venturist4)	20-30 Years	Skype/ Full	The interviewee is an enthusiastic proponent of the IE profession and believes that the profession will make big strides in the next industrial revolution. She has over 20 experience years in consulting and working for her own business.
(IE-Venturist5)	4-5 Years	Skype/ Abridged	The interviewee is an industrial engineer who did work in various industries and is now focused on developing her entrepreneurial ventures. She is also getting further experience in consulting for technical IE projects.

Semi Structured Interview Insights & Results

❖ *Interviewee Experience Data*

As can be seen by the list of interviewees, a diverse set of individuals participated in evaluating the findings of this study. The researcher was fortunate to be able to gather insights from these professionals and incorporate them in this study. Collectively, the interviewees have more than 320 years of experience which is reflected in this study. Most of the pioneers lived in a time when IE was not yet available as a field of study and thus have particular history worth noting with regards to the development of the field in South Africa. The list of sectors, using the UN classification of economic activity ISIC, that the interviewees have worked in is:

- ❖ **A - Agriculture, forestry and fishing**
- ❖ **B - Mining and quarrying**
- ❖ **C - Manufacturing**
- ❖ **D - Electricity, gas, steam and air conditioning supply**
- ❖ **E - Water supply; sewerage, waste management and remediation activities**
- ❖ **F - Construction**
- ❖ **G - Wholesale and retail trade; repair of motor vehicles and motorcycles**
- ❖ **H - Transportation and storage**
- ❖ **I - Accommodation and food service activities**
- ❖ **J - Information and communication**
- ❖ **K - Financial and insurance activities**
- ❖ **L - Real estate activities**
- ❖ **M - Professional, scientific and technical activities**
- ❖ **N - Administrative and support service activities**
- ❖ **O - Public administration and defense; compulsory social security**
- ❖ **P - Education**
- ❖ **Q - Human health and social work activities**
- ❖ **R - Arts, entertainment and recreation**
- ❖ **S - Other service activities**
- ❖ **T - Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use**
- ❖ **U - Activities of extraterritorial organizations and bodies**

Moreover, the list of countries that the interviewees have worked in or consulted in is shown on the map below:

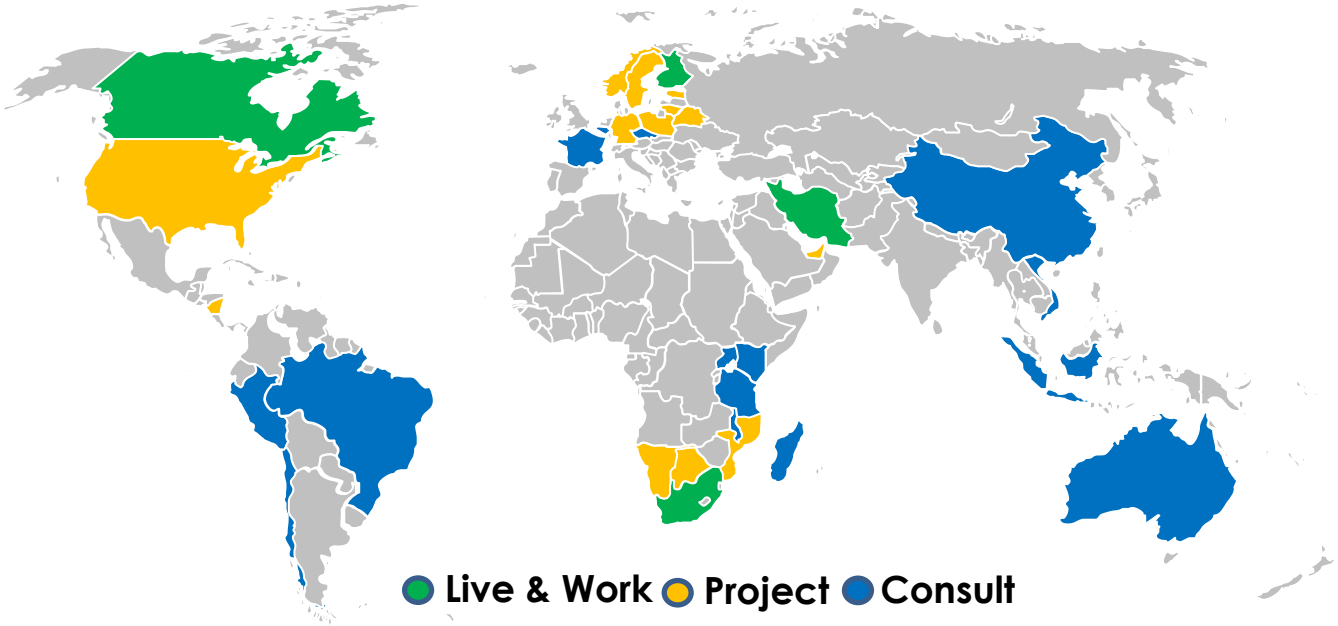


Figure 27: Map of Global Interviewee Experience

❖ *Section 1: Research Overview*

Open Ended Question [OE0.1] *- Do you feel that there is a common thinking style strongly present amongst industrial engineers that can be called "Industrial Thinking"? Is it available in us by virtue of being industrious? Should it be codified or made explicit? How would you define it? Is it available in others?*

The interviewees were supportive of the idea of a unique thinking style for the profession. However, some noted that it must be inclusive of others (since they also might display Industrial Thinking) and it may not include some who possess the degree but specialize in sub-disciplines. IE-International2 (2017) points out that in addition to being related to industrious behavior, it creates “an urge to improve things”. Other respondents used different terms such as ‘optimize’ but validated that idea of needing (almost biologically) to improve things around us. IE-Professional2 (2017) defined Industrial Thinking as “not accepting things as they are, and always wanting change and challenge and improve and question”. Interestingly, IE-Pioneer5 (2017) gave a historical account stating that “when an IE does his job he creates a system for knowledge or process control. There is much more appreciation in IE for human factors. The IE by nature designs abstract things. There definitely is a commonality between IE and it lies in the simplicity. Other disciplines differ in their solutions because they face different problems… However, an abstract thing is applied anywhere”.

It stood out that most interviewees remain unaware of where this thinking style develops. As they discuss, its not linked to a specific course or experience but is the result of their combination. IE-Professional4 (2017) explains that “I dont know whether its something that comes out of the engineering degree. It has a lot do with the positions that we get appointed in that forces us think in a certain way. For many, even industrial engineers, it does not come that natural. Not everyone has the ability to see the bigger picture and improving something for the sake of improvement. The positioning of the team in a certain way forces you to think a certain way”.

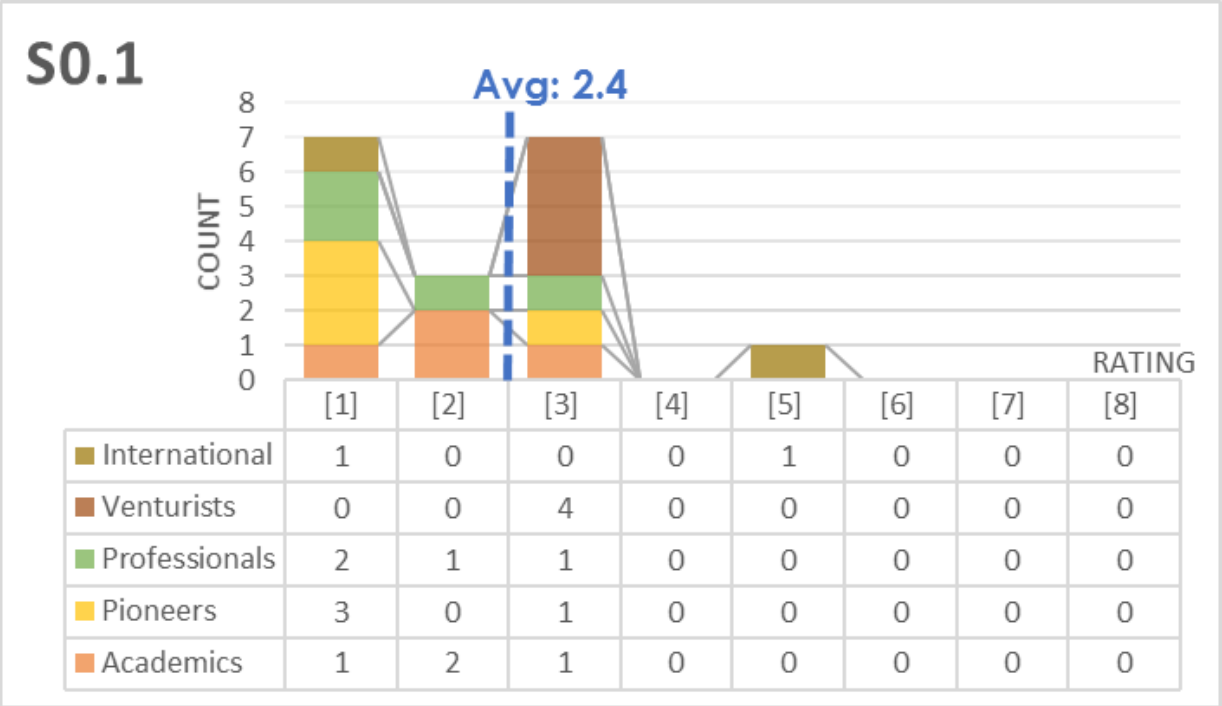
There was also overwhelming support to codify this thinking style. This could help crystalize the role of the IE in an organization. An interesting point taken from the discussion with IE-Pioneer1 (2017) highlighted the importance of having IE available on demand to help make improvements. IE-Pioneer1 (2017) explains that “more progressive companies have management services which does exactly what a IE function should do. Provides services to every other function in an organization. If they have a problem (any problem) this must be resolved by an IE. At the moment most of the time this is solved by the IT guy. The IT guy does not know enough about all the functions and optimizing the system. Thus IE should be like a management service call our function to resolve problems. Part of the problem with IE at the moment is there is only the engineer. There should be multiple levels ranging from technical to more senior management”. This point was echoed by most of other Pioneers.

Statements [S0.1-S0.5]

The full evaluation of S0.1-S0.5 can be found in E3 – Interviewee Evaluation of Statements. Overall, the statements received lukewarm support (average of between 1.9 and 2.4). S0.1 attracted most of the points of contetion/reseavation from participants.

The statement reads **S0.1:** Research Overview - industrial engineers appear to share a common way of thinking and the ability to instigate it in others, yet, unlike other fields, this seems to be largely implicit and difficult to communicate with society at large.

Chart 13: Interviewee Responses (Using Kaner Gradient of Agreement) to S0.1



	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	1	0	0	0	1	0	0	0
Venturists	0	0	4	0	0	0	0	0
Professionals	2	1	1	0	0	0	0	0
Pioneers	3	0	1	0	0	0	0	0
Academics	1	2	1	0	0	0	0	0

[1] Whole Hearted Endorsement [2] Agree With Minor Point of Contention [3] Support With Reservations [4] More Discussion Needed [5] Abstain (Does not Affect Me) [6] Don't Like But Will Support [7] Serious Disagreement [8] Veto (I Block this Proposal)

***Open Ended Question [OE0.2]** – Research Summary*

The minor point of contentions on the above statement surrounded the idea of being able to instigate it in others. The respondents appeared to be split on the first issue since not all industrial engineers share the ability to develop others. This was countered by various examples where interviewees, even those more technically focused, stated their desire to develop others. IE-Professional7 (2017) provided the most unique take on an African perspective explaining that “we used the crossover model [Based on TPS]. If you go on the shop floor you will see the workers and offices understand lean and 5S. My experience at **X** is that they indeed understand industrial engineering and we trained 30 people to do all types of industrial engineering things. They further train 20 people; we call it the thlokolemo (African word meaning focus). The types of tools are very simple and practical exercises but they transcend”. Overall, the interviewees agreed with the need for a Systemigram to communicate.

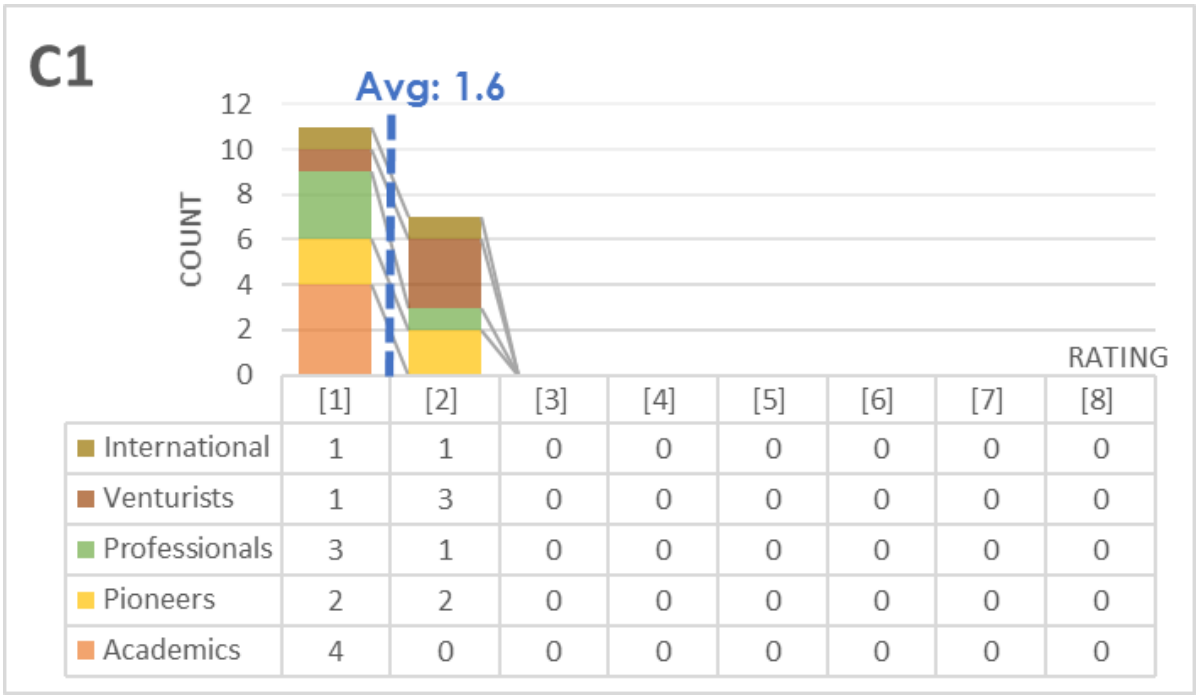
❖ *Section 2: Article 1*

Statements [S1.1-S1.4 & C1]

The full evaluation of S1.1-S1.4 can be found in E3 – Interviewee Evaluation of Statements. Overall, the supporting statements received enthusiastic support (average of between 1.5 and 2.4). The semi-structured interview of section was based on article 1 and the first desirable systemic change. The main focus of the open-ended discussion was conclusion C1.

Conclusion 1 [Desirable Systemic Change]: In order to hold true to their professional identity (IE-ID) of designing balanced solutions, an industrial engineer must continuously advance their interdisciplinary awareness (to connect) and cognition abilities (to master).

Chart 14: Interviewee Responses (Using Kaner Gradient of Agreement) to C1



	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	1	1	0	0	0	0	0	0
Venturists	1	3	0	0	0	0	0	0
Professionals	3	1	0	0	0	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	4	0	0	0	0	0	0	0

[1] Whole Hearted Endorsement [2] Agree With Minor Point of Contention [3] Support With Reservations [4] More Discussion Needed [5] Abstain (Does not Affect Me) [6] Don't Like But Will Support [7] Serious Disagreement [8] Veto (I Block this Proposal)

Open Ended Question [OE1.1] *– Article 1 Supporting Argument*

The point that received the least support from respondents was **S1.1**. With that being said, many respondents still agreed but had some reservations. IE-Pioneer2 (2017) cited that IE went through phases and that the role and identity was always clear to an industrial engineer but only in later stages did it expand to what it is today (which perhaps facilitated the perception of jack of all trades). That is why, at a certain phase of development, "it was easier to tell someone you were a statistician [because people understood what they did]" (IE-Pioneer2, 2017). From the discussions conducted during this section, it was also apparent that the 'identity' crisis was not an international phenomenon. All 3 international respondents highlighted that in their respective countries, the role of an IE and respect for their work was clear. **S1.4** & **C1** received support. It was noted that IE could become masters of the system.

Open Ended Question [OE1.2] [Article 1 Artefact and Abstract] - *What do you conclude from the abstract and action taken above? Is this a desirable systemic change? How can this model help develop the industrial engineering profession & industrial thinking?*

IE-Pioneer5 (2017) provided a concise history which shed light on the lack of an identity historically, explaining that "Scientists and applied scientific knowledge has been valued throughout the ages. But engineering as such only arose in the Roman times when they had people that they ingenious ones. That is the root of the word engineer and they were the first engineers. However, quite quickly they had to distinguish between civil engineers and military engineers. Civil engineers combined all the disciplines available today. However, they quickly split to mechanical and civil. In my day mechanical and electrical were almost the same as well. The mechanical also gave rise to the chemical and in my day, this also split into industrial. However, all the forms of engineering up to creation of Industrial was concerned with the design of artefacts but the industrial engineer designs operating systems (something intellectual)".

Overall, the metaphor, visual depiction and use of marketing theory was well received and commended. IE-Venturist1 (2017) "this can be a useful [visual representation] because… one can know better where to expand their roots and leaves whilst sensing the environment". IE-Professional1 (2017) adds that "It is a visual easy concept to grasp. It can be made into a badge and a shirt. It can be an identity and marketing tool". IE-Professional6 (2017) "there is so much more to uncover when it comes to Industrial Engineering and there is much more depth. The colorfulness of the leaves explains exactly what we are, and we do a little bit of everything. The metaphor helps solidify an identity for industrial engineers. You can choose how you want to thrive as an IE". The main points of contention was that it does not have much value or use outside marketing activities (IE-Academic1, 2017). However, various interviewees pointed out that if it were to become official, they would adapt it to become more representative of the full community. Respondents suggested the following changes:

1. Adding identify as a skill to L3
2. Adding analysis as a skill to L3
3. Adding data sciences as a knowledge field to L4
4. Adding human resources as a knowledge field to L4

Interestingly, the specific brand of tree (the Aspen tree) was well received given its ability to describe multiple industrial engineers within a family after the first child joined the profession. IE-Pioneer2 (2017) explains that there is a "pattern that once a child breaks the pattern and studies IE, it is very likely that siblings or close family will follow. In terms of personality people who study IE are a little bit different. A little bit rebels and they know they want to do something, but they don't know what exactly."

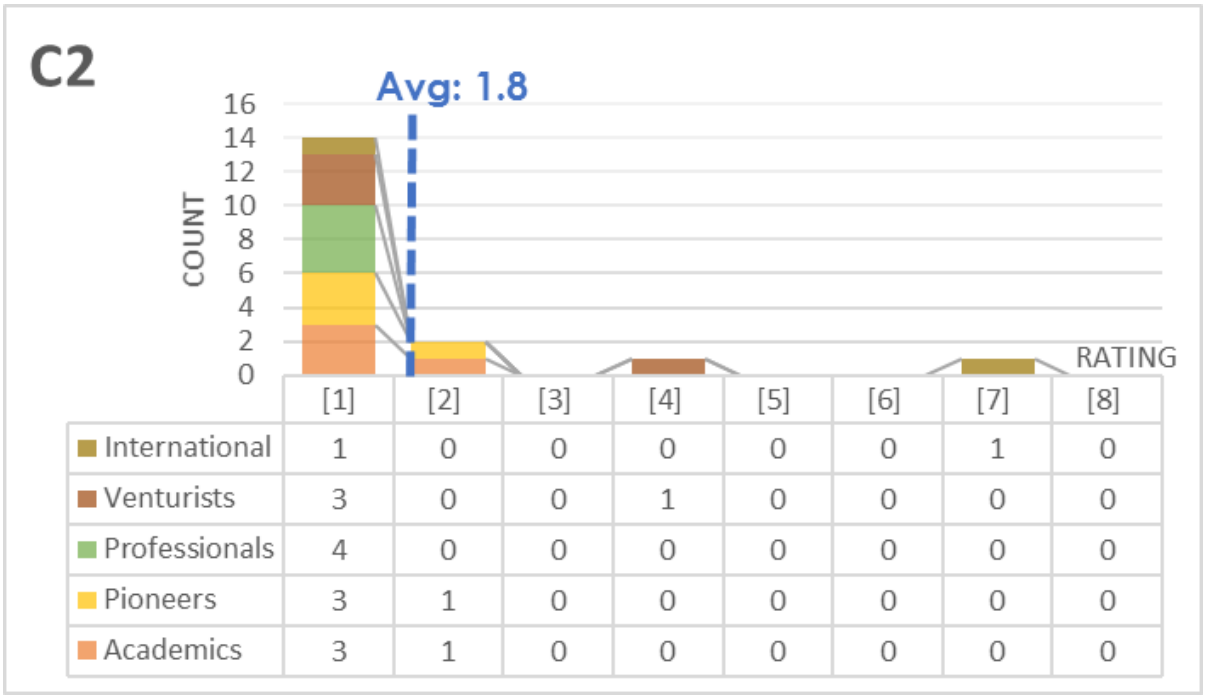
❖ *Section 3: Article 2*

Statements [S2.1-S2.4 & C2]

The full evaluation of S2.1-S2.4 can be found in E3 – Interviewee Evaluation of Statements. Overall, the supporting statements received enthusiastic support (average of between 1.5 and 1.7). The semi-structured interview of section was based on article 2 and the second desirable systemic change. The main focus of the open-ended discussion was conclusion C2.

Conclusion 2 [Desirable Systemic Change]: In the knowledge era, it becomes vital for professional communities to create knowledge & resource sharing platforms that act as incubators and places to congregate for initiatives that can further develop the profession and attract the next generation of entrants into IE.

Chart 15: Interviewee Responses (Using Kaner Gradient of Agreement) to C2



	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	1	0	0	0	0	0	1	0
Venturists	3	0	0	1	0	0	0	0
Professionals	4	0	0	0	0	0	0	0
Pioneers	3	1	0	0	0	0	0	0
Academics	3	1	0	0	0	0	0	0

[1] Whole Hearted Endorsement [2] Agree With Minor Point of Contention [3] Support With Reservations [4] More Discussion Needed [5] Abstain (Does not Affect Me) [6] Don't Like But Will Support [7] Serious Disagreement [8] Veto (I Block this Proposal)

Open Ended Question [OE2.1] *– Article 2 Supporting Argument*

The respondents showed support for the statements made in this section. However, some highlighted that they do not want to see Industrial Engineering lowered to the level of technicon training with a focus on practical/work-based learning (IE-Pioneer4, 2017; IE-Professional1, 2017). Many further pointed that there should be some ratio of BTechs to BEng in the workplace. The suggestions with regards to gamification received a lot of interest but they must not be "viewed as derogatory gaming. Must not make [IE] look like they are simple [since] they have to be taught through games" (IE-Venturist3, 2017). A thought that emerged from the discussions is whether a practical real world game activity could take place with BTech and BEng simulating factory environments and attempting improvements.

Open Ended Question [OE2.2] [Article 2 Artefact and Abstract] *- What do you conclude from the abstract and action taken above? Is this a desirable systemic change? How can this model help develop the industrial engineering profession & industrial thinking?*

Overall, the feedback was positive to the platform and many respondents shared a similar vision. Some had even tried to get something of this sort initiated on existing platforms. The key concern with regards to the second desirable change, much like any platform, was adoption. IE-Venturist1 (2017) points out that "ideally something like this should become the bridge between industry and academia. That is where students can truly get exposure to experts and even lecturers can refer them to forums and experts. This can become a centralized connection platform". The consulting firm which IE-Venturst1 works at has a similar system which has benefitted them profoundly. IE-Professional2 (2017) points out that "We work in such different environments that it is sometimes hard to find common ground" and IE-Professional6 (2017) adds that "in terms of developing as an industrial engineer one needs this collaboration. I already work in an environment with no IE so I build my own sphere. However, when I look for mentorship or development there is nothing like that. That is one thing that would also help develop the identity because it allows us to keep describing ourselves as industrial engineers instead of changing our titles to operations mangers, quality managers and so on".

With regards to the concerns, the key suggestions were that if this platform came to fruition, it would have to have a very clear value proposition (IE-International2, 2017), especially since other platforms exist and professionals are not very interested being active on yet another platform. Additional concerns were raised about the implementation of the platform and practical integration into university activities. However, a implementation plan slowly clarified after the discussion with IE-International1 (2017) who explained that "students are not very much interested in the mundane. You can always give points to the students that show participation."

In order to ensure adoption, the proposed implementation would involve partnering with the 4 South African universities (initially) to use this platform to combine efforts to share resources and effectively connect the 4 departments. This proposal would see the best content in each subdiscipline being taught by the expert in that field to all 4 universities. Naturally, this platform will act as supplementary to existing courses. However, even in that capacity, it holds great potential. Additionally, in order to further gamify the platform, students will be given points and awards for being active participants, developing content and sharing expertise. Academics and lecturers can act as side admins and ensure the quality of the content by screening change suggestions. Initially, professionals will participate only by providing vacation work and final year project opportunities. However, over time, their involvement can increase if the platform manages to develop a clear value proposition that attracts them.

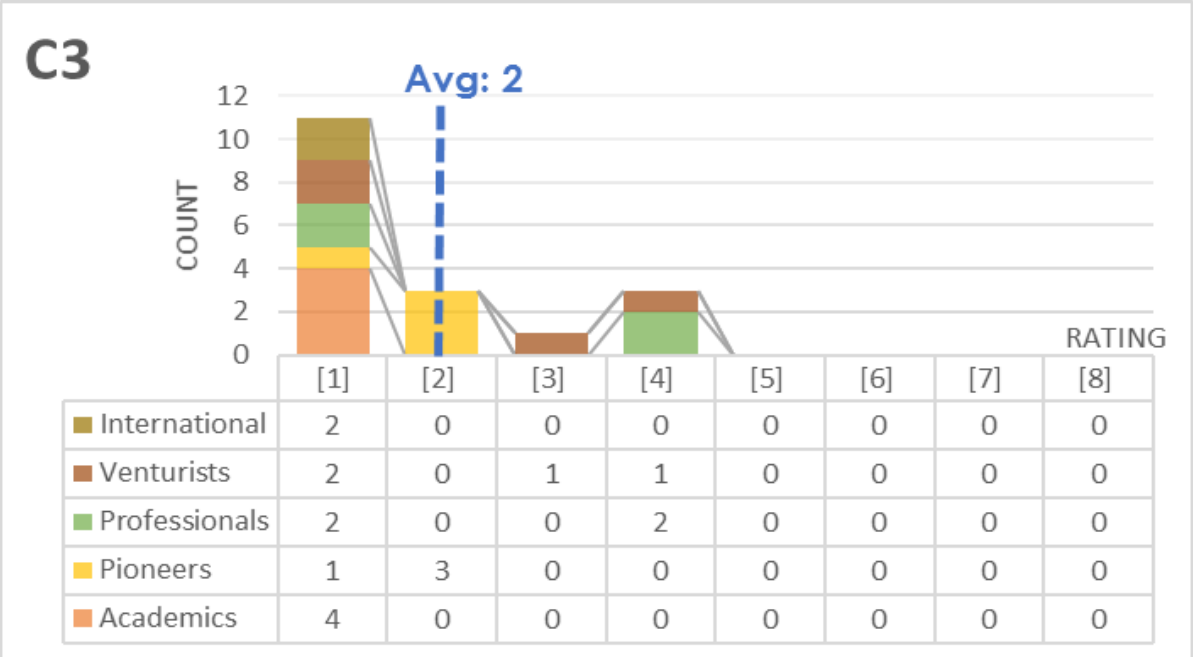
❖ *Section 4: Article 3*

Statements [S3.1-S3.4 & C3]

The full evaluation of S3.1-S3.4 can be found in E3 – Interviewee Evaluation of Statements. Overall, the supporting statements received lukewarm support (average of between 2.1 and 3.2). The semi-structured interview of section was based on article 3 and the third desirable systemic change.. The main focus of the open-ended discussion was conclusion C3.

Conclusion 3 [Desirable Systemic Change]: Since Industrial Engineering is deeply rooted in designing and managing the above socio-technical systems, transdisciplinary frameworks need to be created using Industrial Thinking to correctly evaluate the impact of macro-disruptors and successfully react to them.

Chart 16: Interviewee Responses (Using Kaner Gradient of Agreement) to C3



	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	2	0	0	0	0	0	0	0
Venturists	2	0	1	1	0	0	0	0
Professionals	2	0	0	2	0	0	0	0
Pioneers	1	3	0	0	0	0	0	0
Academics	4	0	0	0	0	0	0	0

[1] Whole Hearted Endorsement [2] Agree With Minor Point of Contention [3] Support With Reservations [4] More Discussion Needed [5] Abstain (Does not Affect Me) [6] Don't Like But Will Support [7] Serious Disagreement [8] Veto (I Block this Proposal)

Open Ended Question [OE3.1] *– Article 3 Supporting Argument*

The respondents showed mixed support for the statements. Within a South African context, it appears that disruptive technologies (like 3D printing) are not able to fully change the landscape as of yet. This has, admittedly, made industries comfortable and allowed them to maintain their positions in the chain. However, the fact that change is not immediate does not mean that these industries are ready to face the challenges of the knowledge era (especially ones relating to network behavior of consumers). IE-Venturist1 (2017) explains that “Industry is not adapting fast enough to macro disruptions. Business entities need to be faster in matching rapidly altering consumer needs”. That is particularly why an IE needs translate between the technical and non-technical and help their respective industries in adapting.

Open Ended Question [OE3.2] [Article 3 Artefact and Abstract] *- What do you conclude from the abstract and action taken above? Is this a desirable systemic change? How can this model help develop the industrial engineering profession & industrial thinking?*

The main question discussed under this open-ended section was whether an IE should be a proactive, reactive or predictive role in relation to the technologies shaping the knowledge era. The respondents were split in opinion. On one hand, respondents believed that industrial engineers should play a more active role in developing technologies that answer their industry problems. On the other hand, respondents pointed out that this would further specialize the field (which is not desirable) and detract from the ability to integrate. IE-Pioneer2 (2017) explains that “other engineers are very good at discussing technology but Industrial need to really consider the bigger picture. You cant change overnight because of people. Many other engineers think if you have this fantastic technology it solves the problem. Industrials know better”. IE-Professional1 (2017) adds that “the scary thing with technology is that you spend a lot of time figuring it out and something quickly comes with makes it obsolete. It takes a lot of time and energy and one has to be careful. We simply do now know what we do not know. There could be an interest group on keeping up with the future. You will definitely always use technology but it only becomes valuable when it solves a business problem (only selected then)”.

Thus, to summarize the discussion, it appears that the community prefers being predictive of technologies that may disrupt. This allows them to rapidly integrate when technologies have reached their maturity. Notably, in addition to transdisciplinary frameworks, it became apparent that what is truly needed within the profession is socio-technical maturity roadmaps. This concept does not exist, per se, at the moment but could be extremely helpful in visualizing the maturity and readiness of a technology to add value in addition to the maturity and readiness of the social culture (cognitively) to be able to integrate it. Yet, it is important for the overall economy to be conducive to these efforts.

An good example comes from the respected IE-International3 (2017) who stated that “in Finland our society and government is strategically positioning itself as a knowledge society. The state is [already] in knowledge economy which helps create efficiency and value for society”. The interviewee further discussed that South Africa will naturally face bigger challenges given income inequality and an ecosystem that does not have the ability to protect high quality workers and keep them within the country (which is an important factor in the knowledge economy).

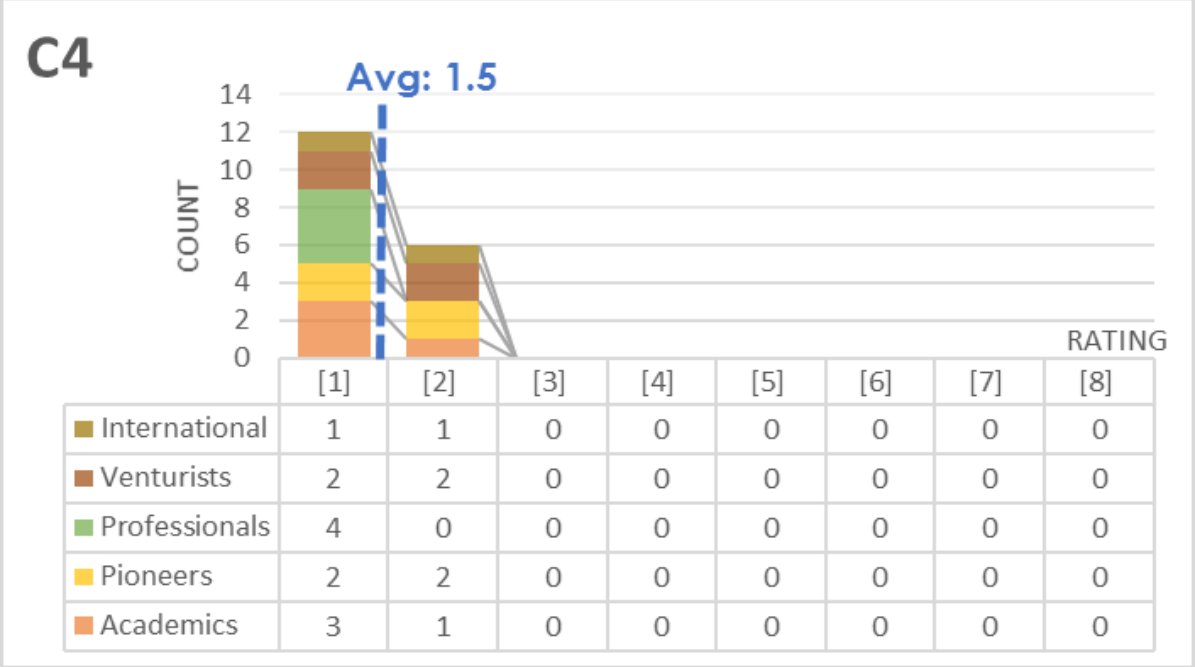
❖ *Section 5: Article 4*

Statements [S4.1-S4.4 & C4]

The full evaluation of S4.1-S4.4 can be found in E3 – Interviewee Evaluation of Statements. Overall, the supporting statements received lukewarm to meager support (average of between 1.8 and 3.8). However, given that the section was based on article 4 and the fourth desirable system change. The main focus of the open ended discussion was conclusion C4.

Conclusion 4 [Desirable Systemic Change]: Since the majority of society (80%) lives in the outer network, it is fundamental for industrial engineers to design new systems that connect them to resources (in the broadest sense) that can help them develop socio-economically and cognitively to be able integrate to global network society

Chart 17: Interviewee Responses (Using Kaner Gradient of Agreement) to C4



	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	1	1	0	0	0	0	0	0
Venturists	2	2	0	0	0	0	0	0
Professionals	4	0	0	0	0	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	3	1	0	0	0	0	0	0

[1] Whole Hearted Endorsement [2] Agree With Minor Point of Contention [3] Support With Reservations [4] More Discussion Needed [5] Abstain (Does not Affect Me) [6] Don't Like But Will Support [7] Serious Disagreement [8] Veto (I Block this Proposal)

Open Ended Question [OE4.1] *– Article 4 Supporting Argument*

Some respondents gave meaningful opposition to points S4.1 and S4.4 discussed in this supporting argument. The respondents did not agree that assisting society was a necessary part of the IE foundation. Also, although they overwhelmingly agreed that industrial engineers need to have a more impactful role within society, the respondents believed that the systems connecting them to the main stream should not be focused on given that, amongst other things, high cellphone penetration and internet connectivity in BoP communities exist. Moreover, some respondents argued that only part of society in South Africa can be described as a network since a majority of society still lives in rural areas. However, virtually all respondents agreed with the conclusion that industrial engineers should be more involved in assisting where they can with regards to social development. The form, however, remained unclear.

Open Ended Question [OE4.2] [Article 4 Artefact and Abstract] *- What do you conclude from the abstract and action taken above? Is this a desirable systemic change? How can this model help develop the industrial engineering profession & industrial thinking?*

The Modularize model was very well received and commended. The conceptual design of involving industrial engineers in designing and supporting small businesses received special interest since it is not a traditional IE function. However, respondents highlighted that this could form part of undergraduate training where students can use this less risky and finance bound environment to develop their skills and also gain a better understanding on social impact of IE activity (IE-Academic2, 2017; IE-Academic3, 2017; IE-Pioneer1, 2017).

It became apparent in interview that the relationship with society is an impactful problem. IE-Pioneer4 (2017) elaborates that “very recently we realized our systems at this institute is geared to manage white collar workers. A very simple example [of why this does not work with BoP] is [they] do not have access to computer systems. Yet, when recruiting them we found out they had smartphones and Facebook”. The interviewee further discussed that IEs, in this capacity, can attempt to understand the context better and help design better systems to connect previously disconnected individuals using technologies they have already adopted.

An interesting concern came about by comparing cultures. The international interviewees barely experienced a social problem of this scale. In both European contexts, the importance of society is highlighted in each and every postgraduate qualification and it is very natural to see social entrepreneurs. Yet, the South African context presents very specific challenges. The key concern is that even if industrial engineers would want to actively participate in social development, some political and cultural elements would hinder this effort. Moreover, the interviewees pointed out that promoting equality is not really the role of specialty of the IE. Making it a ‘responsibility’ would further strengthen the perception of ‘soft engineering’ and further limit what industrial engineers can do. IE-Pioneer6 (2017) elaborates “we obviously should be concerned like everyone else (especially BEng degree). However, falling back to my definition we should focus more on integrating processes that lead to social equality. In the government sectors we should play the role of sorting out the system and integrating it. We need to, however, realize that it is ultimately the role of government. If we want to optimize and lead to better social results, we need to look at the system and try to get everyone an equitable fair share (not equal) which is best done through participating in public sector. We must help in getting resources through the right systems. We have a moral obligation and that is what we can give back to society”.

Returning to the modularize mode, some adaptation and suggestions will be incorporated in order to ensure a higher chance of success. Yet, it appears from the interviews that this could be one of the best ways for industrial engineers to contribute their skills to benefit society.

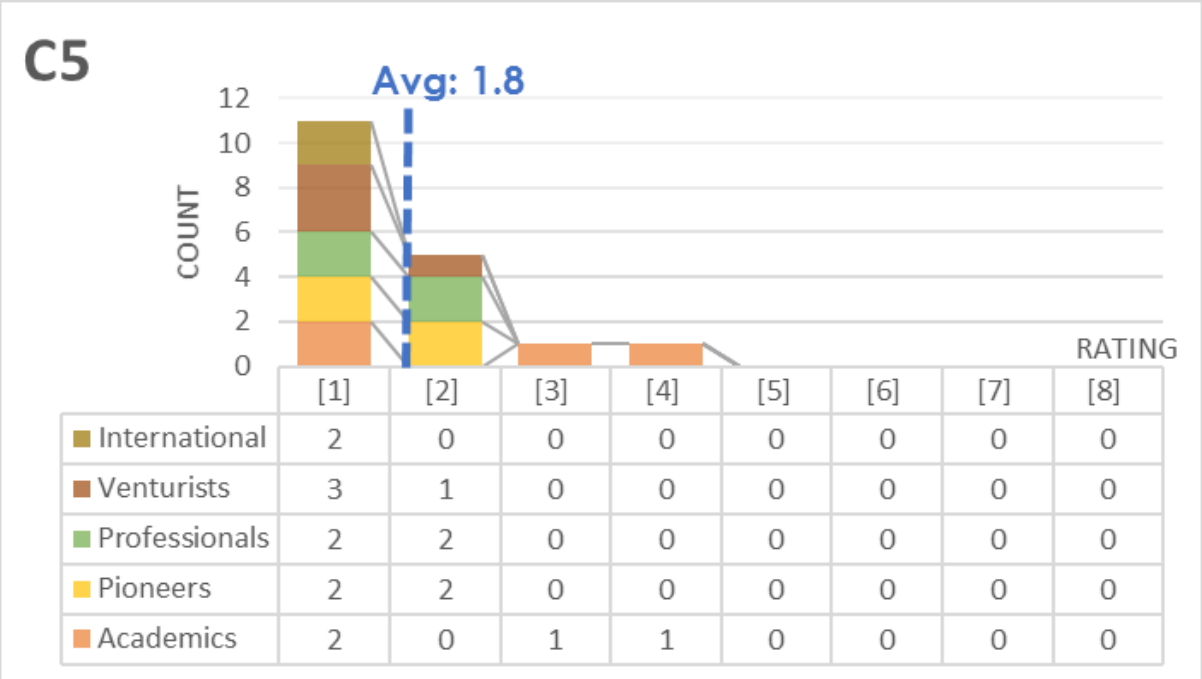
❖ *Section 6: Article 5*

Statements [S5.1-S5.4 & C5]

The full evaluation of S5.1-S5.4 can be found in E3 – Interviewee Evaluation of Statements. Overall, the supporting statements received lukewarm support (average of between 1.5 and 2.7). The semi-structured interview of section was based on article 5 and the fifth desirable systemic change. The main focus of the open-ended discussion was conclusion C5.

Conclusion 5 [Desirable Systemic Change]: IE is one of the fields affected by this problem which can be largely resolved by adapting some of the IE body of knowledge to reflect developments in biomimesis and a modern understanding of human needs

Chart 18: Interviewee Responses (Using Kaner Gradient of Agreement) to C5



	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	2	0	0	0	0	0	0	0
Venturists	3	1	0	0	0	0	0	0
Professionals	2	2	0	0	0	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	2	0	1	1	0	0	0	0

[1] Whole Hearted Endorsement [2] Agree With Minor Point of Contention [3] Support With Reservations [4] More Discussion Needed [5] Abstain (Does not Affect Me) [6] Don't Like But Will Support [7] Serious Disagreement [8] Veto (I Block this Proposal)

Open Ended Question [OE5.1] *– Article 5 Supporting Argument*

Similar to statements about society, interviewees argued that it is ultimately the role of government to consider this supra-system. International respondents agreed that what worked best in their countries (specifically Europe) was having strong regulations limiting business activity. Notably, the respondents cited that there is some integration of environmental concern but it can be seen as unnatural given that the 'impact' is only assessed on a scorecard. Overwhelmingly the interviewees agreed that, although very difficult, IE needs to expand to take a more genuine concern for both the societal and environmental macro systems. IE-Pioneer1 (2017) points out that "industrial engineers have unfortunately not be pressured to necessarily follow some laws in most countries. We are somewhat of a lawless group. We don't need professional insurance. But it is important to really get some form of accountability".

Open Ended Question [OE5.2] [Article 5 Artefact and Abstract] *- What do you conclude from the abstract and action taken above? Is this a desirable systemic change? How can this model help develop the Industrial Engineering Profession & Industrial Thinking?*

Building on the argument and proposed step, IE-Pioneer6 (2017) pointed out that part of the reason for this disconnect with environmental concerns is that "Industrialists of the 19th and 20th didn't care about the environment and or society. They simply trampled whoever was in their way. Even in the modern society we find something called the supply chain gorilla who trample downstream and upstream competition. They cause a lot of damage. Whenever the relevant size of the people in the supply chain is unbalanced then it causes a lot of social damage".

When discussing the importance of learning from and creating synergy with natural systems IE-Pioneer6 (2017) pointed out that "there are industries that go into decline and disappear over time. This follows natural behavior. Certain industries reach end of life. Malls replicate each other so quickly. It is a natural phenomenon for industries to be replaced and revitalized themselves. Businessmen need to reinvent in the same way". This once again points to the central concern of this section which is balance instead of growth as a guiding factor for the field. Industrial engineers must truly allow for the possibility that decline is sometimes a positive thing in that it allows for the rise of something new. However, unlike the behavior of industrialists, this should be not an abrupt destruction of the old in favor for the new. Moreover, artificial enhancement of growth and size can only result in big bubbles which explode in the future and lead to damage (social and environmental) both during and after their lifetime.

Similarly, there was some consensus that improvement lies in the terms that we use and the meanings thereof. IE-Venturist1 (2017) explains that "most terms mentioned above [Time, Work…etc.] should be redefined. Work in the knowledge era should be understood as value adding activities. We need to truly understand what fulfils or gives meaning to an individual doing work also to make sure he is motivated to do it. In the environmental sense we sit with fragmented resources, Energy is actually a suitable alternative to work in this level. If the organism within the society is not fulfilled it creates clusters of energy wasting and environmentally destroying culture". IE-Professional1 (2017) adds that "redefining terms can be valuable to industry. I have to educate the market the whole time but not enough time educating each other (IE's). I don't believe industrial engineers themselves are completely aligned [With environmental and social developments]. We really need to speak the same language with same ideology which strengthen the identity".

In summary, the tremendous impact that incorporating modern developments in social and environmental fields was acknowledged. However, it must be prompted by protective regulation and incentive from government. Otherwise it does not prompt desirable behavior.

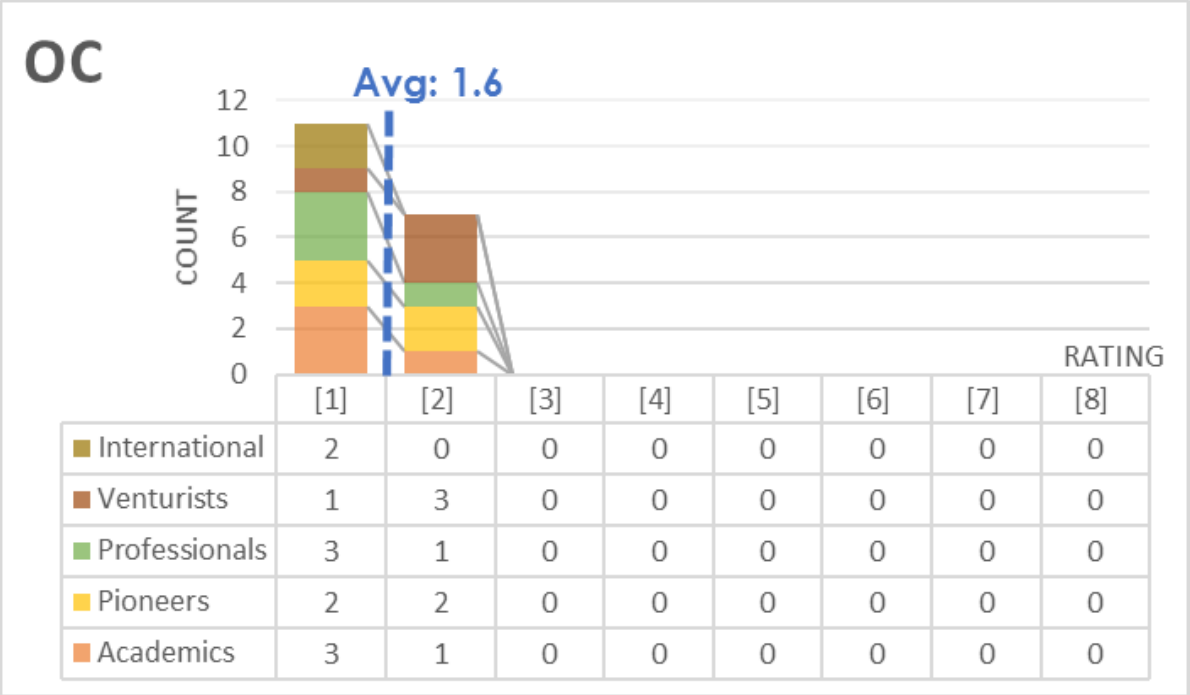
❖ *Section 7: Golden Thread & Overall PhD*

Statements [ES-C1-IT to ES-C2-IT & OC]

The full evaluation of ES-C1-IT to ES-C2-IT can be found in E3 – Interviewee Evaluation of Statements. Overall, the supporting statements received enthusiastic support (average of between 1.5 and 1.7). This section had a focused discussion on the overarching conclusion which was the proposed definition of Industrial Thinking. An open-ended discussion on the Industrial Thinking Systemigram also followed.

OC: Industrial thinking is the cognitive ability to conceptualize balanced industrious solutions which create value for all of society in an ecologically beneficial manner. This is achieved by uncovering optimal courses of action which guide the management of resources supported by technologies. Furthermore, using sound system design processes, progress is assessed and evaluated against expected impact on society and the environment. These elements work together like an industrial ecology.

Chart 19: Interviewee Responses (Using Kaner Gradient of Agreement) to OC



	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	2	0	0	0	0	0	0	0
Venturists	1	3	0	0	0	0	0	0
Professionals	3	1	0	0	0	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	3	1	0	0	0	0	0	0

[1] Whole Hearted Endorsement [2] Agree With Minor Point of Contention [3] Support With Reservations [4] More Discussion Needed [5] Abstain (Does not Affect Me) [6] Don't Like But Will Support [7] Serious Disagreement [8] Veto (I Block this Proposal)

Open Ended Question [OE-OC1] *– Article 5 Supporting Argument*

The respondents showed overwhelming support for the definition with all respondents having only minor points of contention. For example, a more prominent role for considering the human 'state of mind' was noted. Additionally, some felt the economic aspects were underrepresented. The word of the term optimal was debated (optimal for whom?). Moreover, technology was defined by some as a resource. These minor points of contention were taken seriously and a revised definition based on these inputs is provided in Chapter 12.

Open Ended Question [OE-OC2] [Industrial Thinking Systemigram] *- What do you conclude from the conceptual model above? Is this a desirable cultural change that can create some common ground between the thinking style of the different sub-disciplines of IE?*

The visual depiction and metaphor used to create the systemigram was well commended. One interviewee pointed out, however, that some who may not be familiar with biology would appreciate a standard model. Additionally, several interviewees pointed out that stem cells cannot return to stem cell state after converting. However, given that this is merely a metaphor, the ability to regenerate one's 'industrial thinking' in this metaphor was sufficiently addressed through the idea of creating new cells (which is part of the goal).

IE-Pioneer1 (2017) was one of the only to see a "connotation with system dynamics [With the way the Systemigram is structured]. This is actually very much like system dynamics, it is seeing all the links and connections and neural networks. There needs to be feedback loops, and this is very important". Moreover, IE-Professional3 (2017) saw a real "need to embed this in the ethos of industrial engineering. I like the idea that the core thinking, and fundamentals are linked to stem cells. As you gain industry experience you maintain your stem knowledge, but you become specialized. Thus, it can be considered as a starting point". IE-Professional5 (2017) appreciated that "it is generic enough to match the different industries that industrial engineers work in. It does cover most of what you spend your time doing".

Some of the suggestions to improve the model were also noted by the interviewees. IE-Professional6 (2017) noted that "the change aspect needs to be [better] included. The only constant is change. Something that has to do with the evolving and continuous development aspect should be better implemented" but appreciated that the diagram does not necessarily prescribe a step-based methodology and captures the dynamic thinking style. IE-Pioneer6 (2017) also felt that management thinking is not necessarily appropriate (given that management is an activity) and should be replaced with integrative thinking. Minor changes to some terms used were also noted (based on previously provided definition).

Overall, the community appeared to accept and appreciate the codification of the thinking style. Interviewees who were initially skeptical of the possibility enjoyed the simplicity and visual appeal of the metaphor. Additionally, many followed up and mentioned that it was a surprisingly easily metaphor to explain. IE-Professional2 (2017) praised that "it resonates with my thinking and it puts words to something I was unable to describe. I liked the layman's terms, that it has the ability to act as a function [*sic*]". IE-Venturist4 (2017) expressed that "essentially what you are looking at here is how we need to re-position the whole education to some extent. If that is the outcome and those are the different inputs that we need to get to the outcome (the new cell)… from an engineering education perspective, we need to invest in the things that lead to the most value…. [ultimately we must] overlay this over the curriculum".

12. Research Concluding Remarks

Building on the evaluation and results discussed in Chapter 11, this Chapter will focus on providing the generalizable findings from the study as a whole, discussing future research that can stem from this study and providing the concluding remarks of the researcher.

12.1. Generalizable Findings

Using the insights provided by the interviewees, this section will start by rephrasing the key conclusions (which represent desirable systemic changes) to match the collective aspirations of the community and attend to their points of contention (to be considered valid):

Conclusion 1 [Desirable Systemic Change]: In order to hold true to their professional identity [IE-ID] of designing balanced industrious solutions, an industrial engineer must continuously advance their interdisciplinary awareness (to connect to emerging knowledge) and cognition abilities (to obtain mastery in navigating networks and systems).

Conclusion 2 [Desirable Systemic Change]: In the knowledge era, it becomes vital for professional communities to use networking, knowledge & resource sharing platforms that act as incubators and places to congregate for initiatives that can further develop the profession and attract the next generation of entrants into IE.

Conclusion 3 [Desirable Systemic Change]: Since Industrial Engineering is deeply rooted in designing and managing socio-technical systems (prone to disruption by emerging technologies and changing societal behavior), a genuine effort must be invested by industrial engineers within their organization (using their unique thinking style) to correctly evaluate the impact of macro-disruptors (by developing technology roadmaps) and successfully respond to them (by ensuring cognitive readiness). **Note:** This may require a new tool which can be described as a socio-technical maturity roadmap.

Conclusion 4 [Desirable Systemic Change]: Since the majority of society (80%) lives in the outer network, it is fundamental for industrial engineers to contribute their skills in the design of initiatives that connect the outer network society to resources (in the broadest sense) which can help them develop socio-economically and cognitively to be able integrate to global network society.

Conclusion 5 [Desirable Systemic Change]: IE environmental activity is often guided by governmental regulation, however, in order to promote a more environmentally conscious view within the discipline the IE body of knowledge and the associated terminology (used by professionals and taught in educational institutes) must reflect developments in biomimicry (to

design sustainable industrial ecologies) a modern understanding of human needs (to design services that do not artificially deviate ethical human behavior).

Moreover, 2 versions of the Industrial Thinking Systemigram were created (with and without encompassing metaphor). Both versions accommodated some of the changes suggested by the community. The plain version of the Industrial Thinking Systemigram is presented in Figure 28 below:

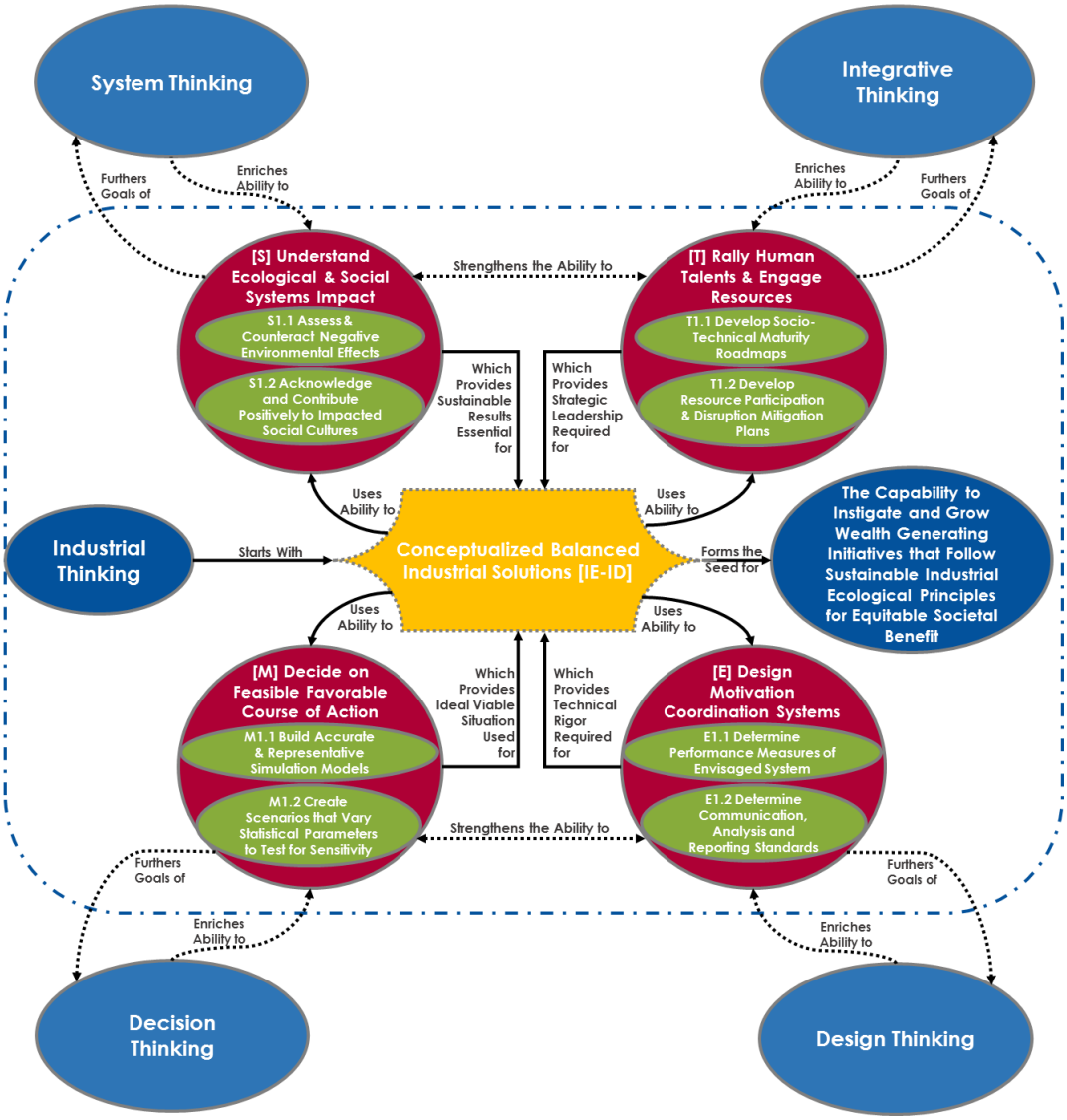


Figure 28: Reworked Industrial Thinking Systemigram Without Metaphor [Own Work]

Interviewees validated the structure and content of the Systemigram as well as the thoughts underlying its development. Furthermore, changes to the Systemigram were taken from the discussions with the interviewees. However, building on the extracted insight gained by the researcher and in order to maintain alignment with some developments in human resource management, the management element was rephrased to focus on integrating talents and engaging resources. Moreover, minor wording changes were included to better reflect an environmental and social consciousness. Lastly, to increase inclusivity of others who possess industrial thinking the [E] function was rephrased to include less technical terminology.

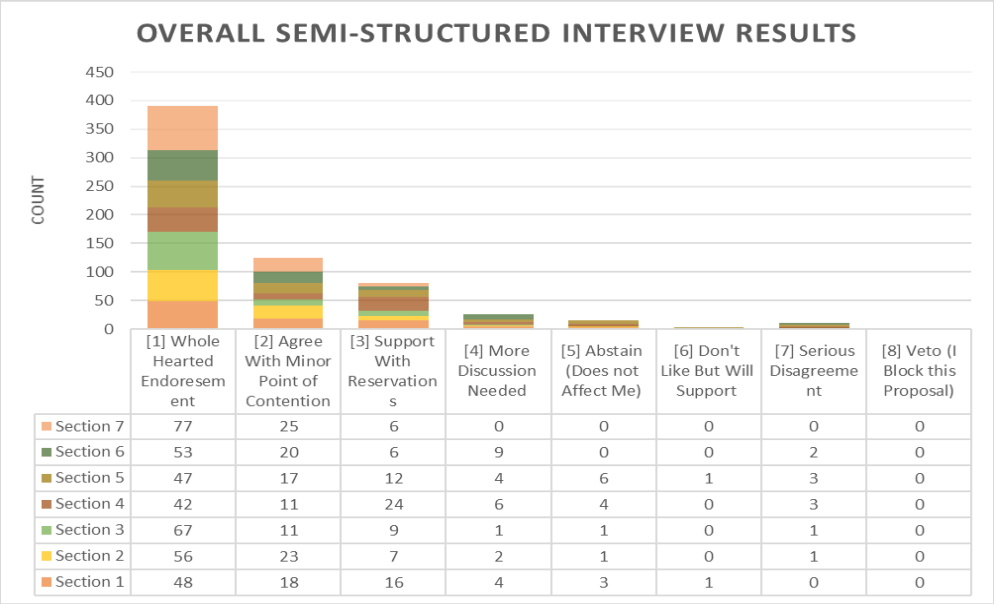
Building on the insight extracted from the interviewees and extracting further insights from the PhD, industrial thinking was further defined as:

> *The cognitive ability to conceptualize balanced industrious solutions which become the seeds for wealth generating initiatives that follow sustainable industrial ecology principles for equitable societal benefit. This is achieved by uncovering feasible favourable courses of action and rallying human talents and resources to develop resilience against macro-disruptions. Furthermore, using motivation coordination systems, performance and goals are set and continuously evaluated. These elements work together like organelles of a stem cell.*

12.2. Future Research

A chart displaying the total responses to all statements is shown below in Chart 20 (showing the overall positive attitude). The researcher is currently undertaking the task of creating a Delphi panel (from interviewees) to further iterate the Industrial Thinking Systemigram and validate it in a stand-alone article publication. The aim is to build on the initial positivity and potentially package the Systemigram in such a way that it could become a form of unstructured methodology used for solving Industrial Engineering problems. Moreover, the implications of the identity can still be studied further. Some of the findings are currently in use at the NWU Industrial Engineering department but a collaborative effort can lead to interesting results.

Chart 20: Overall Interviewee Responses (Using Kaner Gradient of Agreement)



	[1] Whole Hearted Endoresement	[2] Agree With Minor Point of Contention	[3] Support With Reservations	[4] More Discussion Needed	[5] Abstain (Does not Affect Me)	[6] Don't Like But Will Support	[7] Serious Disagreement	[8] Veto (I Block this Proposal)
Section 7	77	25	6	0	0	0	0	0
Section 6	53	20	6	9	0	0	2	0
Section 5	47	17	12	4	6	1	3	0
Section 4	42	11	24	6	4	0	3	0
Section 3	67	11	9	1	1	0	1	0
Section 2	56	23	7	2	1	0	1	0
Section 1	48	18	16	4	3	1	0	0

Using the suggestions of the interviewees, it is also important (within a South African context) to develop clearer distinctions for the role of technologists, scientists and engineers with the broader field. Perhaps this is best addressed by the Engineering Council of South Africa (ECSA) but academics also play an important role in coordinating efforts amongst universities to ensure that the correct individuals are attracted to the correct degrees. In a sense, a lesson

from the European context can be used. In various countries, an implicit ratio of technologists to engineers can be seen in workplaces. This allows for more practically minded people to be better fulfilled with their work, whilst allowing the industrial engineers to have more strategic functions. Additionally, this helps replicate a TPS model where workers continuously have an individual with strong Industrial Thinking at their side (who can also better coordinate efforts with the industrial engineer). This initiative can further help the South African workplace and create cohesion that can lead to less strikes, more knowledge transfer and better relationships with the majority of society (who are BoP workers).

Furthermore, there is a need for a centralized communication platform to share concerns (such as those discussed in this PhD) with the larger community. This is, after all, the only proactive way to deal with those concerns since academic studies do not always match the much-needed responsiveness.

Last but not least is the important task of creating a process that can help individuals from other disciplines who possess Industrial Thinking to get accredited for it. Naturally these individuals might possess other undergraduate degrees and work experience. What they are missing is a structure taught qualification. For this reason, the researcher has embarked, with the assistance of the NWU, to develop a taught PGDip which embraces the modern Industrial Engineering identity by teaching the IE body of knowledge using the cognitive developments of Industrial Thinking discussed in this study.

12.3. Conclusion

Pull a thread here and you'll find it's attached to the rest of the world - Nadeem Aslam

This quote above resonated from its first use in article 1 until the very end of this study. Industrial thinking may be available in others, but it is strongest in those who embrace the modern Industrial Engineering professional identity… it may have been abstract, but now it is codified… it may need iteration, but now there is something to iterate… most important it is now developed to be sensitive to previously disregarded environmental and social issues… allowing it to be a resilient and necessary cognitive thinking style to deal with the complexities of the knowledge era.

Thus, when one finds themselves at a loss for balanced industrious solutions the key is to call on systems thinking to help create an understandable image and ethical objective… ignite design thinking to generate the necessary structures and supports... transform data into meaningful courses of action with the help of some decision sciences… soon thereafter all that is needed to break-free from this confusion is the rallying of all resources and talents to merge into a unified whole that leads to wealth generation initiatives.

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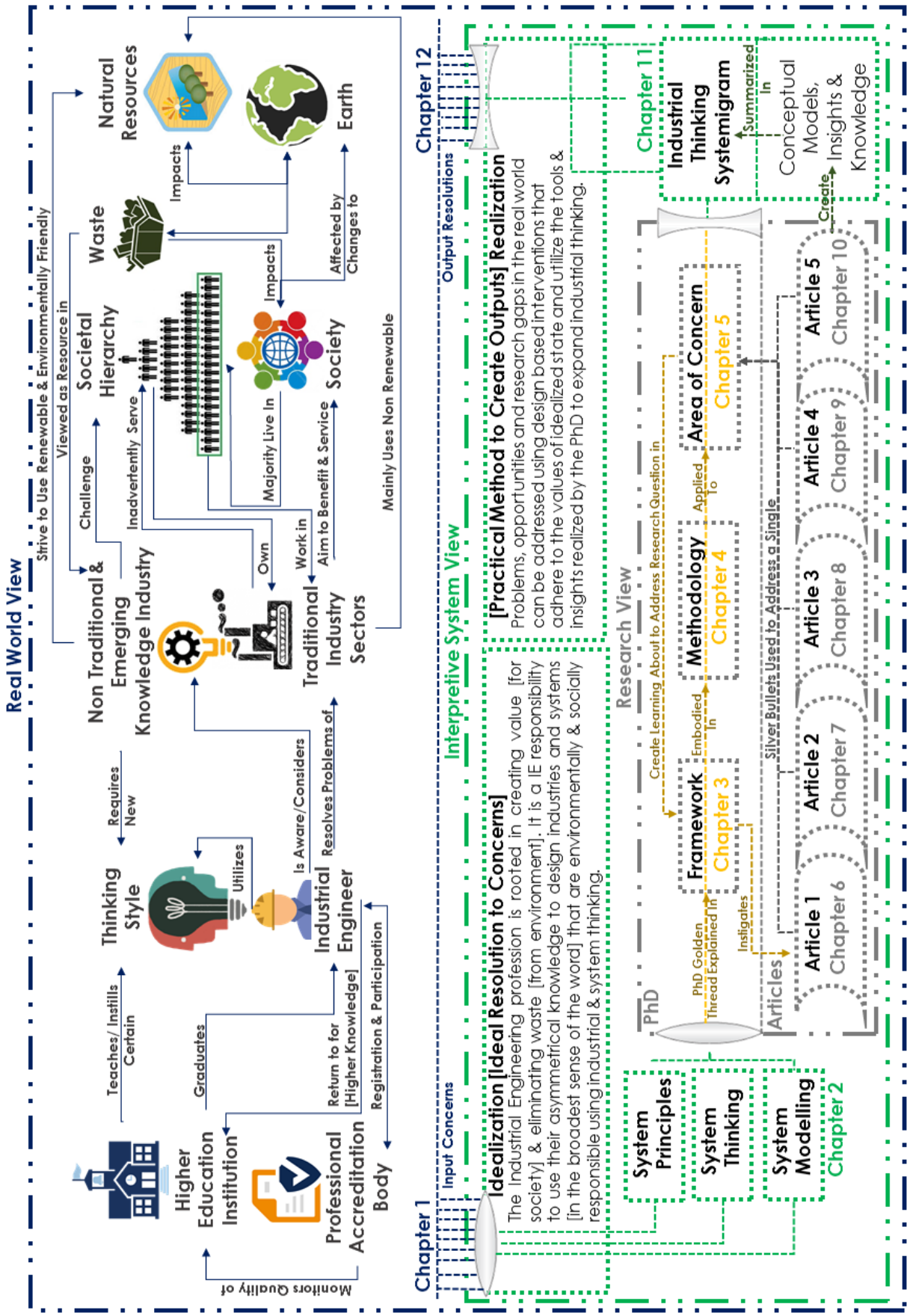
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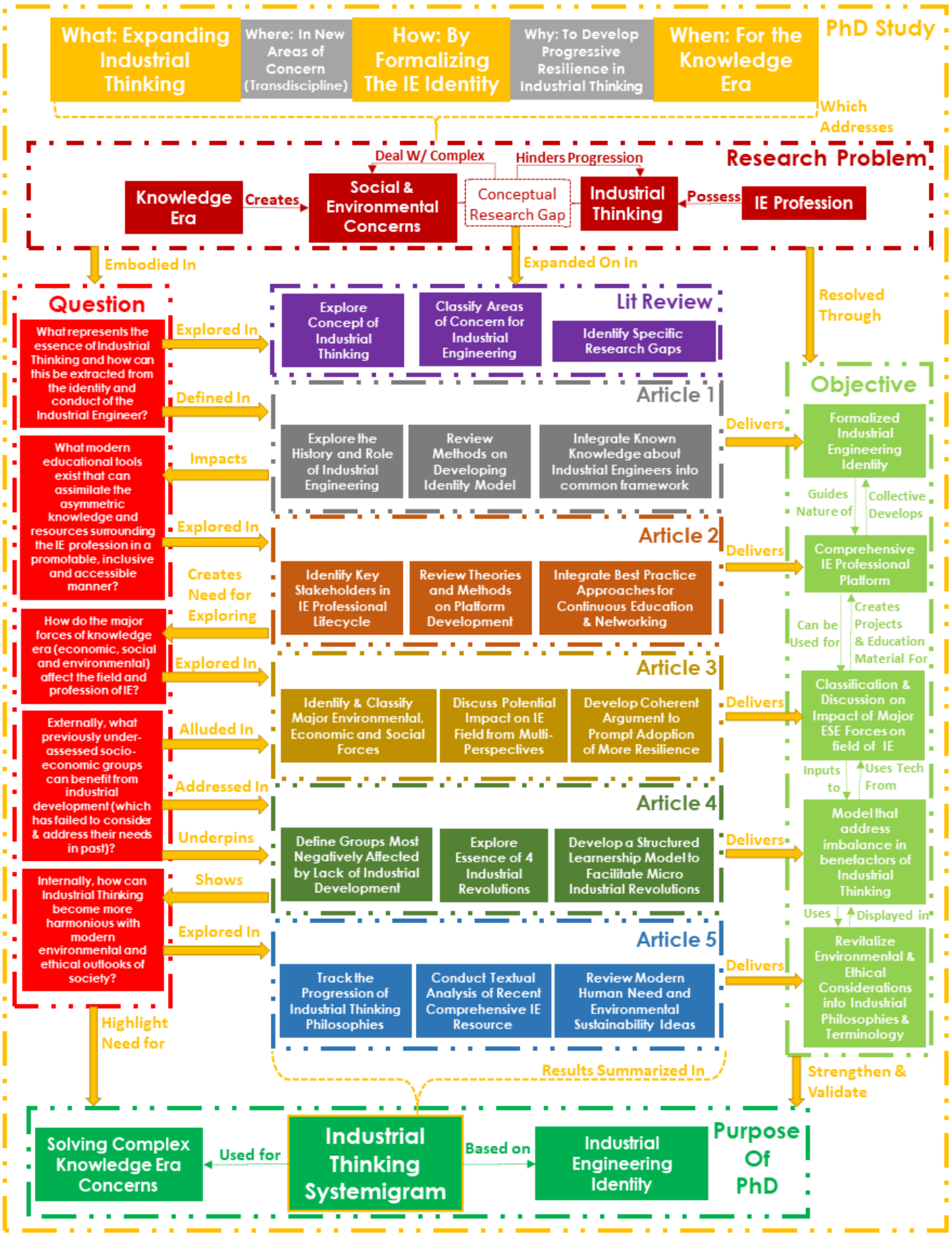
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Appendix A: PhD Visualized Summary & Explanatory Diagrams

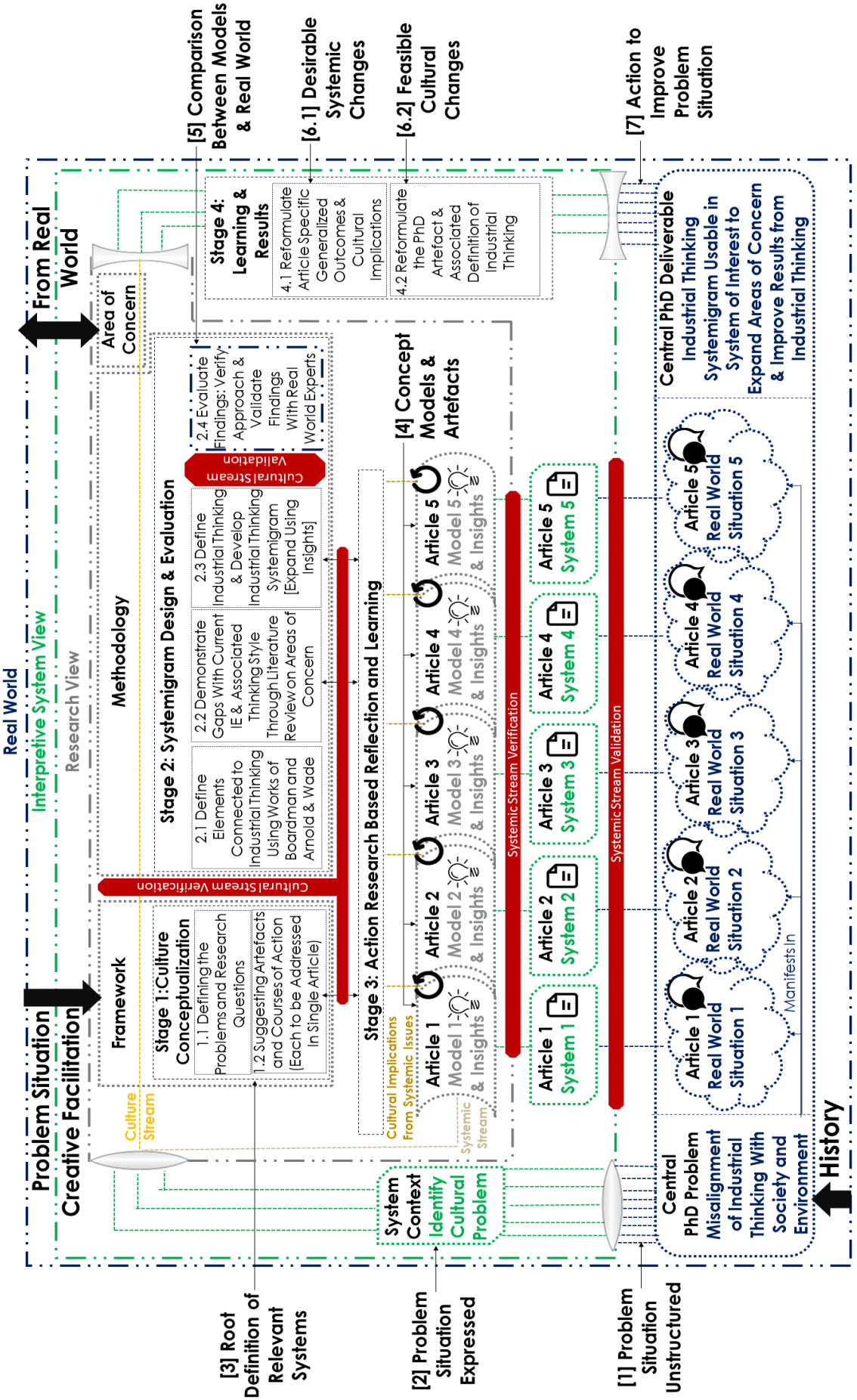
A1 – PhD Visualized System Context



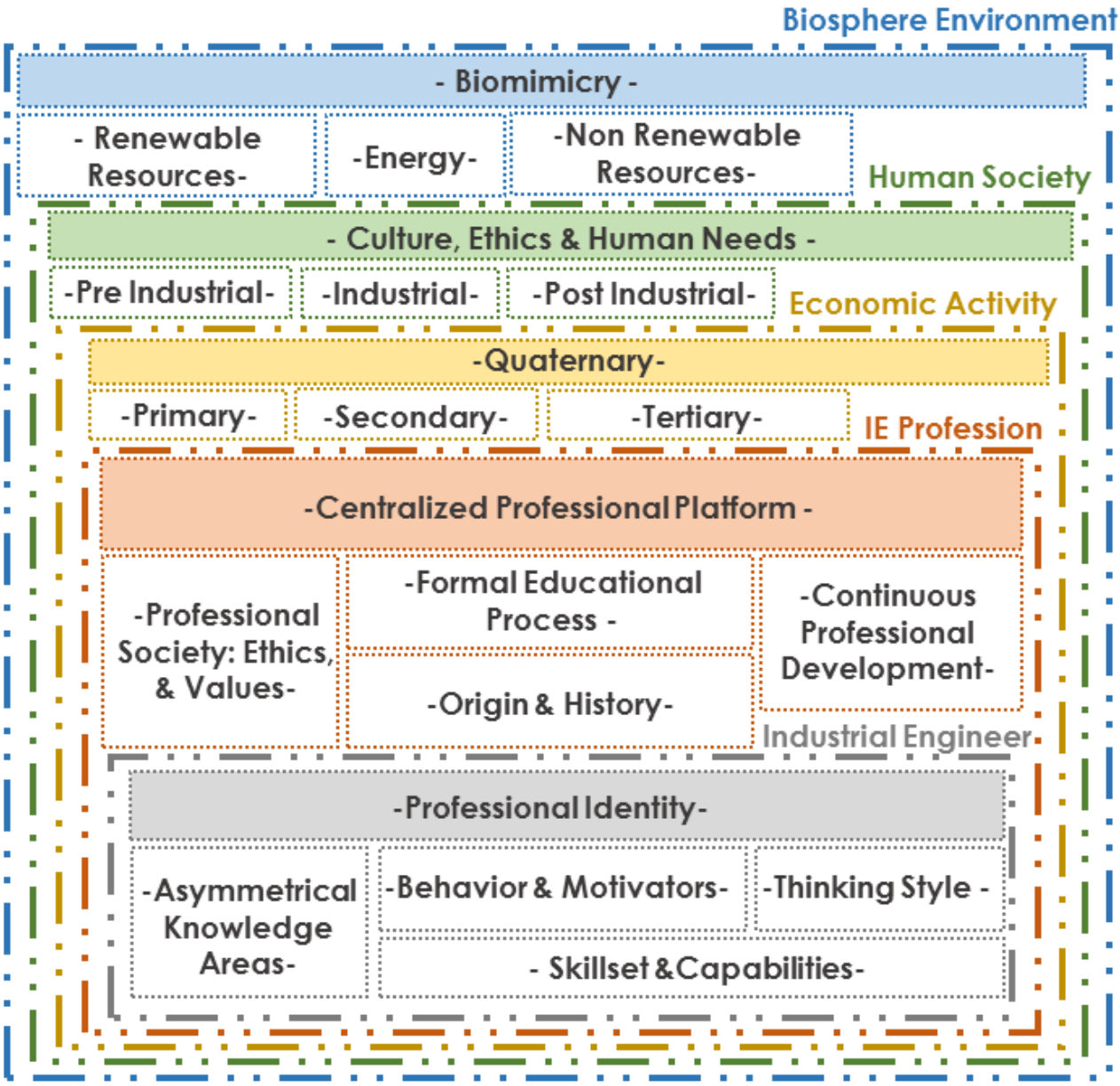
A2 – PhD Visualized Research Framework



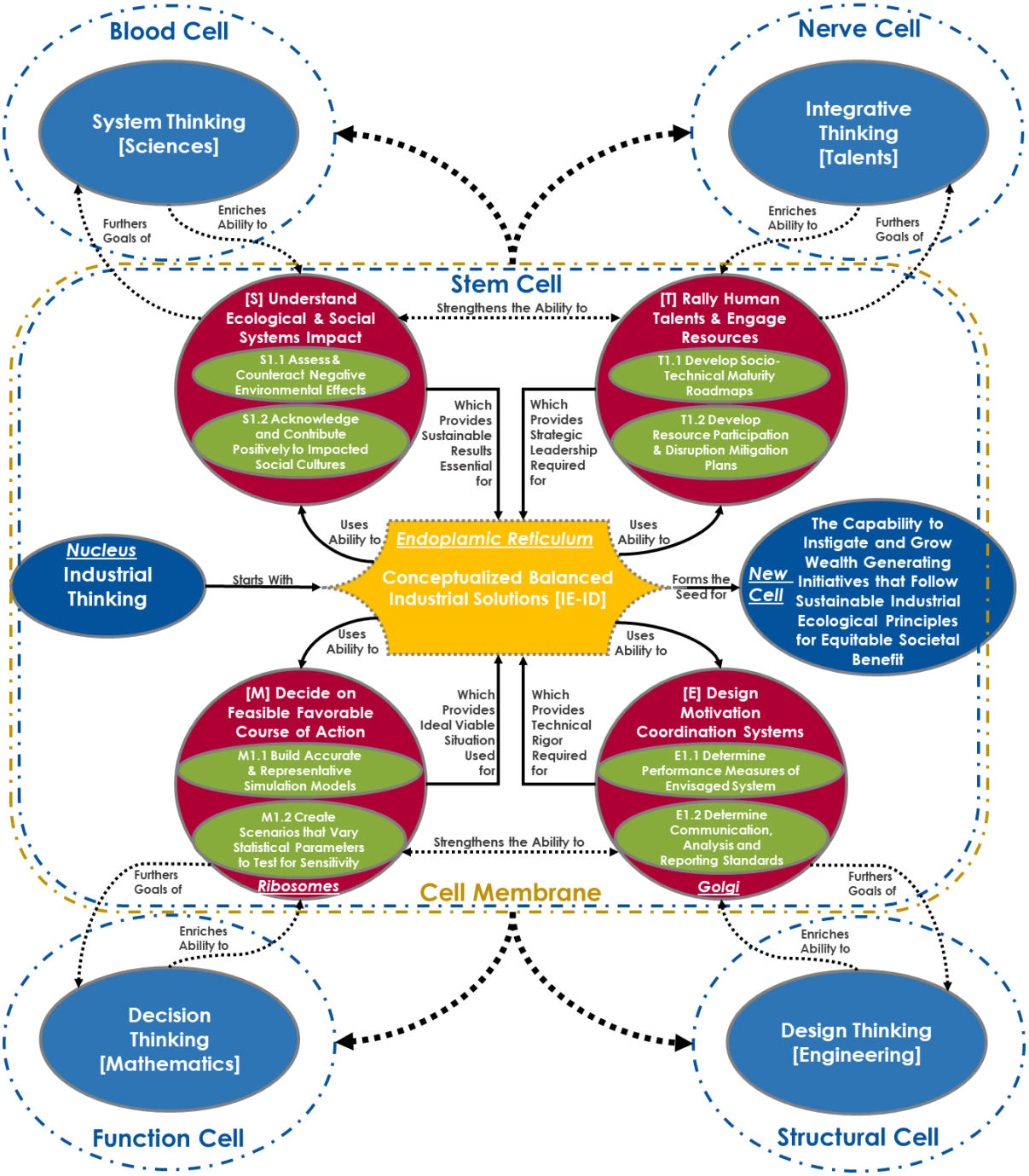
A3 – PhD Visualized Research Methodology



A4 – PhD Visualized Research Areas of Concern



A5 – Industrial Thinking Systemigram With Metaphor



Appendix B: Administrative Documentation

B1 – Acceptance into PhD Dev & Man

NORTH-WEST UNIVERSITY
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NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Private Bag X6001, Potchefstroom
South Africa, 2520

Tel: (018) 299-1111/2222
Web: http://www.nwu.ac.za

Higher Degrees Administration
Tel: 0182992640
Email: 12603880@nwu.ac.za

MR H DARWISH
26 MARAIS STREET
BROOKLYN
0181

2016/02/09

University Number: 28218957

Dear MR DARWISH

DOCTOR OF PHILOSOPHY - DEVELOPMENT AND MANAGEMENT ENGINEERING

Congratulations on your successful application for admission to the Potchefstroom Campus of the NWU. The NWU is pleased to welcome students to our post-graduate programmes, and as a student of the NWU you will become part of a dynamic and exciting academic environment where you will have great opportunities for growth and development.

There was particularly strong competition for places this year, and we were impressed by the quality of your academic record as reflected in your application. We trust that this chapter in your academic career will be both successful and fulfilling.

The NWU, with a proven record of excellence in post-graduate education and research aims to empower post-graduate students through offering quality programmes in order to develop the critical thinking skills which will enable students to serve both the country and all its people.

The NWU therefore welcomes you most cordially and we look forward to receiving you on the Campus.

Study Leader: Prof L van Dyk

Yours sincerely

MRS SA HAVENGA
Higher Degrees Administration

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Faculty Of Engineering
Unit For Engineering Research

Study Leader Nomination [Internal] - Admission

Student Information *(completed by student)*

NWU Number	2	8	2	1	8	9	5	7	Initials & Surname	H DARWISH	
Qualification	PhD		Direction	Development and Management - 703 111					Option	I908P	

Study Leader *(completed by nominated study leader)*

NWU Number	2	4	8	2	7	5	3	3	Title Prof	Initials & Surname	L van Dyk

Mobile Number	0824507988	NWU Building & Office Number	G15 B106
Email address (if using a private email address)	liezl.vandyk@nwu.ac.za		

I, the abovementioned nominee, ✔ **Accept** ○ **Don't Accept** *my nomination as:*

☑ **Study leader** ☐ **Co-study leader** ☐ **Assistant study leader** **commencing** 2016

Office Use / Kantoorgebruik			
Full names		SA ID number	
Marital status		Maiden name	
Gender		Date of birth	
Nationality		Population group	
Home language		Correspondence language	
Work number			
Email address			

I, the undersigned nominee, hereby confirm that I am aware of the rules as set out in the A Rules (http://www.nwu.ac.za/sites/www.nwu.ac.za/files/files/i-governance-management/policy/7P-Arules2014_e.pdf) , as well as the guidelines as set out in the Manual for Postgraduate Studies (http://www.nwu.ac.za/sites/www.nwu.ac.za/files/files/p-aka/M-en-D%20dokumentasie/Manual%20for%20Post%20Graduate%20Studies%202013.pdf), the Guidelines for Promoters and Supervisors and any further applicable rules and/or guidelines as stated by the Executive Management of the North-West University and for the relevant faculty. I further confirm that I am hereby bound as appointed functionary as stated in this form.

Acceptance as Supervisor / Promoter is subject to approval by the Faculty of Engineering's Postgraduate Committee and does not necessarily confirm admission of abovementioned student to the study programme applied for.

Liezl van Dyk	06 Nov 2015	Hasan Darwish	06 Nov 2015
Study Leader	*Date*	*Student*	*Date*

Liezl van Dyk — Digitally signed by Liezl van Dyk, DN: cn=Liezl van Dyk, o=North-West University, ou=Faculty of Engineering, email=liezl.vandyk@nwu.ac.za, c=ZA, Date: 2015.11.06 14:20:17 +02'00'

Hasan Darwish — Digitally signed by Hasan Darwish, Date: 2015.11.06 12:15:28 +02'00'

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South Africa, 2520

Tel: (018) 299-1111/2222
Web: http://www.nwu.ac.za

CERTIFICATE OF REGISTRATION 2016

It is hereby certified that

HASAN DARWISH
(Date of birth: 1992/03/25)
(Student number: 28218957 - 2016)

is registered as a student on the **Potchefstroom Campus**
(PC Faculty of Engineering)

for

PHD IN DEV &MAN
Curriculum - DEVELOPMENT AND MANAGEMENT (I908P)

FULL TIME (First Year)

Academic year : 1
Historical year : 1

Modules:
IIOB 9 71 (H)

Module: H = core module; Module: X = non-core module; A = additional module

Registration date: 2016/02/25 **Date of issue:** 2016/02/25

Last date of qualification and module amendments

*** ***

pp CAMPUS REGISTRAR

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS
Faculty Of Engineering
Unit for Energy and Technology Systems

Title Registration

Section A (page 1 to 3)

To be completed by student, signed by supervisor / promoter, and uploaded by student to eFundi before commencement of the Title Registration colloquium, together with:

- the Research Proposal per PowerPoint template of the Faculty of Engineering
- the signed Code of Conduct for researchers and
- the Invention Disclosure Form (if applicable)

Student Information

NWU Number	2	8	2	1	8	9	5	7	Initials & Surname	HD Darwish	
Qualification	MEng			Direction	Development and Management - 702 111				Option	Option A - I891P	

! Compulsory	Research Group [confirm with study leader]	Industrial Engineering

Provisional Title *Pre-colloquium*	The Industrial Engineering Identity & The Application of Industrial Thinking in the Knowledge Era
Colloquium Date	7 April 2016

Handwritten titles are not accepted.

Are there any confidentiality issues related the proposed research ○ YES ● NO

If YES:

1. Did you consult the rules for the Classification of Thesis and Dissertations? ○ YES ● NO
http://www.nwu.ac.za/content policy_rules

2. Did you complete the Invention Disclosure Form ○ YES ● NO
http://www.nwu.ac.za/i-ttis/invention-process

This form must be uploaded together with your research proposal

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Faculty Of Engineering

Student Statement on Research Ethics

(to be completed before the Proposal colloquium)

NWU Number	2	8	2	1	8	9	5	7	Initials & Surname	HD Darwish

Please answer each question by ticking the appropriate box:

	Y	N
1. Does the study involve participants who are particularly vulnerable or unable to give informed consent? (e.g. children, people with learning or other mental or physical disabilities, people who are incarcerated, unemployed or otherwise compromised in responding to your questions)	○	●
2. Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g. covert observation of people)	○	●
3. Does the study include potentially hazardous laboratory work?	○	●
4. Are drugs, placebos or other substances (e.g. food substances, vitamins) to be administered to the study participants or will the study involve invasive, intrusive or potentially harmful procedures of any kind or any physical, psychological or socio-economic intervention?	○	●
5. Will blood or tissue samples be obtained from participants?	○	●
6. Could the study induce physical, psychological or social stress or anxiety or cause harm or negative consequences beyond the risks encountered in normal life?	○	●
7. Will the study require the personal identification of individuals for follow-up evaluation? (i.e. through names and surnames, identification or staff numbers)	●	○
8. Will financial inducements (other than reasonable expenses and compensation for time) or inducements of any other kind be offered to participants?	○	●
9. Could the image of the NWU, the relevant academic department, your employer, or any other institution however affected by/involved in the project be negatively affected by this research or put in a bad light?	○	●
10. Are you planning on making use of NWU students and/or direct and/or secondary/contracted staff members as research subjects in this research?	●	○

If you answered yes to *any* of the above questions, you will need to describe more fully how you plan to deal with the ethical issues raised by your proposal. A slide is available for this purpose, in the research proposal PowerPoint template which can be found on eFundi. *This does not mean that you cannot do the research, only that your proposal will need to be approved by the Faculty Research Ethics Committee. Attach a full description of the specific issues to this declaration, for discussion by the panel at the Proposal Colloquium.*

Please note that it is your responsibility to follow NWU's *Guidelines for Ethical Research* as set out in the Manual for Postgraduate studies and any other relevant academic or professional guidelines in the conduct of your study. This includes providing appropriate information sheets and consent forms, and ensuring the confidentiality in the storage and use of data, and anonymity of participants. Any significant change in the question, design or conduct over the course of the research should be notified to the supervisor / promoter and may require a new application for ethics approval.

	Y	N
I have read the NWU's Manual for Postgraduate Studies and am familiar with the Guidelines for Research Ethics contained therein.	●	○
I have familiarised myself with the NWU Policy on Plagiarism and Academic Misconduct, and submit myself thereto.	●	○

Declaration by Supervisor / Promoter

I am familiar with the content of the research proposal and I agree that the student present it to the scientific committee by means of a colloquium. I also agree with the ethics checklist as completed by the student.

Liezl van Dyk	07 Apr 2016
Supervisor / Promoter	Date

eFundi 1st Colloquium Submission Details:

Site Title: ENGINEERING POSTGRAD
Site ID: 399f98b1-70b1-4f0f-901c-37bc84c4575f

Assignment title: Research Proposal Colloquium (First Colloquium)
Assignment Due Date: Apr 9, 2016 5:00 pm

Student: HASAN DARWISH(28218957)

Submission ID: 3d5b6e6d-3f61-4a4f-8829-46e1e03c4e1d
Submitted on: Apr 7, 2016 9:05 am

Attachments:
The Industrial Engineering Identity - PhD - Hasan Darwish.docx (308 KB)The Industrial Engineering Identity - PhD Colloquium - Hasan Darwish.pptx (1 MB)Title Registration - Hasan Darwish - PhD.pdf (4 MB)

Section B

To be completed by the scientific committee

	Yes	No	Refer: Formative Feedback
Research Topic			
Does the topic fall within the scope of the Research Group?	◉	○	○
Does the topic represent an important/key problem area that warrants research?	◉	○	○
Research Title			
Does the title reflect the content and full scope of the research proposal?	◉	○	○
Is the title concise (around 10 words) while at the same time being descriptive of the research?	◉	○	○
Background and Rationale			
Does the introduction lead the reader into the context and scope of the research topic?	◉	○	○
Is sufficient information provided to contextualise the research topic and the research problem?	◉	○	○
Is the rationale and/or justification clearly illustrated?	◉	○	○
Is sufficient motivation for doing the research provided?	◉	○	○
Literature Review			
Is the literature review relevant to the research topic, the problem statement and the overall purpose of the study?	◉	○	○
Is the literature review adequate and comprehensive enough to justify the proposed research?	◉	○	○
Does the literature review attend to relevant theories pertinent to the proposed study?	◉	○	○
Is the literature review properly integrated and synthesized, including a justification of an own point of view?	◉	○	○
Are terminology and concepts clearly defined and clarified?	◉	○	○
Purpose and Problem Statement			
Does the problem statement flow naturally from the introduction?	◉	○	○
Is the problem of practical and/or scientific significance which could lead to the creation of knowledge?	◉	○	○
Is the problem statement congruent to the research title?	◉	○	○
Is the problem statement congruent to the overall purpose of the research?	◉	○	○
Are the theory(ies), practical problems and/or prior research upon which the proposed study is built, clearly described?	◉	○	○
Research Objectives			
Do the research objective(s) flow naturally from the problem statement?	◉	○	○
Are the research objective(s) clearly and unambiguously formulated?	◉	○	○
Are the research objective(s) limited to the issues at stake in respect of the research?	◉	○	○

Research Method/Design			
Does the research design provide sufficient evidence of an understanding of research paradigms and philosphical approaches to research?	◉	○	○
Is the proposed research method appropriate for the proposed research problem?	◉	○	○
Are the specified research method(s) adequately justified?	◉	○	○
Are the research population and sampling procedures adequately described?	◉	○	○
Are the data collecting techniques and administering briefly described?	◉	○	○
Are the analysis techniques (quantitative and qualitative) briefly explained?	◉	○	○
Editing			
Are all the references in the text listed in the reference list?	◉	○	○
Are all the references in the reference list used in the text?	◉	○	○
Is the referencing technique throughout the text and the reference list?	◉	○	○
Are the references used adequately relevant and reliable for post-graduate research purposes?	◉	○	○
Is the language and grammar acceptable and without spelling errors?	◉	○	○

Formative Feedback

Did the scientific committee make a voice recording to capture formative feedback, whilst completing the checklists above? Are all members of the scientific commitee clearly identified and will you upload this voice recording, together with this form?

○ YES ◉ NO

If feedback is not provided by voice recording, please provide formative feedback on the issues indicated in the checklist

After some discussion the title was changed as indicated below.
The ethical issues of administering the proposed survey to students and industry was contemplated and the candidate is advise to attend ethics training and following appropriate procedures.

Recommendation

Please complete page in full:

Final Recommendation by Scientific Committee

1.	The research proposal is accepted by the scientific committee, without further changes.	◉
2.	The research proposal is accepted, provided that the formative feedback of the scientific committee is addressed under supervision of the supervisor/ promoter	○
3.	The student should rework the proposal, resubmit it and present it at another colloquium.	○
4.	The student should prepare a new proposal on a new topic.	○

Assessment of Ethical Risk:

1.	**No Risk**: There is no possible risk that the research may lead to any undesirable effects or unexpected negative consequence.	○
2.	**Minimal, Low or Negligible Risk**: The probability, magnitude or seriousness of unexpected negative consequences, harm or discomfort anticipated in the research is **negligible** and not greater than that ordinarily encountered in daily life ("Daily life" as a benchmark should be that of daily life experienced by the average person living in a safe "first world" country). Research in which the only foreseeable risk is one of **minimal unexpected negative consequences, discomfort or inconvenience.**	◉
3.	**Medium Risk**: Research in which there is a potential risk of unexpected negative consequences, harm or discomfort, but where appropriate steps can be taken to mitigate or reduce overall risk. Remedial interventions can be undertaken should harm occur.	○
4.	**High Risk:** Research in which there is a real and foreseeable risk of unexpected negative consequences, harm and discomfort, and which may lead to serious adverse consequences if not managed in a responsible manner.	○

Title as approved by the scientific committee	Expanding Industrial Thinking by Formalizing the Industrial Engineering Identity for the Knowledge Era

7 April 2016	Prof Liezl van Dyk	Liezl van Dyk
Date	**Name: Chair of Scientific Committee**	**Signature: Chair of Scientific Committee**

Name and signature: ***First Additional*** *Member of Scientific Committee (excluding supervisor)*

Prof Chris van Schoor — **Name:**

Signature:

Name and signature: ***Second Additional*** *Member of Scientific Committee (excluding supervisor)*

Prof. Hannelie Nel — **Name:**

Signature:

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Tel: 018 299-1111/2222
Web: http://www.nwu.ac.za

Faculty of Engineering
Office For Postgraduate Studies
Email: EngineeringPostgrad@nwu.ac.za

20 October 2016

28218957

H Darwish

After due consideration by the Postgraduate Committee of the Faculty of Engineering, the result of your title registration / amendment is as follows:

Degree registered for:	PhD in Development and Management Engineering
Main Study Leader:	Prof L van Dyk
Proposed Title	**Expanding Industrial Thinking by formalizing the Industrial Engineering identity for the knowledge era**
Commitee Result:	Approved
Committee Remarks (if any):	

Best regards,

Ms Landi Viljoen

Postgraduate Administrative Officer

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South Africa, 2520

Tel: (018) 299-1111/2222
Web: http://www.nwu.ac.za

PROOF OF REGISTRATION 2018

It is hereby certified that

HASAN DARWISH
(Date of birth: 1992/03/25)
(Student number: 28218957 - 2016)

is registered as a student on the **Potchefstroom Campus**
(NWU Faculty of Engineering)

for

DOCTOR OF PHILOSOPHY IN DEVELOPMENT AND MANAGEMENT ENGINEERING
Curriculum - DEVELOPMENT AND MANAGEMENT (I908P)

FULL TIME (Final)

Academic year : 2
Historical year : 3

Modules:
Module: H = core module; Module: X = non-core module; A = additional module

IIOB 9 71 (H)

Registration date: 2018/02/07 **Date of issue:** 2018/02/07

Last date of qualification and module amendments

Year Subject 2018/02/16

pp REGISTRAR

From: IEOM 2017 Conference <noreply@xcdsyste
To: hasandarwish@gmail.com
Date: Fri, Dec 9, 2016 at 7:52 PM
Subject: Acceptance of Doctoral Dissertation Competition - 2017 IEOM Morocco Conference

Acceptance of Doctoral Dissertation Competition - 2017 IEOM Morocco Conference

Dear Hasan:

Congratulations! The program and publication team has recommended that your doctoral synopsis (ID 354: Expanding Industrial Thinking by Formalizing the Industrial Engineering Identity for the Knowledge Era) has been accepted for presentation and publication as part of the IEOM Doctoral Dissertation Competition for the 7th International Conference in Industrial Engineering and Operations Management, Rabat, Morocco, April 11-13, 2017. It must be presented at the conference in Morocco to be considered for the Doctoral Dissertation Competition. The venue is Sofitel Hotel in Rabat.

Available Online [As part of 7th IEOM Conference Proceeds] at following address:
http://ieomsociety.org/ieom2017/papers/354.pdf

Proceedings of the International Conference on Industrial Engineering and Operations Management
Rabat, Morocco, April 11-13, 2017

Expanding Industrial Thinking by Formalizing the Industrial Engineering Identity for the Knowledge Era

Hasan Darwish
School of Industrial Engineering
North West University
Potchefstroom, North West Province, South Africa
PhD Engineering (Development and Management) Student
Hasan.Darwish@nwu.ac.za

Synopsis

To date, the formal identity of the Industrial Engineer remains vague. Due to the broad knowledge base and application areas made available to Industrial Engineers, pinning down the commonality has proven difficult. This problem is further magnified by global forces shaping the knowledge era. Various works touch on some elements that can help in forming an identity (such as IE skills, work preferences, thinking styles…etc) but they have not been combined into a common identity. To do so is no easy task but for the sake of the field it must be done. There is no doubt that IE knowledge is valuable and has proven itself, but employers rarely hire a person with the title Industrial Engineer (rather it is process engineer, supply chain manager…etc). Defining this brand and identity can massively improve awareness about the field itself, create a resource to refer students to and help develop new application areas for industrial thinking and modernization of industrial methods. A modern understanding of the role of the Industrial Engineer can be established (namely that they are the connection to all fields of knowledge and a master of some) by developing an Industrial Engineering Identity and exemplifying the industrial thinking style by means of case studies on facing or shaping disruptive forces on the knowledge era. The research presentation shows that the key requirements for the dissertation are the development of an Industrial Engineering identity, the definition of the unique features of Industrial thinking and the demonstrate the value gained by designing artefacts with this new identity in mind.

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Web: http://www.nwu.ac.za

Higher Degree Administration
Tel: 018 299 4124
Email: yolandie.combrink@nwu.ac.za

16/01/2018

Dear Mr Darwish

NOTICE OF SUBMISSION

Note has been taken that you wish to submit your dissertation/**thesis** for examination. The registered title as it must appear on the examining copies and on the title page of the final copies is indicated below. An example of your title page will be sent together with this letter.

Expanding Industrial Thinking by formalizing the Industrial Engineering identity for the knowledge era

Your attention is drawn to the following matters regarding the above. You may submit on

- **1 February until 16 March 2018 to qualify for the Winter graduation ceremony (July) in 2018**

No submission for examination for this ceremony will be accepted after 17 March 2018.

You are required to submit your examination copy in the format mentioned below.

O**ne electronic copy in Word format and one electronic copy in PDF format should be submitted on the eFundi website, under your faculty tab, in a drop box created for you for this purpose. (HIGHER DEGREES ENGINEERING 2018)**

The following forms should be included when you submit for examination:

- The signed Solemn Declaration form
- A copy of your identity document/passport
- Personal particulars form (only applicable for PhD students

Yours sincerely

Ms Yolandie Combrink

FOR REGISTRAR

Original details: Marietjie Ackermaann(10512128) C:\Users\10512187\Desktop\Notice of submission.docm

29 Nov 2016/File reference: 7.1.11.2.1

hasandarwish@gmail.com
Per e-mail

Private Bag X6001, Potchefstroom,
South Africa, 2520

Tel: +27(18) 299-1111/2222
Web: http://www.nwu.ac.za

Engineering Research Ethics Committee
Tel: 018 299 1317
Email:Willem.VanNiekerk@nwu.ac.za

11-Oct-2017

Dear **MR HASAN DARWISH**

APPROVAL OF MINIMAL RISK APPLICATION: NWU-HS-2017-0162

The following application has been reviewed by the Engineering Research Ethics Committee (EngREC) on 10-Oct-2017.

Name of student: HASAN DARWISH.
Name of supervisor/promoter: PROF LIEZL VAN DYK.
Title of study: Expanding Industrial Thinking by Formalizing the Industrial Engineering Identity for the Knowledge Era.
Application Risk Level: Minimal, low or negligible risk.

This letter serves to inform you that your application has been approved as a minimal risk study from **10-Oct-2017** to **09-Oct-2018.**

Special conditions of the approval (if applicable):
None.

Yours Sincerely

Mnr W.M.K van Niekerk
Chairperson: Engineering Research Ethics Committee (EngREC)

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South Africa, 2520

Tel: (018) 299-4900
Faks: (018) 299-4910
Web: http://www.nwu.ac.za

Institutional Research Ethics Regulatory Committee
Tel: +27 18 299 4849
Email : Ethics@nwu.ac.za

ETHICS APPROVAL CERTIFICATE OF STUDY

Based on approval by the **Engineering Research Ethics Committee (EngREC)** on **10/10/2017**, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby **approves** your study as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Project title: Expanding industrial thinking by formalizing the industrial engineering identity for the knowledge era

Project Leader/Supervisor: Prof Liezl van Dyk
Student: Hasan Darwish

Ethics number: N W U - HS - 2 0 1 7 - 0 1 6 2
(Institution | Year | Project Number)

Application Type: Single study
Commencement date: 2017-10-10 **Expiry date**: 2018-10-09 **Risk:** Minimal

Special conditions of the approval (if applicable):

- Translation of the informed consent document to the languages applicable to the study participants should be submitted to the EngREC (if applicable).
- Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the EngREC. Ethics approval is required BEFORE approval can be obtained from these authorities.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- *The project leader (principle investigator) must report in the prescribed format to the NWU-IRERC via EngREC:*
  - *annually (or as otherwise requested) on the progress of the study, and upon completion of the project*
  - *without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.*
  - *Annually a number of projects may be randomly selected for an external audit.*
- *The approval applies strictly to the proposal as stipulated in the application form. Would any changes to the proposal be deemed necessary during the course of the study, the study leader must apply for approval of these changes at the EngREC. Would there be deviated from the study proposal without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC via EngREC and new approval received before or on the expiry date.*
- *In the interest of ethical responsibility the NWU-IRERC and EngREC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the study;*
  - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the project are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the EngREC or that information has been false or misrepresented,*
    - *the required annual report and reporting of adverse events was not done timely and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*
- *EngREC can be contacted for further information or any report templates via Tania.Visser@nwu.ac.za or 018 285 2278.*

The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC or EngREC for any further enquiries or requests for assistance.

Yours sincerely

Prof LA Du Plessis
Digitally signed by Prof LA Du Plessis
Date: 2017.10.20 12:40:04 +02'00'

Prof Linda du Plessis
Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)

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Higher Degrees Administration

SOLEMN DECLARATION AND PERMISSION TO SUBMIT

1. Solemn declaration by student

I, **Hasan Darwish**

declare herewith that the thesis/dissertation/mini-dissertation/article entitled (**exactly as registered/approved title**),

Expanding Industrial Thinking by formalizing the Industrial Engineering identity for the knowledge era

which I herewith submit to the North-West University is in compliance/partial compliance with the requirements set for the degree:

Philosophiae Doctor in Development and Management Engineering

is my own work, has been text-edited in accordance with the requirements and has not already been submitted to any other university.

LATE SUBMISSION: If a thesis/dissertation/mini-dissertation/article of a student is submitted after the deadline for submission, the period available for examination is limited. No guarantee can therefore be given that (should the examiner reports be positive) the degree will be conferred at the next applicable graduation ceremony. It may also imply that the student would have to re-register for the following academic year.

Signature of Student: Hasan Darwish — Digitally signed by Hasan Darwish Date: 2018.01.31 09:05:30 +02'00'

University Number: 28218957

Signed on this 31 day of January of 20 18

2. Permission to submit and solemn declaration by supervisor/promoter

The undersigned declares that the thesis/dissertation/mini-dissertation complies with the specifications set out by the NWU and that:

- the student is hereby granted permission to submit his/her mini-dissertation/ dissertation/thesis:
  - (•) Yes ( ) No
- that the student's work has been checked by me for plagiarism (by making use of TurnItIn software for example) and a satisfactory report has been obtained:
  - (•) Yes ( ) No

Signature of Supervisor/Promoter: Liezl van Dyk (acting) — Digitally signed by Liezl van Dyk (acting) DN: cn=Liezl van Dyk (acting), o=North-West University, ou=Faculty of Engineering, email=liezl.vandyk@nwu.ac.za, c=ZA Date: 2018.02.06 05:49:53 +02'00'

Date: 2018-02-05

Original details: Marietjie Ackermann(10512187) R/SSupport doc's\SOLEMN DECLARATION AND PERMISSION TO SUBMIT.docm 28 july 2017

File reference: 7.1.11.3.2/3

Appendix C: Additional Courses Undertaken by Researcher (Ethics & Systems)

C1 – Basics of Health Ethics & New Roles of Ethics Committees

I hereby confirm attendance of both training sessions as per the recommendation made in the title registration form B4 in order to familiarize myself with the internal structures of the NWU for ethical clearance. The sessions provided valuable information but due to the nature of the research and the development of an internal ethics clearance committee within the Faculty of Engineering the researcher and supervisor agreed to follow the internal process. Additionally, no major ethical risks or conflict of interests were identified as part of this study (including the use of any personally identifying information which can harm human participants in any way).

NOTIFICATION OF RESEARCH ETHICS TRAINING FOR STAFF AND POST-GRADUATE STUDENTS
(RESEARCH WITH HUMAN PARTICIPANTS)

19-20 April 2016

Dear Staff and Post-graduate students

Following the promulgation of the new Department of Health and the National Health Research Ethics Council (NHREC) document in June 2015, it has become a legal requirement for all researchers applying for ethical approval to provide proof of formal training in research ethics over the past three years. As the Ethics Office of the Faculty of Heath Sciences, NWU, we will start to apply this rule as from **June 2016.**

For permission to apply for ethics approval to the **Health Research Ethics Committee** (HREC), the letter of attendance of the two day training entitled, "The Basics of Health Research Ethics" (as indicated below), will be sufficient *or* an appropriate online course if you are unable to attend the training (See letter on compulsory modules of TRREE circulated earlier this year via Karen Tredoux).

The following training session will occur as indicated below:

The Basics of Health Research Ethics

Date: 19-20 April 2016 (Both days must be attended in full to obtain the letter of attendance)

Time: 08:00 to 16:30

Venue: Building G20, 101

Presenters: Prof Minrie Greeff

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Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: http://www.nwu.ac.za

Health Sciences Ethics Office for Research, Training and Support

Tel: 018 299 2092
Email: minrie.greeff@@nwu.ac.za

6 April 2016

Dear chairpersons and vice-chairpersons of Scientific/Proposal Committees

Invitation to attend a training session on the "New Roles of Scientific/Proposal and Ethics Committees"

The changes in the *governance of science and research ethics* on the campus have led to a need for a short training session to prevent future confusion. You as chairpersons and vice-chairpersons of Scientific/Proposal Committees are cordially invited to attend a three hour training session on the new roles of Scientific/Proposal Committees. You are welcome to bring other members of your committee along.

The training will focus on:

- What does a scientific/proposal committee have to review?
- What does a research ethics committee have to review?
- How do you interpret risk levels if humans or animals are involved in the research or if there is the possibility of an environmental impact?
- How do you decide on which REC to involve?
- How do you communicate your decision to the appropriate REC?

Detail about the training:
Name of the course: New Roles of Scientific and Ethic Committees
Date: 6 May 2016
Time: 09:00 – 12:00
Venue: Building N2B – Room G02
Registration is required by completing the attached registration form and sending it to **poncho.molaudzi@nwu.ac.za** before 26 April 2016.

Kind regards,

Prof Minrie Greeff
Head of the Faculty of Health Sciences Ethics Office

Original details: (23239522) C:\Users\23239522\Google Drive\Letter head.docm
6 April 2016

Certificate of Completion

This certifies that

Hasan Darwish

has completed the 5 day professional development course:

Systems Engineering

15 April 2016
Date of Completion

PROJECT PERFORMANCE
INTERNATIONAL

Alwyn Smit
Course Presenter

This course is recognised by Engineers Australia for CPD purposes (40 hours).
This course may be credited toward the maintenance of the INCOSE Certified Systems Engineering Professional (CSEP) accreditation for 40 Professional Development Units.
This course is recognised by ECSA South Africa (ref. INCOSE 15/027) for CPD 5 points.



Southern African
Systems Analysis Centre

Emerging Researchers' Programme
21 August – 9 September 2016

This certificate is proudly awarded to

Hasan Darwish

for the completion of the above programme

Congratulations

Professor Mary Scholes
Co-Director: SASAC
University of the Witwatersrand

Appendix D: Article Supporting Documents

D1.1 – Article 1: Research Output Administrative Details

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Faculty of Engineering

Journal Output Submission

THIS OUTPUT BELONGS TO THE FOLLOWING RESEARCH GROUP:
Industrial Engineering

Journal Information

Journal Name
South African Journal of Industrial Engineering

Type
National

Accredited
Yes

Accreditation Type
Scopus

Volume
27

Number
3

1 Year Impact Factor
0.188

5 Year Impact Factor
0.192

ISSN / ISBN Number of Journal
2224-7890

Title of Paper
The Industrial Engineering Identity: From Historic Skills to Modern Values, Duties and Roles

Paper Start Page
50

Paper End Page
63

Supporting Documentation

Upload Copy of Paper
- 1638-5834-1-PB.pdf

Journal Output Submission

1st Author

Type
Staff

Author's Research Group Affiliation
Industrial Engineering

NWUNumber
28218957

Name
MR Hasan Darwish

2nd Author

Type
Staff

Author's Research Group Affiliation
Industrial Engineering

NWUNumber
24827533

Name
Prof Liezl van Dyk

General Remarks

Remarks
Primary Author: Hasan Darwish
Supervisor and Co Author: Prof Liezl van Dyk

Submission Details

Submitted by:
Hasan Darwish

Submitted on:
17/11/2016

Journal Output: South African Journal of Industrial Engineering

D1.2 – Article 1: Author Guidelines

All submissions must as per the following guidelines.

1. It is required that all authors have their draft article reviewed for language proficiency before submitting. Sometimes excellent submissions have to be drastically amended or even rejected because of linguistic ineptitude.
2. The editors reserve the right to make minor editorial adjustments without consulting the author.
3. The use of abbreviations should be avoided as far as possible.
4. Manuscripts of no longer than 15 pages (5 000 - 6 000 words) must be submitted in MS Word format.
5. Authors are required to conform to the instructions and format below.
6. A Word template for use by authors is available for downloading:- ZIP or DOTX (The DOTX does not always open correctly, depending on the browser, so if it does not download, rather download the ZIP version and unzip.)
7. The Trebuchet font at 9-point size, single spacing and a page margin of 20 mm along the sides and 20 mm at the top and 25 along the bottom, gutter 10 mm, gutter position left, with full justification, should be used on B5 paper size. Header and footer layout 15 mm.
8. Figures and tables should fit within the prescribed margins and should form an integral part of the article and be numbered consecutively in Arabic numerals. Labelling and lettering of figures and tables should be Trebuchet at 8-point size.
9. References in the text should be by author with the reference number in square brackets e.g. Li[1]. The required reference format is illustrated below.
10. The Title Page should conform to the following centered format. The text of the article should only start on the next page.
11. Photographs must be supplied in TIFF or JPEG format at least 300 dpi for good quality reproduction.
12. Authors need to use email addresses associated with their institutions, using the institution's domain. Personal e-mail addresses such as gmail.com, yahoo.com etc. are not allowed. (Authors may request an exception if no institution email address is available)

Submission Preparation Checklist

As part of the submission process, authors are required to check off their submission's compliance with all of the following items, and submissions may be returned to authors that do not adhere to these guidelines.

1. The submission has not been previously published, nor is it before another journal for consideration (or an explanation has been provided in Comments to the Editor).
2. The submission file is in a Microsoft Word 2007 or later file format, and adheres to the style sheet available for download from the Author guidelines. (Submissions not conforming to the journal's style will be rejected)
3. Where available, URLs for the references have been provided.
4. The text adheres to the stylistic and bibliographic requirements outlined in the Author Guidelines, which is found in About the Journal.
5. The instructions in Ensuring a Blind Review have been followed, and all author details have been removed from the initial review copy.
6. Author email addresses provided are email addresses associated with the author's institution, using the institution's domain, and are not personal "for free" addresses such as gmail.com, or yahoo.com. (An author may request an exception to this rule, if no other address is available, by loading a proof of identity as a supplemental file)

7. Author acknowledges the following fee structure for 2016:
    - Submission Fee: USD175 for international submissions and R1250 for South African Submissions.
    - Publication Fee: USD275 for international submissions and R2250 for South African Submissions.

    You will be notified when these fees are payable.

8. Author acknowledges that a review takes on average 6-12 months to complete. Following these guidelines helps for a speedy review. Not following these guidelines causes delay, and may result in a submission rejection.

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1. Authors retain copyright and grant the Journal right of first publication with the work simultaneously licensed under a Creative Commons Attribution License that allows others to share the work with an acknowledgement of the work's authorship and initial publication in this Journal.
2. Authors are able to enter into separate, additional contractual arrangements for the non-exclusive distribution of the Journal's published version of the work (e.g., post it to an institutional repository or publish it in a book), with an acknowledgement of its initial publication in this Journal.

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Author Fees

This journal charges the following author fees.

SUBMISSION FEE:-: 1250.00 (ZAR)

Authors are required to pay an Article Submission Fee as part of the submission process to contribute to review costs.

- R1250 for articles with a South African affiliation
- USD175 for international articles.

Important:- it is not necessary to pay the submission fee until the editor had confirmed suitability and plagiarism is completed, after which you will be invoiced.

Very Important*: Please select the "**Payment has already been sent**" option at the bottom of the final submission screen of the submission process **even if you have not paid yet**. You will only be invoiced once we have confirmed a successful submission. If you do not select this checkbox, your submission will not be considered as submitted by the system, and we will not know that you have submitted.*

Guest editorial

"At least I know who I was when I got up this morning, but I think I must have been changed several times since then."

From "Alice's Adventures in Wonderland & Through the Looking Glass" by Lewis Carroll

This is one of the quotes by mathematician and logician, Charles L. Hodgson (better known by his pen name, Lewis Carroll) that inspired the theme and many conversations at the recent conference of the Southern African Institute for Industrial Engineering (SAIIE), held in Parys, North-West Province. Within a timespan of two months, three communities of concern to Industrial Engineering held their annual conferences in South Africa:

- the 27th annual conference of SAIIE (SAIIE27) (27-29 Oct 2016),
- the 45th annual conference of the Operations Research Society (ORSSA) (11-14 September 2016) and
- the 17th annual international conference of the Rapid Product Development Association of South Africa (RAPDASA) (2-4 November 2016).

To promote the high quality of work delivered to these conferences and to encourage authors to present some of their best research, we introduced the Special Edition of the journal in which the best research presented at the abovementioned conferences would be published. I am honoured to be the guest editor for the special conference edition of this journal.

The same double blind peer review process and criteria used for the journal were also used in this selection process, and the feedback from all reviewers was used to score submissions to create a shortlist. Each submission on the shortlist then underwent an additional round of review, where a senior peer reviewer confirmed the selection, and the editor of the journal confirmed the suitability.

As a consequence, this special edition has a total of 25 articles, making this the edition with the most articles in the history of the journal. Of these 25 articles,

- sixteen originated from SAIIE27 out of a total of 68 peer reviewed papers,
- ORSSA contributed two articles out of 85 presentations and from
- RAPDASA, seven articles were selected out of 37.

The identity and focus of the three respected communities that contributed to this edition are reflected by the papers contributed by each. However, overarching themes of concern for South African Industrial Engineers are mirrored in all the papers: energy and natural resource management; advanced information and manufacturing technology; decision support as well as new innovation and organizational paradigms and approaches, without neglecting the human factors: the well-being of employees and the experience of customers.

For many authors this is the first time that their work is published in a full academic journal. I trust that this experience has provided them with the confidence and enthusiasm to keep on contributing to the knowledge base of Industrial Engineering. I hope that this will be an annual edition, taking research in Industrial Engineering and its associated disciplines forward.

Liezl van Dyk
Guest Editor and Programme Director: SAIIE 27

From: "Liezl van Dyk" <liezlvandyk@gmail.com> Friday - August 7, 2016 11:52 PM
To: Hasan.Darwish@nwu.ac.za
Subject: [SAIIE27] Editorial Decision on Paper

Dear Mr Hasan Darwish:

We are pleased to let you know that the paper, " The Industrial Engineering Identity: From Historic Skills To Modern Values Duties And Roles", which you submitted for the 27th Annual Conference of the Southern African Institute for Industrial Engineering was selected for inclusion in the special edition of the Southern African Journal for Industrial Engineering (SAJIE), provided that revisions are applied to the satisfaction of all reviewers (refer to comments below).

Reviewer A:

Does the paper make a contribution to the field of industrial Engineering in terms of theory, methodology or practice?
Yes. Contribution also in terms of theory or methodology. May also be suitable for a journal paper.

Please comment on the contribution of the paper (optional):
This is very important work for the IE discipline, and I would love to see this in SAJIE. However, the research rigour is a little lacking, and this makes me think that it needs a little more work to get it to journal standard.

Does the paper relate to what has already been written in the field?
Yes

Please comment on the related to field content of the paper (optional)

Are the arguments employed valid and supported by the evidence presented?
Yes. Some of the evidence and arguments are still lacking, because some work is still in progress. Suitable for conference proceedings.

Please comment on the arguments and evidence (optional):
Refer my comments in the text - what is lacking it the argumentation how you get to your identity statements and the identity levels

Is the paper clearly structured, easy to read and with a logical flow of thought?
Yes

Please comment on the structure of the paper (optional):
The author uses a nice writing style, that is easy to read. Sometimes a little too informal and imprecise perhaps.

Please comment on the conclusions of the paper (optional):

Please comment on the language and style of the paper (optional):

Reviewer B:

Does the paper make a contribution to the field of industrial engineering in terms of theory, methodology or practice?
Yes. Definitely be suitable for a journal paper.

Please comment on the contribution of the paper (optional):
Yes, the paper provides a new and interesting perspective regarding. The identity of the industrial engineer, phrased as “connected to all trades and masters of some”. The a

Does the paper relate to what has already been written in the field?
Yes

Please comment on the related to field content of the paper (optional):

The authors draw on existing knowledge to develop an IE identity model. The paper relates to different Neuro Logical Levels in Figure 2. It is suggested that the model is first explained prior to applying the model when formalizing an IE identity. Figure 3: Should Level 3 not be expanded in terms of disciplines and knowledge areas? Of perhaps indicate that the list is not exhaustive.

Are the arguments employed valid and supported by the evidence presented?
Yes. Evidence and arguments are comprehensive enough to be considered for publication as a journal article.

Please comment on the arguments and evidence (optional):
Claims are well-referenced. Further research is suggested to obtain evidence from the IE community whether they adopt or agree with the IE identity model.

Is the paper clearly structured, easy to read and with a logical flow of thought?:
Yes

Please comment on the structure of the paper (optional):

Please comment on the conclusions of the paper (optional):
The conclusion is interesting, but a new problem is defined in the conclusion, i.e. challenges in educating generation Z. The numbered conclusions do not flow logically from the newly-developed IE identity model. It is suggested that the authors suggest opportunities for applying the IE identity model, indicating how the new model would impact both education and industry if the IE community adopts the model. It is also suggested that the authors suggest further research to confirm whether the existing IE community agrees with the IE identity model.

Please comment on the language and style of the paper (optional):
Small errors – see mark-up.

Reviewer C:

Does the paper make a contribution to the field of industrial engineering in terms of theory, methodology or practice?
No

Please comment on the contribution of the paper (optional):
The paper is eccentric and a bit unusual. Although its contribution to the discipline of Industrial Engineering is limited, its contribution to understanding the nature of the profession is considerable.

Does the paper relate to what has already been written in the field?
No

Please comment on the related to field content of the paper (optional):

I am not familiar with the extended literature of this domain, however I feel confident that the paper makes a considerable contribution.

Are the arguments employed valid and supported by the evidence presented?:
Yes

Please comment on the arguments and evidence (optional):
Is the paper clearly structured, easy to read and with a logical flow of thought?
Yes

Please comment on the structure of the paper (optional):
The paper is well written and contains logical ideas in a neatly structured flow. Again, structurally, this paper differs considerably from a standard industrial engineering article

Please comment on the conclusions of the paper (optional):

Please comment on the language and style of the paper (optional):

From: "Liezl van Dyk" <liezlvandyk@gmail.com> Friday - August 19, 2016 6:56 PM
To: Hasan.Darwish@nwu.ac.za
Subject: [SAIIE27] Submission Acknowledgement

Mr Hasan Darwish:

Thank you for your submission, "The Industrial Engineering Identity: From Historic Skills To Modern Values Duties And Roles" to SAIIE27. With the online conference management system that we are using, you will be able to track its progress through the editorial process by logging in to the conference web site:

Reviewer A:

Please indicate which of the following applies:
This paper is ALMOST camera ready for publication in the Special Edition of the SA Journal for Industrial Engineering. Minor revisions are suggested below. The final check can be done by the journal director.

Please outline specific revisions required (if applicable):
Nice work and nearly all comments address sufficiently. However I suggest that you expand on the 8 levels at the back though. See uploaded document (Don't worry if you exceed page length - inSAJIE we only frown when it starts to exceed 20 pages...)

Reviewer B:

Please indicate which of the following applies:
This paper is ALMOST camera ready for publication in the Special Edition of the SA Journal for Industrial Engineering. Minor revisions are suggested below. The final check can be done by the journal director.

Please outline specific revisions required (if applicable).:
Some of the language errors indicated during the first review were not corrected: "ad Sparrius" instead of "Ad Sparrius" similar structure Fig. 2" should be "similar structure than Figure 2 "one of the most prominent belief" should be "one of the most prominent beliefs"

NORTH-WEST UNIVERSITY
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NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS
Faculty of Engineering

Output Submission

Research Group Affiliation

Output Year
2017

THIS OUTPUT BELONGS TO THE FOLLOWING RESEARCH GROUP:
Industrial Engineering

Output Information

Output Type
Conference

Type
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Output Title
Gamifying the In dustrial Engineering Profession

Publisher
Industrial Engineering and Operations Management Society

Publication Name
Proceedings of the 7th International Conference on Industrial Engineering and Operations Management

Name of Conference
7th International Conference on Industrial Engineering and Operations Management

City
Rabat

Country Where Held
Morocco

Conference Start Date
11/04/2017

Conference End Date
13/04/2017

Output Submission

ISBN
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Start Page
1148

End Page
1161

Total Pages Claimed
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Supporting Documentation

Copy of Paper
- Paper-347-Gamifying-the-Industrial-Engineering-Profession-Hasan-Darwish.pdf

Proceedings
- Conference-Programme-IEOM-7th.pdf

Proof of Peer Review
- 7th-IEOM-Peer-Review-Process-Confirmaiton.pdf

1st Author

Type
Engineering Staff

Surname, Initials
Darwish HD

NWUNumber
28218957

General Remarks

Remarks
The proceeds are available online and not in pdf. Link: http://www.xcdsystem.com/ieom/2017Annual/index.html

Submission Details

Submitted by:
Hasan Darwish

Submitted on:
04/06/2017

Conference: Gamifying the In dustrial Engineering Profession

D2.2 – Article 2: Author Guidelines

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The international Conference on IEOM has developed the following responsibilities for authors, reviewers and our Editorial Board and expects all parties to adhere to these guidelines:

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IEOM Society is organizing Seventh International Conference on Industrial Engineering and Operations Management in Rabat, Morocco, April 11-13, 2017. ***Venue is Hotel Sofitel Rabat Jardin des Roses.***

Authors can submit full paper(s) or abstract(s) only. IEOM Society encourages to submit full paper(s). All full papers will be subjected to double peer review. Accepted papers will be published in the Proceedings. Any submission implies that an author will attend IEOM 2017 Rabat Conference and present the paper or abstract.

Deadlines

Abstract/Paper Submission: November 15, 2016 (Extended)
Review Feedback: November 30, 2016
Final Paper: **January 31, 2017**

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International Conference on Industrial Engineering and Operations Management
Rabat, Morocco, April 11-13, 2017

April 11, 2017

To whom it may concern:

Peer-Review Process / Confirmation

(1) On behalf of IEOM 2017 Morocco Conference Committee, I like to confirm that that the manuscripts were peer-reviewed by two (2) or more technical specialists. The review process is conducted anonymously.

(2) The conference proceedings are available online and are indexed by Scopus.

(3) This conference provides formalised peer-review reports (PRR); in case no commentary has been provided – then this letter attests that the peer-review process (PRP) yielded in acceptance of the articles.

If you have any question, please contact Dr. Taufiq (Conference Secretariat) at taufiq@ieomsociety.org.

Regards,

Ahad Ali, Ph.D.
Conference Co-Chair – IEOM 2017 Rabat
Executive Director – IEOM Society International
Associate Professor of Lawrence Technological University, Southfield, Michigan, USA
ahad@ieomsociety.org

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From: "IEOM 2017 Conference" <noreply@xcdsystem.com>
To: hasandarwish@gmail.com
Date: Mon, Dec 12, 2016 at 2:29 PM
Subject: Paper Acceptance - 2017 IEOM Morocco Conference

Paper Acceptance - 2017 IEOM Morocco Conference

Dear Hasan:

Congratulations! The program and publication team has recommended that your paper (ID 347: Gamifying the Industrial Engineering Profession) has been accepted for presentation and publication for the 7th International Conference in Industrial Engineering and Operations Management, Rabat, Morocco, April 11-13, 2017. The venue is Sofitel Hotel in Rabat. Full paper will be indexed in Scopus subject to fulfilling IEOM formatting and quality guidelines.

The paper has been accepted with minor revision. Please address the review comments which are available online and upload a final (revised) version of your paper in MS Word no later than December 31, 2016. If you would like to see the review feedback, please login to your IEOM 2017 Morocco submission account: https://www.xcdsystem.com/IEOM/abstract/index.cfm?ID=2ntobg6.

***Note:** Comments on uploaded document were minor formatting and grammatical changes

Review # 1

Recommendation:

Accept

Comments:

1. The author developed gamified web-based platform providing work & networking opportunities and linked to mobile application that will help provide continuous learning & assessment for IE. Noble method. Well written paper.

2. The title suitable and adequate

3. The literature references adequate and up to date

4. No logical errors

5. Necessary descriptions for all figures and tables are provided

6. the summary and conclusion bring out the main points of the paper

Review # 2

Recommendation:

Accept

Comments:

None



International Conference on Industrial Engineering and Operations Management (IEOM), Rabat, Morocco, April 11-13, 2017

Best Track Paper Award – 2017 IEOM Morocco Conference

The quality of the entries made it difficult for the judges to select the best track paper for the 7th International Conference on Industrial Engineering and Operations Management, Rabat, Morocco, April 11-13, 2017. After considering all entries, IEOM Society International is pleased to announce that your paper has been awarded the ***Best Track Paper*** *for the 2017 IEOM Morocco Conference:*

Engineering Education Track
ID 347: Gamifying the Industrial Engineering Profession
Hasan Darwish
School of Industrial Engineering
North West University
Potchefstroom, North West Province, South Africa

Awards will be given at the IEOM Conference Award Dinner during IEOM 2017 Conference at Sofitel Hotel Ballroom on April 12, 2017. Please make sure to attend conference award dinner and receive the award. We need a digital photo of each author for award presentation. Please send a high resolution picture.

All of IEOM Society joins me in extending to you our sincere congratulations for being selected from a list of outstanding papers. I wish you continued success in your career and look forward to your continued professional involvement with IEOM Society International.

We look forward to seeing you in Rabat, Morocco.

Sincerely,

Dr. Ahad Ali, Conference
Co-Chair – IEOM 2017 Rabat
Associate Professor, Lawrence Tech University, USA
www.ieomsociety.org/ieom2017/ ahad@ieomsociety.org

Dr. Ilham Kissani
Conference Co-Chair – IEOM 2017 Rabat
Assistant Professor, Al Akhawayn University, Ifrane, Morocco
I.Kissani@aui.ma

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International Conference on

Industrial Engineering and Operations Management

Rabat, Morocco, April 11 – 13, 2017

Best Track Paper Award

This award is presented to

Hasan Darwish

Department of Industrial Engineering, North West University South Africa

In Recognition of the Outstanding Research Paper entitled
"Gamifying the Industrial Engineering Profession"
In *Engineering Education Track* for 2017 in the 7th IEOM Conference at Hotel
Sofitel Rabat Jardin des Roses, April 12, 2017.

Dr. Ilham Kissani
Conference Co-Chair – IEOM 2017
Al Akhawayn University, Ifrane, Morocco

Dr. Ahad Ali,
Conference Co-Chair – IEOM 2017
Lawrence Technological University, MI, USA

Dr. Mohammed Khadem
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Sultan Qaboos University, Oman

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Conference Output Submission

THIS OUTPUT BELONGS TO THE FOLLOWING RESEARCH GROUP:
Industrial Engineering

Conference Information

Conference Name
27th Annual Conference of the SA Institute for Industrial Engineering

Country Where Held
South Africa

City Where Held
Parys

Conference Start Date
27/10/2016

Conference End Date
29/10/2016

Proceedings

Title of Proceedings
Proceedings of the 27th annual Southern African Institute for Industrial Engineering Conference, 27-29 Oct, Stonehenge, Parys, South Africa

Publisher
Southern African Institute for Industrial Engineering (SAIIE)

ISBN
978-1-86822-671-9

Title of Paper
The impact of major environmental, social and economic forces on the field of industrial enigineering

Paper Start Page
525

Paper End Page
535

Total Pages Claimed
10

Supporting Documentation

Copy of Paper
- The-impact-of-major-environmental-social-and-economic-forces-on-the-field-of-industrial-enigineering-H.-

Proceedings
- SAIIE-27th-Conference-

Proof of Peer Review
- Double-Blind-Peer-Review-

Conference Output Submission

Darwish-2737.pdf | Proceedings.pdf | SAIIE-27-Prof-Liezl.pdf

1st Author

Type
Staff

Author's Research Group Affiliation
Industrial Engineering

NWUNumber
28218957

Name
MR Hasan Darwish

Submission Details

Submitted by:
Hasan Darwish

Submitted on:
12/12/2016

Conference Output: 27th Annual Conference of the SA Institute for Industrial Engineering

All submissions must as per the following guidelines.

13. It is required that all authors have their draft article reviewed for language proficiency before submitting. Sometimes excellent submissions have to be drastically amended or even rejected because of linguistic ineptitude.
14. The editors reserve the right to make minor editorial adjustments without consulting the author.
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20. Figures and tables should fit within the prescribed margins and should form an integral part of the article and be numbered consecutively in Arabic numerals. Labelling and lettering of figures and tables should be Trebuchet at 8-point size.
21. References in the text should be by author with the reference number in square brackets e.g. Li[1]. The required reference format is illustrated below.
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12. The text adheres to the stylistic and bibliographic requirements outlined in the Author Guidelines, which is found in About the Journal.
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15. Author acknowledges the following fee structure for 2016:
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    - Publication Fee: USD275 for international submissions and R2250 for South African Submissions.

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PREFACE



The vision of the Southern African Institute for Industrial Engineering (SAIIE) states: "We are a vibrant, learned society, representing and promoting Industrial Engineering in Southern Africa". SAIIE's annual conference epitomizes this vision by bringing together academics and professionals from all over the country and abroad to share best practices and new knowledge concerning Industrial Engineering.

The first call for papers was sent out almost a year ago. About 10% of the initial 163 responding authors opted from the onset for the *Abstract and Presentation Only* track, which does not require a full paper. The remaining 90% of submissions were made to the *Abstract and Full Peer-reviewed Paper* track. These papers were provisionally approved on the basis of an abstract, followed by a double-blind peer review process.

Of the 163 initial abstracts, 68 full papers successfully passed the double-blind peer review process. Of these 68 papers, 52 papers appear in these proceedings. The remaining 16 papers were diverted to a special edition of the *Southern African Journal for Industrial Engineering* (SAJIE).

All review comments and editorial decisions taken during the process have been recorded and can be traced by means of the online conference management system used for this conference. In an effort to avoid any possible conflict of interest, the reviewers were usually not from the same institution as the author to whose papers they were allocated. When the reviewers recommended minor improvements, the final checks were performed by only one of the two reviewers and the programme director. When major improvements were required, both reviewers were involved in a second (and in some cases, a third) review round. All papers published in these proceedings passed this double peer-reviewed process.

This conference has culminated in three outputs:

1. The **conference proceedings** (this document) is an electronic document that will be distributed on USB Flash drives to all delegates. It contains the full-length papers that were submitted, reviewed and approved for the "Full Peer Reviewed Track", excluding those diverted to the special edition of SAJIE. The proceedings are also available online to ensure that it remains accessible and indexed by scholarly search engines.
2. An abstract of each conference presentation is printed in the **conference programme and abstract book**. This includes papers printed in these proceedings, those diverted to the special edition of SAJIE, as well as all the other non-peer-reviewed submissions (presentations, workshops and keynote speakers).
3. Sixteen papers from this conference will be published in a **special edition of SAJIE**.

We trust that you will enjoy interacting with the authors of the papers that appear in these proceedings and other delegates of the 27th Annual SAIIE Conference, and, in doing so, being part of this "vibrant and learned society, presenting and promoting Industrial Engineering in South Africa".

Prof Liezl van Dyk
Faculty of Engineering, North-West University
Proceedings Editor
October 2016

From: "Liezl van Dyk" <liezlvandyk@gmail.com> Monday- July 25, 2016 10:57 AM
To: Hasan.Darwish@nwu.ac.za
Subject: [SAIIE27] Editorial Decision on Paper

Mr Hasan Darwish:

Thank your for your submission to SAIIE27. Congratulations, after a careful review of your submission, "The Industrial Engineers' Perception of Major Forces Changing the Environmental, Economic and Social Landscape" will be considered for publication in the SAIIE27 proceedings, if the revisions indicated below are successfully implemented.

Reviewer A:

Does the paper make a contribution to the field of industrial Engineering in terms of theory, methodology or practice?
Yes. Contribution also in terms of theory or methodology. Will definitely be suitable for a journal paper.

Please comment on the contribution of the paper (optional):

Does the paper relate to what has already been written in the field?
Yes, to some extent

Please comment on the related to field content of the paper (optional)

Are the arguments employed valid and supported by the evidence presented?
Yes. Evidence and arguments are comprehensive enough to be considered for publication as a journal article.

Please comment on the arguments and evidence (optional):
Refer my comments in the text - what is lacking it the argumentation how you get to your identity statements and the identity levels

Is the paper clearly structured, easy to read and with a logical flow of thought?
Yes

Please comment on the structure of the paper (optional):
Methodology needs explanation

Please comment on the conclusions of the paper (optional):

Please comment on the language and style of the paper (optional):

Reviewer B:

Does the paper make a contribution to the field of industrial engineering in terms of theory, methodology or practice?
A well-chosen topic, well argued. An interesting paper on an interesting and relevant topic.

Please comment on the contribution of the paper (optional):
Well researched, well-argued and well presented. A worthy paper for the conference. Some edits still required as several typing and grammatical errors through the paper." Therefor my view is that the paper is certainly suitable for the conference.

Does the paper relate to what has already been written in the field?
Yes

Please comment on the related to field content of the paper (optional):
The paper builds on what has been written in the field and builds on it.

Are the arguments employed valid and supported by the evidence presented?
Yes.

Please comment on the arguments and evidence (optional):
The evidence and arguments are comprehensive enough to be considered for publication as a journal article.

Is the paper clearly structured, easy to read and with a logical flow of thought?
Yes

Please comment on the structure of the paper (optional):
The paper is clearly structured, easy to read and with a logical flow of thought.

Please comment on the conclusions of the paper (optional):
The conclusions are clear and valid and present the field with a challenge on the way forward.

Please comment on the language and style of the paper (optional):
The paper conforms to accepted academic and conference standards. The paper is certainly of a standard that could be published in the conference proceedings. It is certainly of the standard to make a good oral presentation.

Reviewer C:

Does the paper make a contribution to the field of industrial engineering in terms of theory, methodology or practice?
Yes. Suitable for conference proceedings.

Please comment on the contribution of the paper (optional):
It draws attention to IMPACT OF MAJOR ENVIROMENTAL, SOCIAL AND ECONOMIC FORCES ON THE FIELD OF INDUSTRIAL ENIGINEERING

Does the paper relate to what has already been written in the field?
Yes, to some extent

Please comment on the related to field content of the paper (optional):
But these current referencing is inadequate, and so this is not clearly demonstrated in the paper.

Are the arguments employed valid and supported by the evidence presented?:
Yes. Evidence and arguments are somewhat limited to a specific case. Suitable for conference proceedings.

Please comment on the arguments and evidence (optional):
Is the paper clearly structured, easy to read and with a logical flow of thought?
Yes

Please comment on the structure of the paper (optional):
But the additive manufacturing thread is introduced too late in the paper

Please comment on the conclusions of the paper (optional):

Please comment on the language and style of the paper (optional):
The language is colloquial and conversational, and need to be more formal in many places



Southern African Institute for
Industrial Engineering

Best Poster Presentation at the

27th Annual SAIIE Conference

for the paper

THE IMPACT OF MAJOR ENVIROMENTAL, SOCIAL AND ECONOMIC FORCES ON THE FIELD OF INDUSTRIAL ENIGINEERING

Hasan Darwish

Date of issue : 29 October 2016

President

A vibrant, learned society representing and promoting Industrial Engineering in Southern Africa

Journal of Industrial Integration and Management
Innovation & Entrepreneurship

For more information, please visit the JIIM website at http://www.worldscientific.com/worldscinet/jiim

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The title should be descriptive and concise. In addition, an abbreviated title (no more than 50 characters) to be used as a running head should be supplied.

The abstract should be brief, self-contained, explicit, and should not exceed 200 words.

Equations should be numbered sequentially in parentheses by the right margin. Equations and formulas should include the appropriate punctuation.

Table captions should be placed immediately above the table, while figure captions should be placed immediately below the figure.

References cited in the text should be listed at the end of the manuscript. They should be listed in alphabetical order of the first author's surname. References should not be numbered.

Authors should submit a short statement (not more than 150 words) on important aspects of their professional career such as degrees obtained, positions held, research interests, and journals in which they have previously published.

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Authors are reminded that submission of a manuscript to JIIM is held to imply that it contains original unpublished work which is not under consideration for publication elsewhere.

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D4.2 – Article 4: Proof of Submission

From: "J. of Industrial Integration (JIIM)" <em@editorialmanager.com> Sunday - January 28, 2018 9:13 PM

To:

Subject: JIIM: Submission Confirmation for BOTTOM OF PYRAMID 4.0: MODULARISING AND ASSIMILATING INDUSTRIAL REVOLUTION COGNITION INTO A 4-TIERED SOCIAL ENTREPRENEURSHIP UPLIFTMENT MODEL FOR PREVIOUSLY DISCONNECTED COMMUNITIES

Dear Mr Hasan Darwish,

Your submission entitled "BOTTOM OF PYRAMID 4.0: MODULARISING AND ASSIMILATING INDUSTRIAL REVOLUTION COGNITION INTO A 4-TIERED SOCIAL ENTREPRENEURSHIP UPLIFTMENT MODEL FOR PREVIOUSLY DISCONNECTED COMMUNITIES" has been received by Journal of Industrial Integration and Management: Innovation and Entrepreneurship

You will be able to check on the progress of your paper by logging on to Editorial Manager as an author. The URL is https://jiim.editorialmanager.com/.

Your submission entitled "BOTTOM OF PYRAMID 4.0: MODULARISING AND ASSIMILATING INDUSTRIAL REVOLUTION COGNITION INTO A 4-TIERED SOCIAL ENTREPRENEURSHIP UPLIFTMENT MODEL FOR PREVIOUSLY DISCONNECTED COMMUNITIES" has been assigned the following manuscript number: JIIM-D-18-00004.

Thank you for submitting your work to this journal.

With kind regards

Journal of Industrial Integration and Management: Innovation and Entrepreneurship

Journal of Industrial Integration and Management: Innovation and Entrepreneurship

BOTTOM OF PYRAMID 4.0: MODULARISING AND ASSIMILATING INDUSTRIAL REVOLUTION COGNITION INTO A 4-TIERED SOCIAL ENTREPRENEURSHIP UPLIFTMENT MODEL FOR PREVIOUSLY DISCONNECTED COMMUNITIES

--Manuscript Draft--

Manuscript Number:	
Full Title:	BOTTOM OF PYRAMID 4.0: MODULARISING AND ASSIMILATING INDUSTRIAL REVOLUTION COGNITION INTO A 4-TIERED SOCIAL ENTREPRENEURSHIP UPLIFTMENT MODEL FOR PREVIOUSLY DISCONNECTED COMMUNITIES
Article Type:	Research Paper
Keywords:	Social Entrepreneurship; Upliftment Model; Industry Development; Learnership; Micro Franchise; Bottom of Pyramid; Industrial Engineering; Industrial Revolution
Corresponding Author:	Hasan Darwish, MEng,MA,BEng North-West University





Ethical Guidelines for Authors

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All authors must declare they have read and agreed to the content of the submitted manuscript.

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Competing interests

Authors must declare all potential competing interests involving people or organisations that might reasonably be perceived as relevant. [See Appendix for examples.]

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Plagiarism in any form constitutes a serious violation of the most basic principles of scholarship and cannot be tolerated. Examples of plagiarism include:

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Medical writers, or anyone else who assisted in the preparation of the manuscript, should be acknowledged in the manuscript, either as an author, or in the Acknowledgements section, as per the guidelines of the European Medical Writers Association. Medical writers should list their source of funding and/or employer as appropriate.

Experimental research on humans must have been approved by an appropriate ethics committee and comply with the Helsinki Declaration.

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Appendix

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Examples of competing interests include but are not limited to financial, professional and personal interests such as:

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Appendix E: Verification and Validation

E1 – NWU M & D Guidelines

The topic:

- Is the topic demarcated meaningfully, appropriate and is it worthy of research?
- Is the research design scientifically based?

Problem statement, aims or central theoretical statement:

- Are they formulated clearly and unambiguously, do they link up and have a bearing on one another?
- Is the problem statement scientifically relevant and are the aims clear?

The research method:

- Does the study show that the student adequately control the theoretical basis?
- Is the research method suitable, selected in a critical and accountable manner, and described clearly?
- Is there evidence that the student properly controls the methods and/or techniques?
- Is the student's own contribution clear in the case of a multidisciplinary study or project, and also the scientific processing, content and contribution that the work makes?
- Is the work systematic, logically developed, and well-structured and balanced?
- Do the chapters form meaningful units?
- Does the content reveal in-depth knowledge of the research field?
- Is there evidence that the student can interpret and argue in a scholarly manner, discuss different views and theories critically, and where necessary motivate his/her own views?
- Is the final summary meaningful and does it reflect the character of the study clearly?
- Is the relative meaning of the study presented briefly?
- Do the conclusions fit in with the problem statement and aims of the study?
- Does the student make meaningful recommendations that may be followed up by other studies?
- Does the student provide meaningful and convincing solutions to problems?
- Are the aims of the study achieved satisfactorily?
- Is adequate attention given to the internal as well as external validity of the findings and interpretation?
- Does the work display originality (in the case of doctoral study) with regard to the retrieval and/or development of knowledge?
- Can the work or parts of it be published? Is the work subject-philosophically and scientifically theoretically accountable (where applicable)?

- In the case of theses, is proof given of a definite contribution to the knowledge of and insight into the subject, and does the work provide proof of independent thinking and that the student has the ability to work and conduct research independently?

Study of sources:

- Does the student provide proof of a thorough knowledge of the related literature and of an argumentative, critical and integrated handling of it, or is the literature merely used as far as it supports the student's own views?
- Has the correct available and related literature been consulted and used in an acceptable manner?
- In the case of qualitative studies, has an adequate literature review been carried out?

Language and style, technical composition, care and finish:

- Is the student's style of writing and expression up to standard, can the text be read easily (with respect to font size, typing format and spacing) and was it language-edited?
- Does the (mini-)dissertation/thesis, as far as technical care is concerned, comply with the requirements (title page, table of contents, footnotes, reference technique, graphs, figures and tables, list of sources)?
- Does the document contain a summary in the language in which it was written, as well as annexures of relevant research documents?
- Are the printing and binding of acceptable quality?

E2 – Semi Structured Interview Questions

Expanding Industrial Thinking by Formalizing the IE Identity for the Knowledge Era
PhD Validation - Semi Structure Interviews

Email address *: _____ (Confidential)

INTRODUCTION: Fellow Industrial Engineering professional, you are kindly invited to participate in a 30-45 minute semi-structured interview being conducted by Hasan Darwish, a PhD Eng student at NWU. The interview focuses on the findings of the PhD Thesis titled: Expanding Industrial Thinking by Formalizing the Industrial Engineering Identity for the Knowledge Era. The focus of this PhD is to take a forward looking at the field given the massive macro-disruptive forces shaping the knowledge era. More specifically, it tries to define Industrial Thinking and propose a Systemigram tool which combines the sub-specializations of IE (supply chain, optimization, strategic thinking...etc.) into one process. You were selected as a participant for your experience and/or contribution to the field of Industrial Engineering in academia and/or industry. PURPOSE: This survey is an important part of the validation of a PhD thesis findings. PROCEDURES: The questionnaire is made up of 7 sections each with 5 statements which you need to evaluate according to the given scale of how much you agree with this statement. Room is given for open ended feedback. Your feedback on this survey is very important, and all inputs count. TIME: This will take you approximately 30-45 minutes to complete. RISKS: No potential risks or discomfort are involved with the completion of this survey. CONFIDENTIALITY: Please note that your response is private and confidential. Individual respondents will not be identified in any data or reports since the validation is with aggregate data. However, A copy of your response will be emailed to you to verify it with yourself. RECORDINGS: No voice or video recordings of any kind are made at any stage whatsoever. DATA STORAGE: The collected data will be stored with a password-protected username on Google Drive and will be accessible only by the principle investigator and supervisor. ETHICS NUMBER: NWU-HS-2017-0162 RIGHTS OF RESEARCH PARTICIPANTS: You may withdraw your consent and exit this survey at any time. If you have any questions about this survey or would like further information, please contact Hasan Darwish at the Industrial Department at NWU on +27 71 897 1448 or Hasan.Darwish@nwu.ac.za

I hereby voluntarily grant my permission for participation in the semi-structured interview as explained to me by Mr Hasan Darwish. All issues related to privacy, the confidentiality and the use of the information I will provide, have been explained above to my satisfaction.

By agreeing to participate, you acknowledge the following: - I have read the above information and it is written in a language with which I am fluent and comfortable - I understand that taking part in this study is voluntary and I have not been forced to take part - I may choose to leave the study at any time - I am aware that the results of the investigation may be used for the purposes of publication [Mark only one oval].

- ○ Yes, I grant my permission and accept
- ○ No, I do not accept and want to exit

**** Scale Meanings:** [1] Whole-Hearted Endorsement [2] Agreement with minor point of contention [3] Support with reservations (I can live with it) [4] More discussion needed [5] Abstain (Does not affect me) [6] Don't like but will support [7] Serious disagreement [8] Veto (I block this proposal)

II1 - Country and University in which IE Degree was Obtained [Open Ended]:

_____

II2 - Countries and Industries in which you have Worked [Open Ended]:

_____

II3 - Description of Interviewee [Open Ended]:

_____

II4 - Years of IE Relevant Experience [Mark only one oval].

- 1-3 Years
- 4-5 Years
- 6-8 Years
- 8-10 Years
- 10-20 Years
- 20-30 Years
- 30+Years

II5 - How would you describe Industrial Engineering:

_____

II6 - Classification [Mark only one oval].

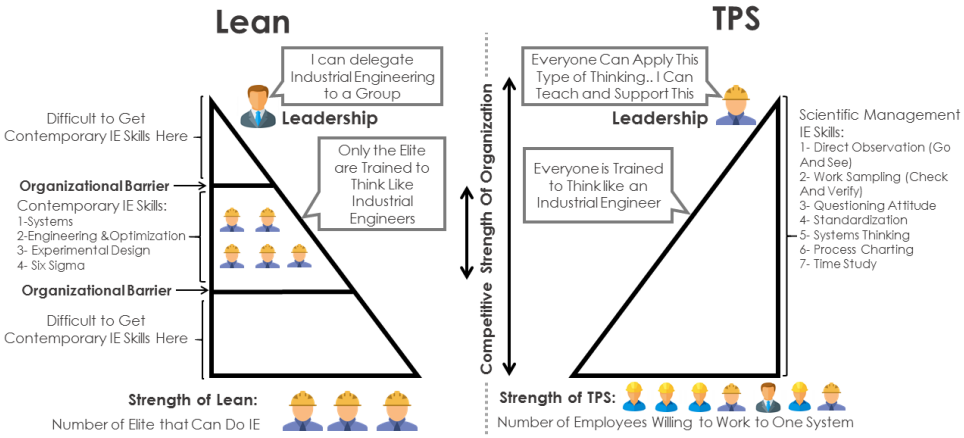
- Industrial Engineering Pioneer
- Industrial Engineering Academic
- Industrial Engineering Professional
- Industrial Engineering Venturist

Chapter 1-5: Research Statements

How does an IE think that makes him valuable?

A unique thinking style is shared by industrial engineers that is not often articulated. This goes beyond process thinking (shared with chemical engineering), shares some tools with (but is different from) systems thinking, and contains strands of creativity and entrepreneurial thinking but with a different end goal in mind. That being said, it is absolutely clear that systems, process, creative, and entrepreneurial thinking are vital to the industrial engineer. Yet IE solutions would be lacking without some Industrial Thinking (the real crux of what makes an industrial engineer unique). Few articles use the term 'Industrial Thinking' or offer a proper definition of it — although collectively they clarify the idea. Industrial thinking "must begin by differentiating value for the customer from munda — the Japanese term for waste" ; it is needed "within research in academia… [due to] the obvious discrepancy between state of the art in robotics research versus actual utilized technology". "Prefabrication action is a good example of when building industry is utilizing Industrial Thinking". The Industrial Thinking style is peculiar. On one hand, it appears to have evolved naturally with a changing economy and in on the other hand it seems that it is an increased awareness that can be developed. Existing descriptions focus on a central feature of Industrial Thinking which is its birth during the shift of society from pre-industrial to industrial. For example, "one place to look for examples of what changed in thinking styles is the famous French revolution that started in 1789. The people of France wanted a change. They couldn't know that they were asking for a change from good agricultural thinking to good Industrial Thinking." For Industrial Thinking, there are inescapable impulses to consider certain concepts: supply and demand, optimization, standardization, end goal, scale,

work, value, and human extraction and perception of value. However, Industrial Thinking was often viewed as reserved and developed by an elite within an industry. This often lead to a disregard for the greater social good or environmental sustainability. There are examples of applied Industrial Thinking that was shared with and expected of workers as well as managers. Perhaps the best approach which embodies this idea is Toyota's Production System (TPS). Yet, no account of Industrial Thinking within the context of the knowledge era and Industry 4.0 exists.



OE0.1 - Do you feel that there is a common thinking style strongly present amongst industrial engineers that can be called "Industrial Thinking"? Is it available in us by virtue of being industrious? Should it be codified or made explicit? How would you define it? Is it available in others? *Similar to Systems Thinking. [Open Ended]:

_____

_____

_____

S0.1: Research Overview - Industrial engineers appear to share a common way of thinking and the ability to instigate it in others, yet, unlike other fields this seems to be largely implicit and difficult to communicate with society at large *Especially current post-industrial knowledge era aspirations such as transparency and environmental sustainability [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S0.2: System Context - This is a problematic situation. In order to resolve it, an interpretive systems approach (Pluralistic-Complex) must be taken to create an idealized state and take steps to realize it *Pluralistic as in taking multiple points of view. Complex as in the nature of the system. This includes a taking a multi or even trans-disciplinary approach in understanding and then resolving [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S0.3: Research Framework - A significant conceptual gap exists that hinders the evolution of Industrial Thinking within the Industrial Engineering profession which would

need to be closed in order for the thinking style to become more harmonious with environmental considerations and social culture & concerns [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S0.4: Research Methodology - The development of an Industrial Thinking Systemigram which accurately reflects the aspirations and asymmetrical knowledge unique to the profession (by addressing cultural stream and systemic changes) is instrumental in ensuring beneficial proliferation of the thinking style necessary for progressive resilience in the face of macro challenges of the knowledge era *Systemigram: System Diagram. Can be used to guide the thought process and act as a 'methodology' **Cultural and Systemic streams as per 2 streams soft system methodology [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S0.5 - Research Area of Concern - A system of systems view reveals two streams: The systemic starting with the Industrial Engineer, reveals 5 macro systems which deserve attention: The industrial engineer, The Profession, The Economy, Society, The Environment. These concerns can be addressed in separate articles [Due to system considerations] whilst discussing the combined 'culture' stream surrounding Industrial Thinking [Which is addressed collectively] *What is meant by system consideration is that macro issues tend to be resolved differently than operational issues **Culture is the current collectively accepted practices and approaches used by the society (profession) involved in it [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

OE0.2 - Research Summary Open Ended Feedback

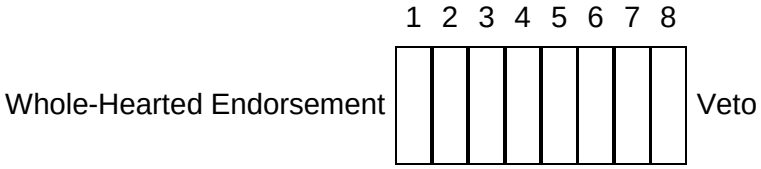
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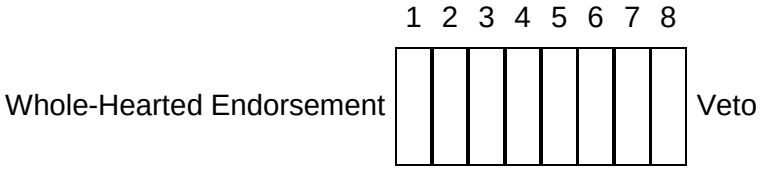
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Chapter 6: Article 1
PhD Area of Concern 1 Argument Evaluation [Professional]

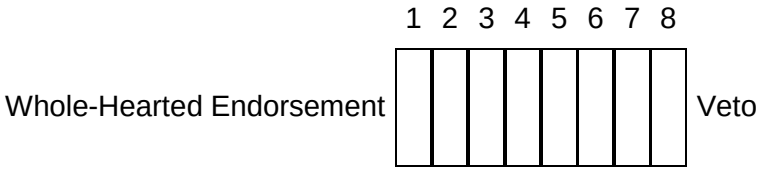
S1.1: Historically, industrial engineers were seen as jacks of all trades but masters of none [Mark only one box].



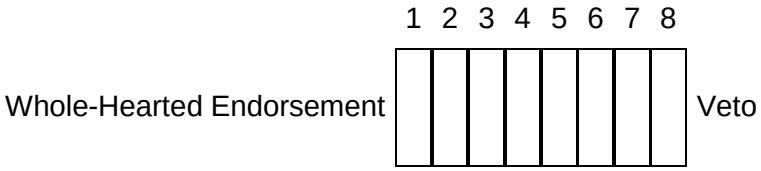
S1.2: The view above is one of the reasons that hindered the progression of a formal identity [Mark only one box].



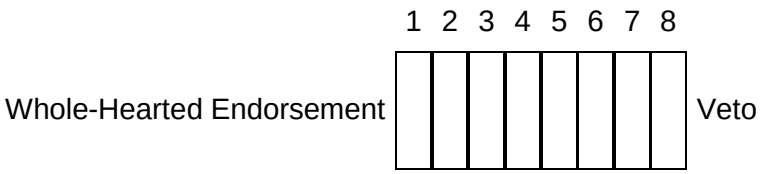
S1.3: The commonality between the thinking style and sub-disciplines tools used in Industrial Engineering is that they focus on designing balanced solution for Industry [Mark only one box].



S1.4: A critical review of the current state of IE finds that the modern identity is centered around being connected to various fields of knowledge whilst being masters of some [Mark only one box].



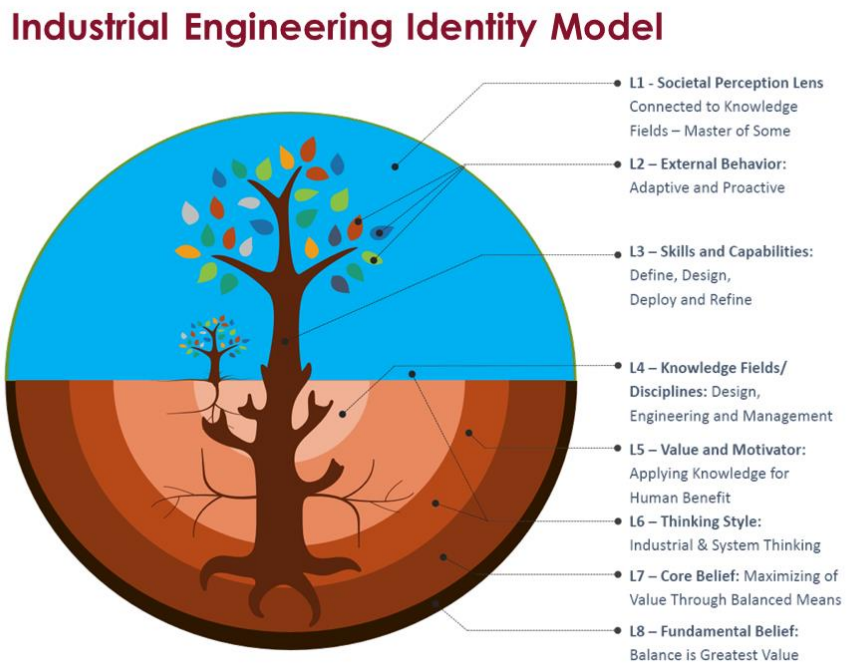
C1 - Conclusion 1 [Desirable Systemic Change]: In order to hold true to their professional identity (IE-ID) of designing balanced solutions, an industrial engineer must continuously advance their interdisciplinary awareness (to connect) and cognitive abilities (to master) [Mark only one box].



OE1.1 - Article 1 Supporting Argument Open Ended Feedback

Article 1 Evaluation

Over the past 100 years, engineering has sub-divided into tens of disciplines in an attempt to deal with the different problems arising from the wide spectrum of human endeavors. One particular field, however, arose from problems relating to industry, interdisciplinary integration, growth, balance, and connectedness. This field is known as industrial engineering (IE). Yet the IE identity and role, although useful, often remains vague. This article presents a review of the factors that made IE what it is today, as well as the fields differentiating the skills. It begins with a brief historical overview of the factors that shaped IE. More importantly, though, the article focuses on the modern identity (made up of the values, roles, and duties) of industrial engineers in the 21st century. This is done by showing that the long-standing cliché of industrial engineers being 'jacks of all trades and masters of none' has actually become 'connected to all trades and masters of some' due to a significant evolution of skills and identity. An industrial engineering identity (IE-ID) tree model is developed by extracting concepts and elements from existing identity models to give structure to the IE-ID model. The model is then populated with questions and answers arising from the literature review. To conclude, the future utility of such a model is anticipated.



OE1.2 - What do you conclude from the abstract and action taken above? Is this a desirable systemic change? How can this model help develop the Industrial Engineering Profession & Industrial Thinking? *How do you see it being used (Industry or Education)?

Chapter 7: Article 2
PhD Area of Concern 2 Argument Evaluation [Profession]

S2.1: Engineering education in the knowledge era (21st century) requires a significant amount of experiential learning and work-based learning to successfully transfer knowledge [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S2.2: Current entrants into university belong to generation Y and Z and their exposure to technology and games from birth suggests that gamification techniques can be an effective teaching method [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S2.3: The Baader-Meinhof Phenomenon (see or hear something everywhere after initial contact) can be used to reinforce certain concepts within different contexts which can strengthen the recollection and application abilities of students [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S2.4: The Industrial Engineering community works in various environments. Sharing insights and resources from the different environments (which are currently dispersed) can help in strengthening relationships throughout the profession [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

C2 - Conclusion 2 [Desirable Systemic Change]: In the knowledge era, it becomes vital for professional communities to create knowledge & resource sharing platforms that act as incubators and places to congregate for initiatives that can further develop the profession and attract the next generation of entrants into IE [Mark only one box].

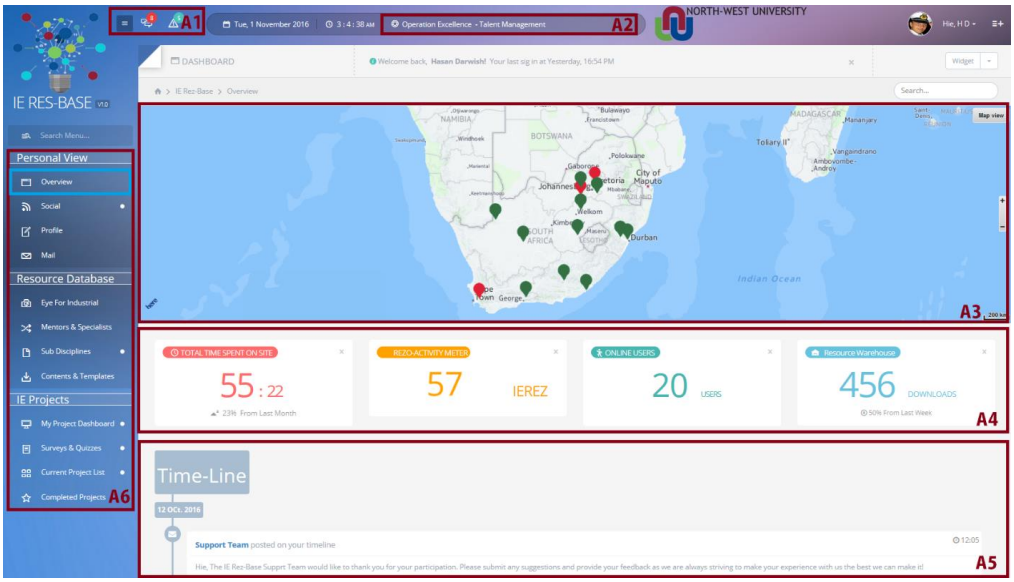
1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

OE2.1 - Article 2 Supporting Argument Open Ended Feedback

Article 2 Evaluation

An age-old problem facing higher education institutes is the verification that the knowledge taught in class was actually learnt and internalized. Many consider that the quality of education is to be measured on this basis. Historically, institutions have developed knowledge assessment mechanisms and resources which are aligned with the type of knowledge being transferred. Yet, in many cases, the time-bound nature of these assessments, the broader applicability of available resources, as well as the lack of appropriate opportunities (to learn from failure) can result in certain knowledge retention abilities instead of genuine understanding and life-long learning. The importance of dealing with this problem is further highlighted when considering generation Y and Z students who, unlike most of their lecturers, have spent most their life exposed to the internet, mobile applications and other technologies. Although several literature resources and commercial software packages deal with elements of this problem through gamification and education dashboards, a holistic system is yet to be proposed. This article consolidates the various needs of high school students, undergraduate students, lecturers and industry sponsors using system analysis and engineering tools. These inputs were used to prototype a gamified web-based platform providing work & networking opportunities and linked mobile application that help provide continuous learning & assessment.



OE2.2 - What do you conclude from the abstract and action taken above? Is this a desirable systemic change? How can this model help develop the industrial engineering profession & industrial thinking? *How do you see it being used (industry or education)?

Chapter 8: Article 3
PhD Area of Concern 3 Argument Evaluation [Economy]

S3.1: Means of production are becoming decentralized and simpler due to 3D printing & additive manufacturing [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S3.2: Employment mechanisms, corporate structures and customer behavior are becoming more network like due to the sharing and knowledge economy
[Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S3.3: Supply chains are becoming shorter due to transport technologies creating radically different supply/demand relationships [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S3.4: Human concerns and values relating to education, health and other concerns are becoming more conscious [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

C3 - Conclusion 3 [Desirable Systemic Change]: Since Industrial Engineering is deeply rooted in designing and managing the above socio-technical systems, transdisciplinary frameworks need to be created using Industrial Thinking to correctly evaluate the impact of macro-disruptors and successfully react to them. [Mark only one box].

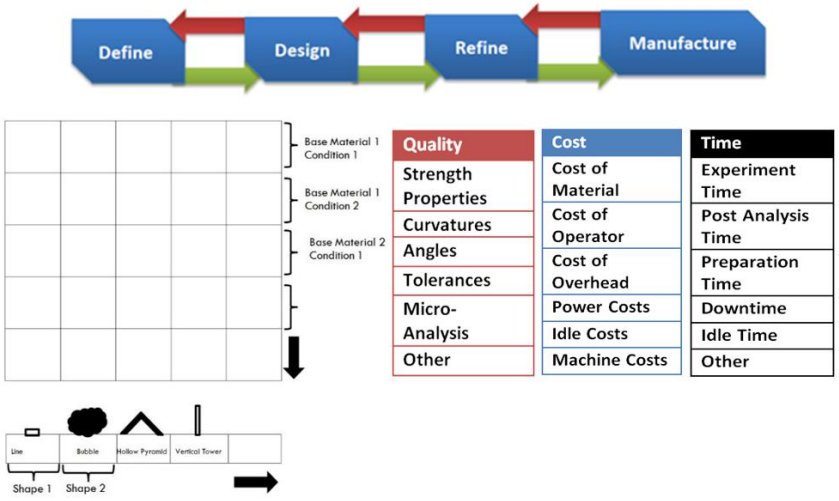
1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

OE3.1 - Article 3 Supporting Argument Open Ended Feedback

Article 3 Evaluation

Every profession is bound to adapt in response to changes in the macro environments. Industrial Engineering is especially affected due to its broad application across various fields, i.e. manufacturing, customer service design, consulting and more. This article argues that the need for change is envisaged to be radical due the deep-rootedness of Industrial Engineering in specific areas where environmental, social and economic (ESE) forces are prompting fundamental transformation. This transformation often manifests itself in an evolving technology. Therefore, Industrial Engineering must adapt to these changes due to its connection with these fields. This article further addresses the major forces impacting Industrial Engineering from 3 starting points: top down (macro-landscape challenge view), bottom-up (technology impact view) and middle ground (IE sub-discipline point of view).



OE3.2 - What do you conclude from the abstract and action taken above? Is this a desirable systemic change? How can this model help develop the industrial engineering profession & industrial thinking? *How do you see it being used (Industry or Education)?

Chapter 9: Article 4
PhD Area of Concern 4 Argument Evaluation [Society]

S4.1: The societal type currently existing in the knowledge era and experiencing the fourth industrial revolution is not post-industrial but post-post-industrial
[Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S4.2: This society is better named the network society; its extraction of value mainly stems from an ability to be connected, collaborate and leverage networks (which has evolved as a cognitive function over 4 industrial revolutions) **Similar to the power of devices in Industry 4.0 being based on the ability to be connected in the broadest sense of the word [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S4.3: What was previously known as the bottom of the pyramid society is, in this scenario, the outer network society and rarely experience the full benefit and value added by Industry 4.0 and the knowledge era due to a lack of appropriate systems in place [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S4.4: Industrial Engineering was founded on ensuring that society (from employees to customers) have a voice in shaping the products and systems that ultimately service them [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

C4 - Conclusion 4 [Desirable Systemic Change]: Since the majority of society (80%) lives in the outer network, it is fundamental for industrial engineers to design new systems that connect them to resources (in the broadest sense) that can help them develop socio-economically and cognitively to be able integrate to global network society *Knowledge is included as a resource [Mark only one box].

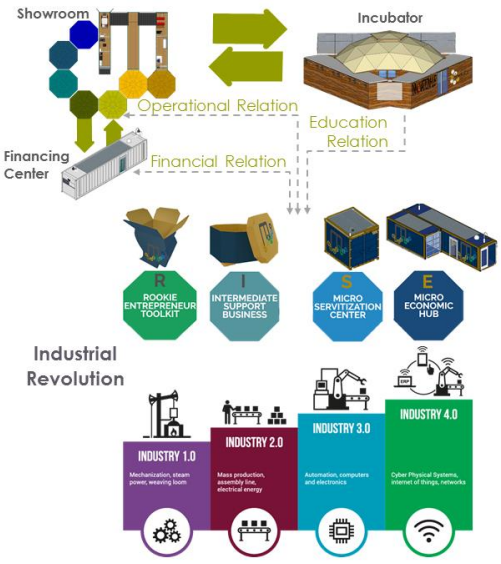
1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

OE4.1 - Article 4 Supporting Argument Open Ended Feedback

Article 4 Evaluation

Developing an entrepreneurial ecosystem is a long-term investment. Much like natural ecosystems, such as the amazon, the multitude of support systems needed to maintain balance and diversity is immense. Various Universities and private companies have succeeded in creating hubs of creativity in different cities around the world. These hubs have achieved commendable results and produced quality entrepreneurs. Yet, there is little success beyond the walls of cities and especially when this is mixed with low income status. Bottom of Pyramid (BoP) Entrepreneurs must either move to cities to make their entrepreneurial ambitions come true or settle for small business status. The article identified 3 core support structures that lead to this unfortunate entrepreneurial brain drain: Education, Operation and Finance. Moreover, a general issue with developing successful initiatives to overcome the structural support problem is the lack of appropriate systems that help bridge cognitive challenges of being exposed to Industry 4.0 futuristic technologies without the proper incentivized build up. This has, in the past, lead to many great initiatives quickly becoming liabilities due to improper incentive structures. Using Industrial Engineering principles and systems thinking; this article designed a product range and upliftment model that helps resolve most of the issues with developing a sustainable social entrepreneurial ecosystem. This is collectively known as the ModulaRISE model. The model has already been launched on a small scale with preliminary pilot case study showing significant promise. The vision is to develop a fully turn-key upliftment in a box model for BoP communities which connects them to the world and allows them to collaborate to mutually enrich their and the global society.



OE4.2 - What do you conclude from the abstract and action taken above? Is this a desirable systemic change? How can this model help develop the industrial engineering profession & industrial thinking? *How do you see it being used (Industry or Education)?

Chapter 10: Article 5
PhD Area of Concern 5 Argument Evaluation [Environment]

S5.1: Beyond biological factors, various psychological factors form the identity of the modern human being which have led to the term Homo Industrialis; By virtue of being industrious, the human being wishes to adapt their environment to better suit their needs [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S5.2: Even though this nature has existed for centuries, its professional function was only formalized relatively recently in the IE field since industrial engineers display more of this industrious behavior as well as understanding the systems perspective surrounding it [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S5.3: However, this behavior can, if remained unchecked, lead to significant societal and environmental decay especially when the terminology used to describe it is value laden with growth as opposed to balanced measures [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

S5.4: Yet, Industrialization is absolutely necessary for development but its current form is environmentally and socially destructive which can be partially attributed to a slow integration of global developments into the terminology and philosophies taught in industry and educational institutes [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

C5 - Conclusion 5 [Desirable Systemic Change]: IE is one of the fields affected by this problem which can be largely resolved by adapting some of the IE body of knowledge to reflect developments in biomimesis and a modern understanding of human needs [Mark only one box].

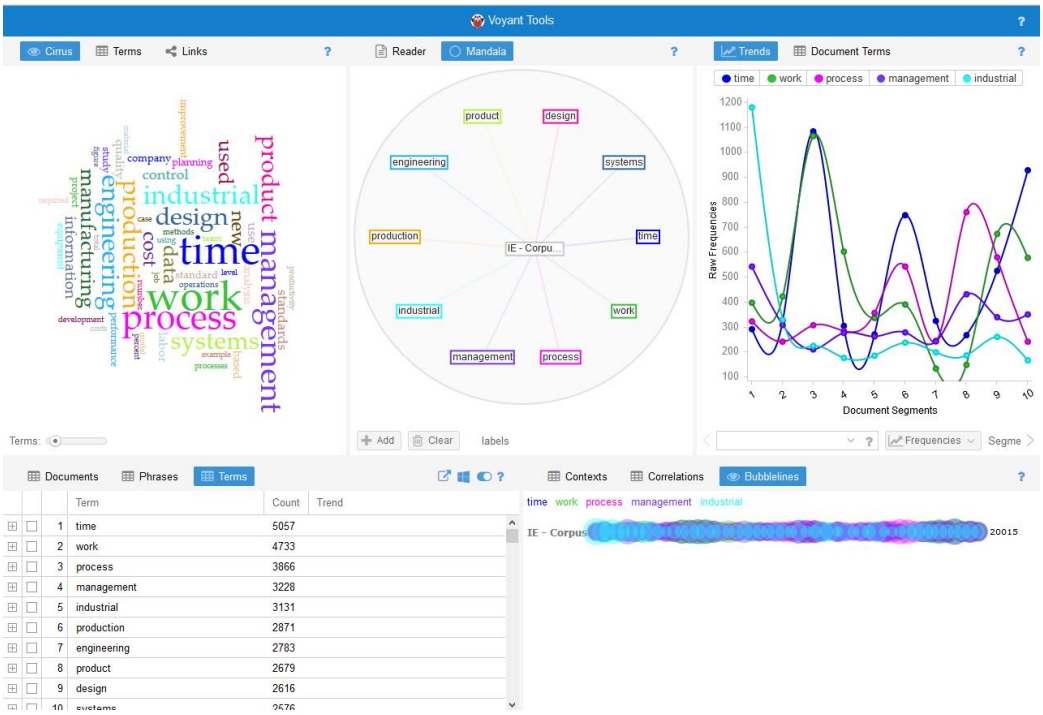
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Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

OE5.1 - Article 5 Supporting Argument Open Ended Feedback

Article 5 Evaluation

In his famous book 'In the footsteps of Homo Industrialis' Frank Sperotto discuss the development of Industrial Engineering, its complimentary thinking style and the industrious nature of the human being over the timespan of millennia. Undoubtedly, Industrial Thinking philosophies have served human development. Yet, the restricted boundary of consideration and value laden formulations of key industrial terminologies, concepts and thoughts has led to undesirable manifestations. Over time, this led to destructive environmental and social decay which is highly problematic for the knowledge era. This article aims to reformulate key philosophies of Industrial Engineering and its sub-disciplines from literature sources to be more adaptable and harmonious to knowledge era situations. A corpus analysis of the 5th edition of the 'Handbook for Industrial Engineering' is conducted for identification of terms and philosophies. Prominent literary sources containing definitions for these terms are reviewed and used as inputs to formulating a generalizable and harmonious definitions using biomimesis and Manfred-Max Neef fundamental human need. Furthermore, the prospective proliferation and impact of this research is discussed.



OE5.2 - What do you conclude from the abstract and action taken above? Is this a desirable systemic change? How can this model help develop the industrial engineering profession & industrial thinking? *How do you see it being used (industry or education)?

Chapter 11: Industrial Thinking
PhD Golden Thread Argument

ES-C1-IT: The associated thinking style of the industrial engineer must hold true to developments in the IE Identity. Thus: Industrial Thinking must develop to be more focused on balanced solutions rather than growth solutions [Mark only one box].

**C1: In order to hold true to their professional identity (IE-ID) of designing balanced solutions; an industrial engineer must continuously advance their interdisciplinary awareness (to connect) and cognition abilities (to master).*

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

ES-C2-IT: It is important to collaboratively engage all stakeholders in shaping the future of a profession if one hopes to get their support. Thus: Industrial Thinking must develop strong transparent interfaces that echo the values of the profession [Mark only one box].

**C2: In the knowledge era, it becomes vital for professional communities to create knowledge & resource sharing platforms that act as incubators and places to congregate for projects & initiative that can further develop the profession and attract the next generation of entrants into IE*

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

ES-C3-IT: The diversity of macro-tech disruptions requires lean and resilient nature. Thus: Industrial Thinking must entail strong management elements and abilities to leverage technologies [Mark only one box].

**C3: Since industrial engineering is deep-rooted in designing and managing the above socio-technical systems; transdisciplinary frameworks need to be created using Industrial Thinking to correctly evaluate the impact of macro-disruptors and successfully react to them*.

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

ES-C4-IT: The loss of diverse societies and ecologies is unacceptable in the knowledge era. Thus: Industrial Thinking demands a holistic understanding of possible negative consequences and must counteract them (possibly even contributing positively to the impacted ecology) [Mark only one box].

**C4: Since the majority of society (80%) lives in the outer network, it is fundamental for industrial engineers to design new systems that connect them to resources (in the broadest sense) that can help them develop socio-economically and cognitively to be able integrate to global network society*

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

ES-C5-IT: Not catering for environmental and social needs can result in devastating scenarios. Thus: Industrial Thinking must inherently involve mechanisms to evaluate and promote the most feasible optimal course of action [Mark only one box].

**C5: IE is one of the fields affected by this gap which can be largely resolved by adapting some of the IE body of knowledge to reflect developments in biomimesis and a modern understanding of human needs*

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

OC - Overarching Conclusion [Desirable Cultural Change]: Industrial thinking is the cognitive ability to conceptualize balanced industrious solutions which create value for all of society in an ecologically beneficial manner. This is achieved by uncovering optimal courses of action which guide the management of resources supported by technologies. Furthermore, using sound system design processes, progress is assessed and evaluated against expected impact on society and the environment. These elements work together like an industrial ecology *Industrial Ecology is a set of industries working together to better process waste [Mark only one box].

1 2 3 4 5 6 7 8

Whole-Hearted Endorsement ☐☐☐☐☐☐☐☐ Veto

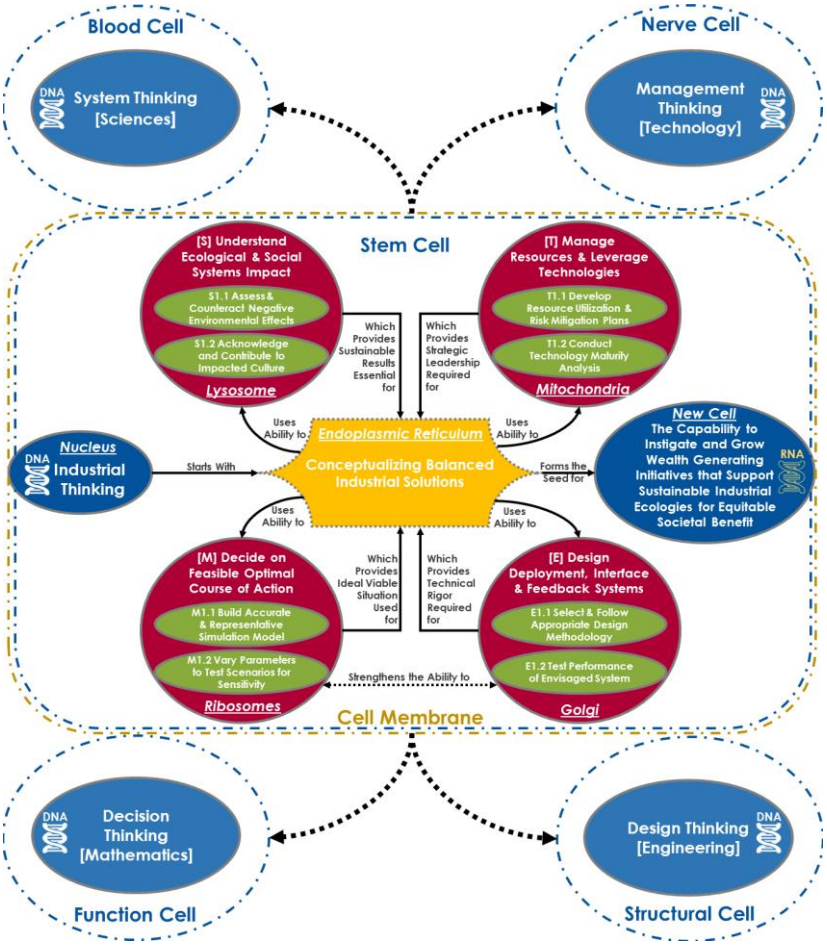
OE6.1: Golden Thread Argument - Open Ended Feedback

_____

_____

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Industrial Thinking Systemigram



OE6.2: What do you conclude from the conceptual model above? Is this a desirable cultural change that can create some common ground between the thinking style of the different sub-disciplines of IE? *How do you see it being used (Industry or Education)?

_____

_____

_____

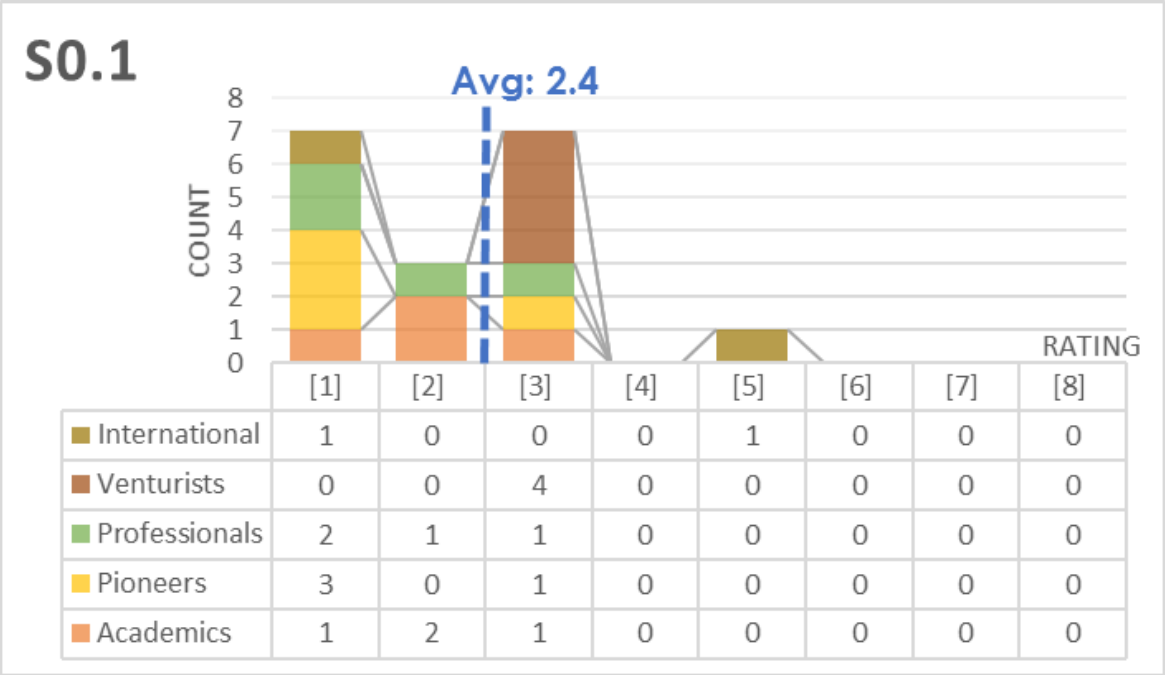
Feedback

[Optional] Please follow the link below to anonymously evaluate the interview and the researcher: https://goo.gl/forms/SKr6zG9zg7WLNJQ62

A copy of your responses will be emailed to the address you provided

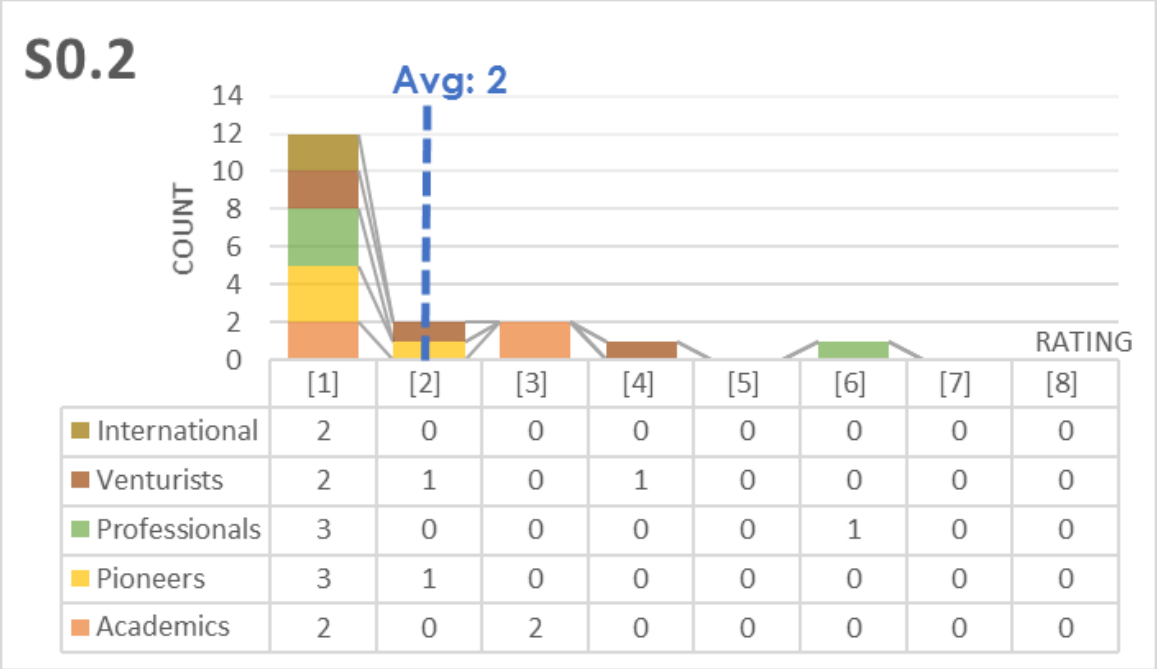
E3 – Interviewee Evaluation of Statements

S0.1: Research Overview - Industrial engineers appear to share a common way of thinking and the ability to instigate it in others, yet, unlike other fields this seems to be largely implicit and difficult to communicate with society at large.



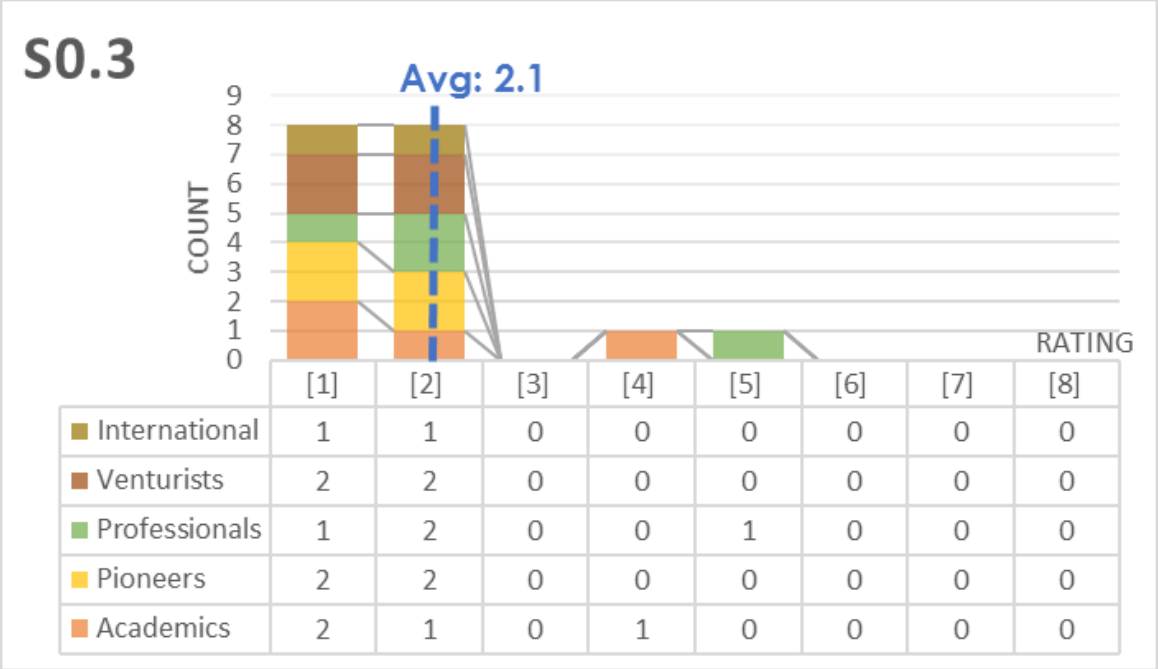
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Venturists	0	0	4	0	0	0	0	0
Professionals	2	1	1	0	0	0	0	0
Pioneers	3	0	1	0	0	0	0	0
Academics	1	2	1	0	0	0	0	0

S0.2: System Context - This is a problematic situation. In order to resolve it, an interpretive systems approach (Pluralistic-Complex) must be taken to create an idealized state and take steps to realize it.



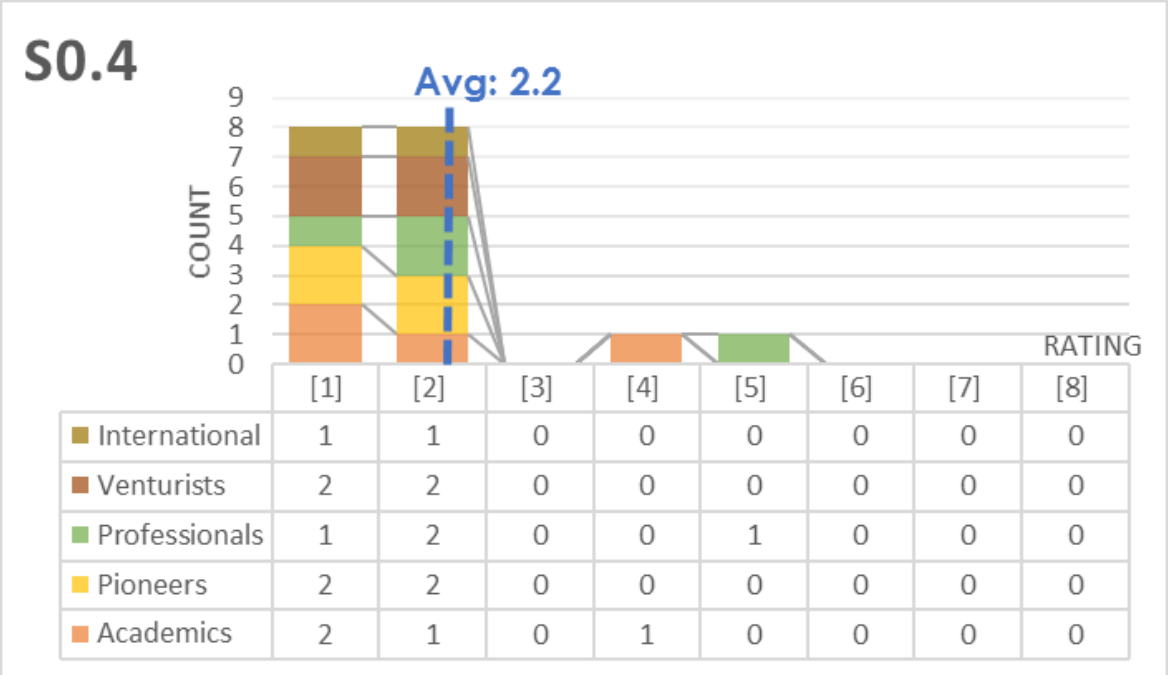
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Professionals	3	0	0	0	0	1	0	0
Pioneers	3	1	0	0	0	0	0	0
Academics	2	0	2	0	0	0	0	0

S0.3: Research Framework - A significant conceptual gap exists that hinders the evolution of Industrial Thinking within the Industrial Engineering profession which would need to be closed in order for the thinking style to become more harmonious with environmental considerations and social culture & concerns



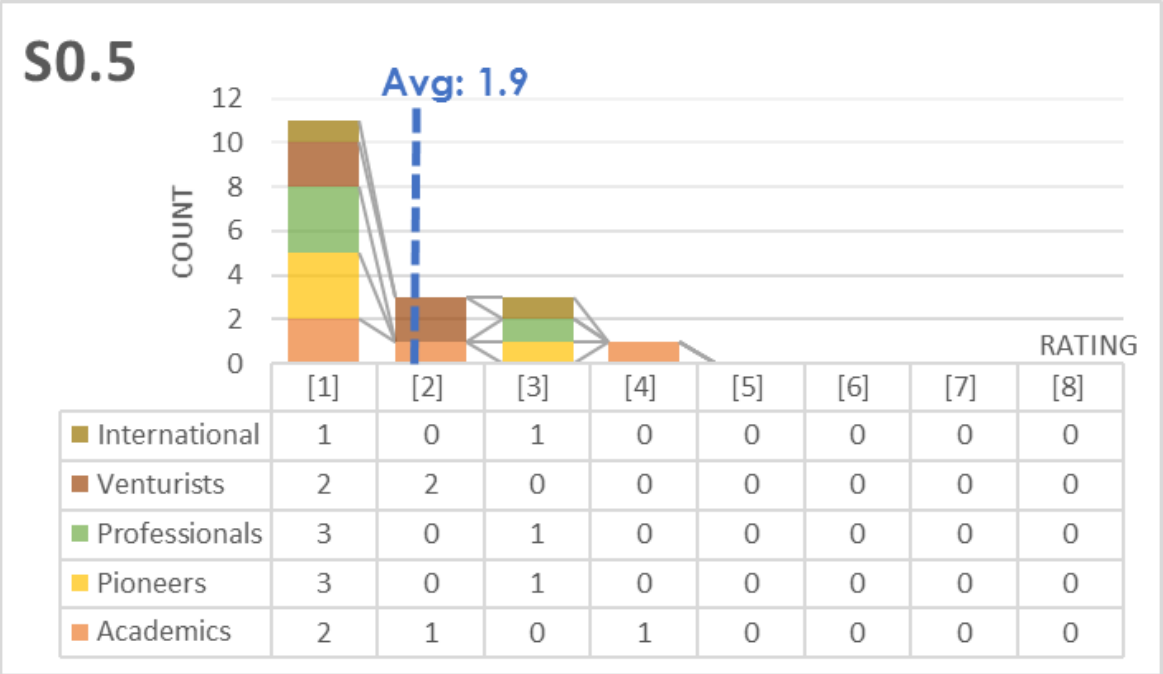
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Professionals	1	2	0	0	1	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	2	1	0	1	0	0	0	0

S0.4: Research Methodology - The development of an Industrial Thinking Systemigram which accurately reflects the aspirations and asymmetrical knowledge unique to the profession (by addressing cultural stream and systemic changes) is instrumental in ensuring beneficial proliferation of the thinking style necessary for progressive resilience in the face of macro challenges of the knowledge era.



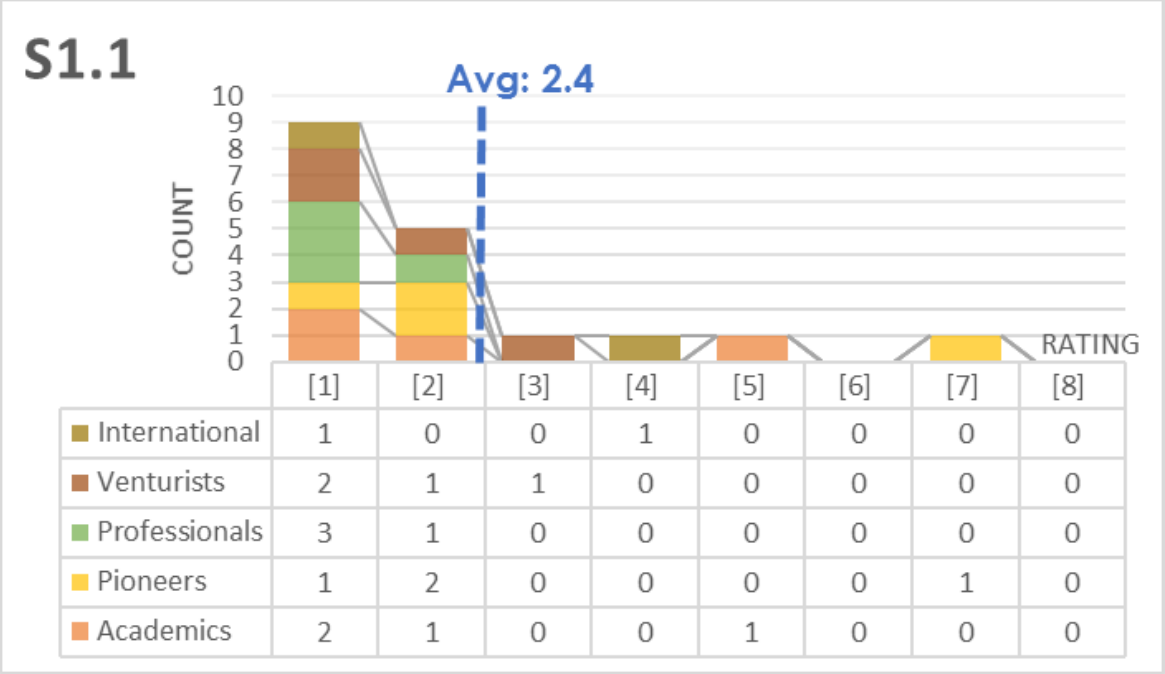
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Professionals	1	2	0	0	1	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	2	1	0	1	0	0	0	0

S0.5: Research Area of Concern - A system of systems view reveals 2 streams: The systemic starting with the industrial engineer, reveals 5 macro systems which deserve attention: The industrial engineer, The Profession, The Economy, Society, The Environment. These concerns can be addressed in separate articles [Due to system considerations] whilst discussing the combined 'culture' stream surrounding Industrial Thinking [Which is addressed collectively]



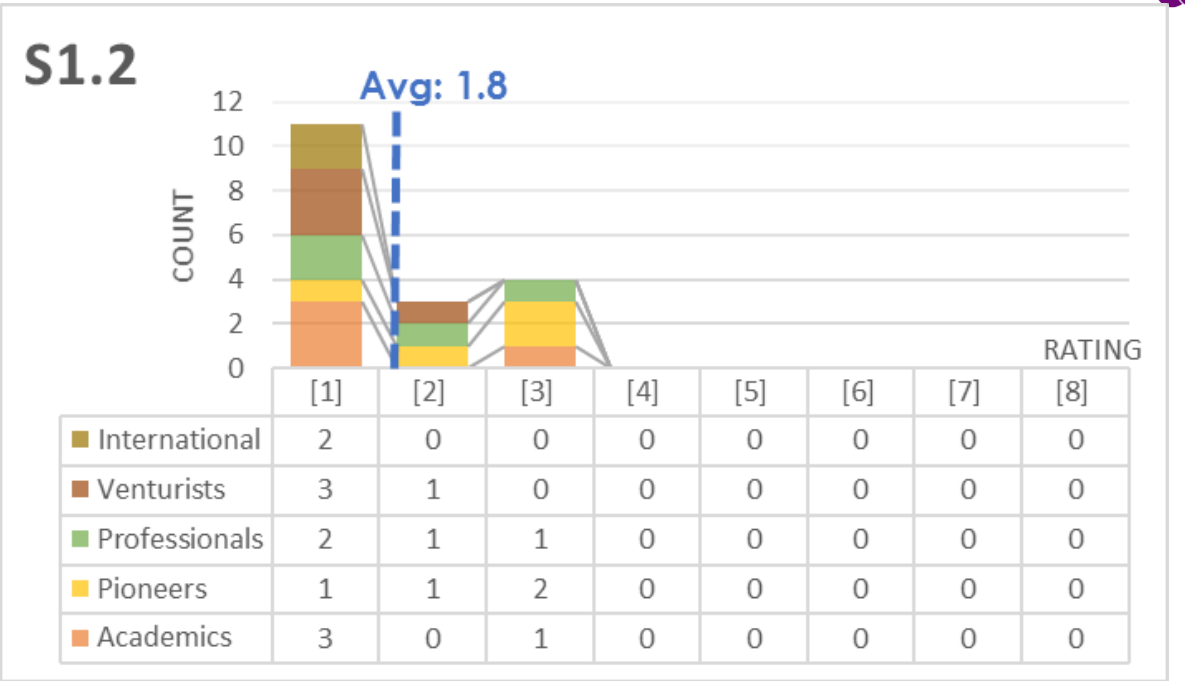
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Venturists	2	2	0	0	0	0	0	0
Professionals	3	0	1	0	0	0	0	0
Pioneers	3	0	1	0	0	0	0	0
Academics	2	1	0	1	0	0	0	0

S1.1: Historically, industrial engineers were seen as jacks of all trades but masters of none



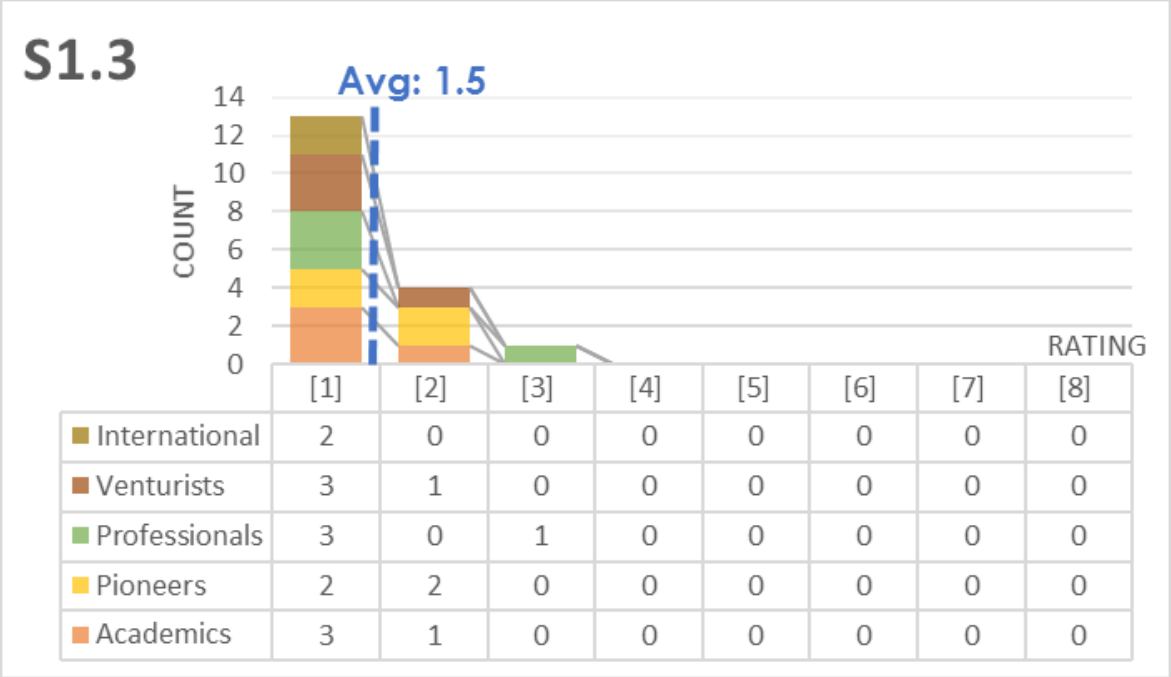
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Professionals	3	1	0	0	0	0	0	0
Pioneers	1	2	0	0	0	0	1	0
Academics	2	1	0	0	1	0	0	0

S1.2: The view above is one of the reasons that hindered the progression of a formal identity



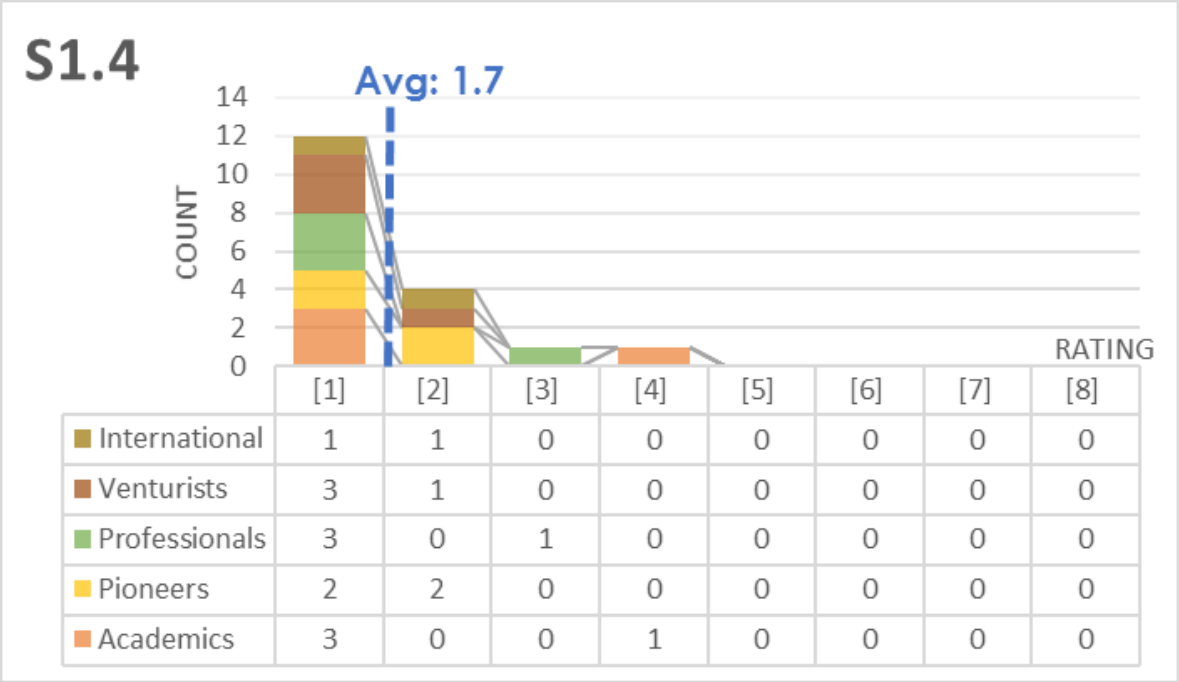
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Professionals	2	1	1	0	0	0	0	0
Pioneers	1	1	2	0	0	0	0	0
Academics	3	0	1	0	0	0	0	0

S1.3: The commonality between the thinking style and sub-disciplines tools used in Industrial Engineering is that they focus on designing balanced solution for Industry



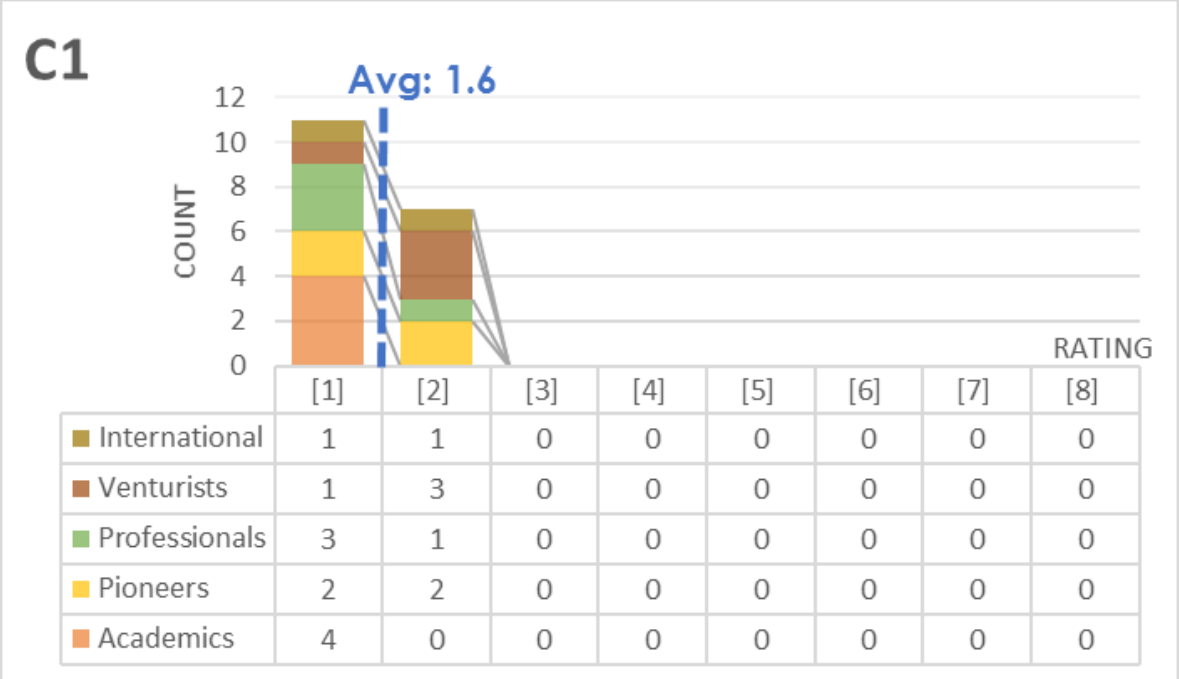
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Professionals	3	0	1	0	0	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	3	1	0	0	0	0	0	0

S1.4: A critical review of the current state of IE finds that the modern identity is centered around being connected to various fields of knowledge whilst being masters of some



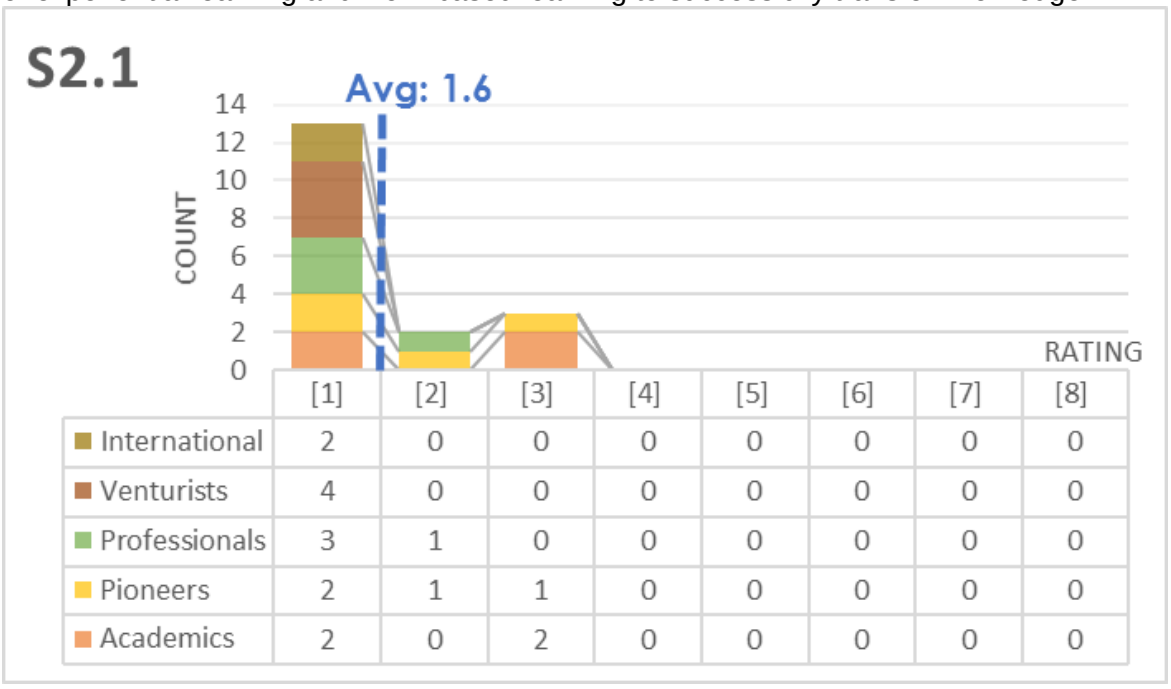
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Venturists	3	1	0	0	0	0	0	0
Professionals	3	0	1	0	0	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	3	0	0	1	0	0	0	0

Conclusion 1 [Desirable Systemic Change]: In order to hold true to their professional identity (IE-ID) of designing balanced solutions; an industrial engineer must continuously advance their interdisciplinary awareness (to connect) and cognition abilities (to master).



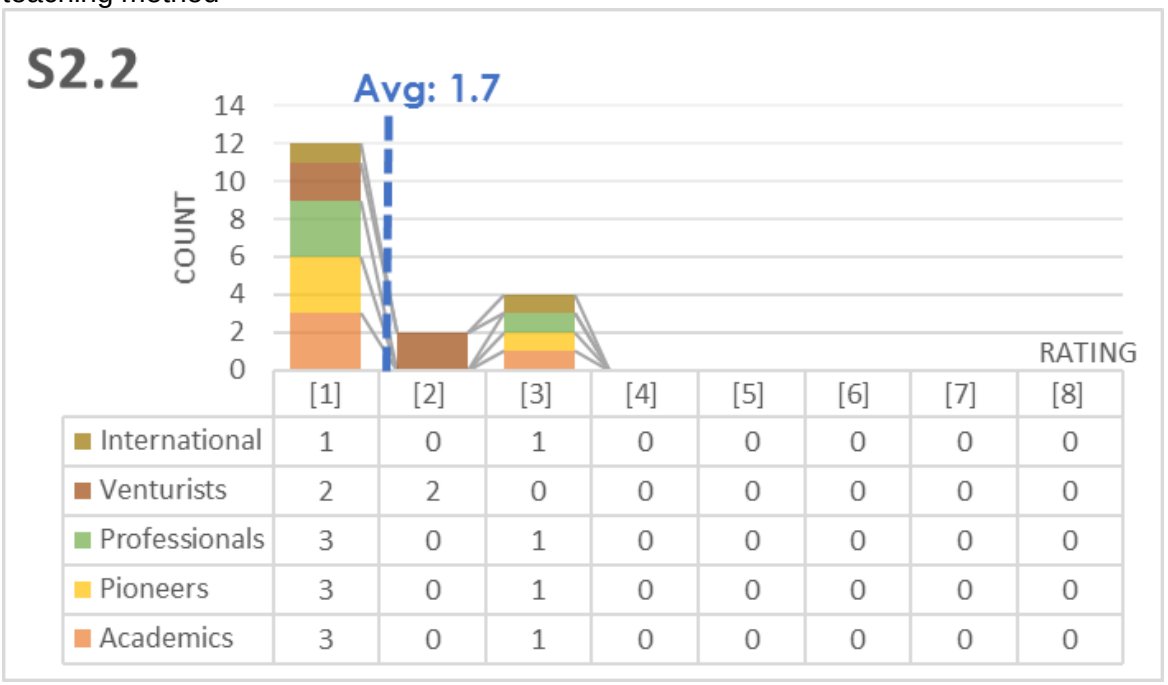
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Professionals	3	1	0	0	0	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	4	0	0	0	0	0	0	0

S2.1: Engineering education in the knowledge era (21st century) requires a significant amount of experiential learning and work-based learning to successfully transfer knowledge



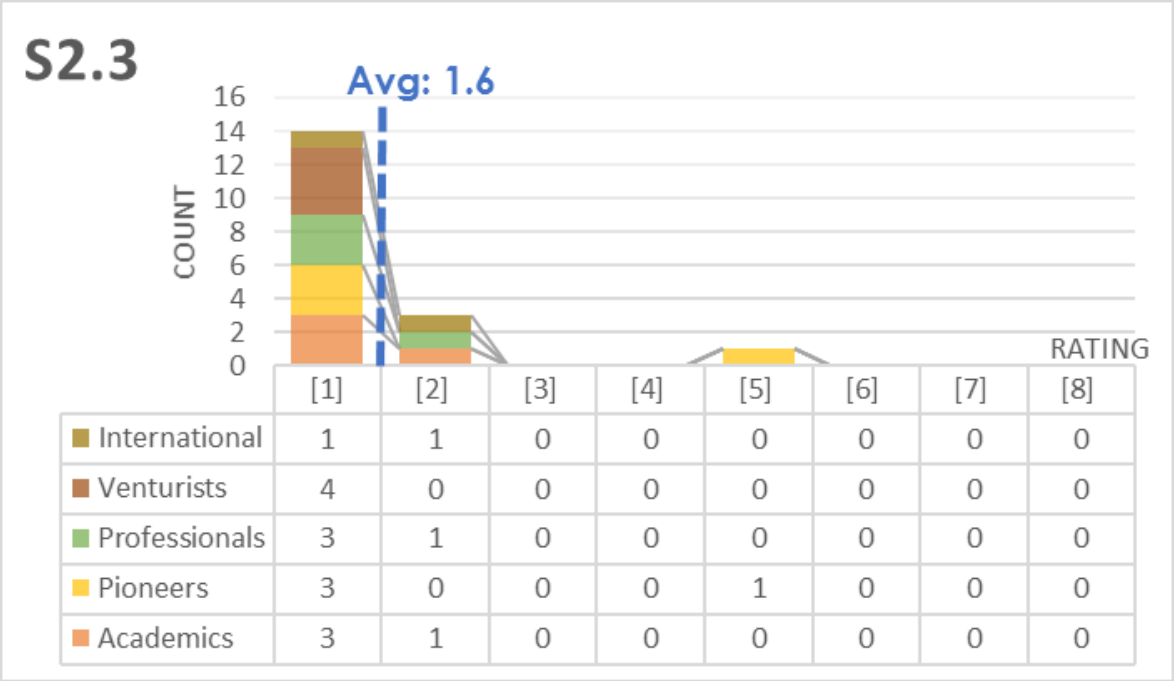
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Venturists	4	0	0	0	0	0	0	0
Professionals	3	1	0	0	0	0	0	0
Pioneers	2	1	1	0	0	0	0	0
Academics	2	0	2	0	0	0	0	0

S2.2: Current entrants into university belong to generation Y and Z and their exposure to technology and games from birth suggests that gamification techniques can be an effective teaching method



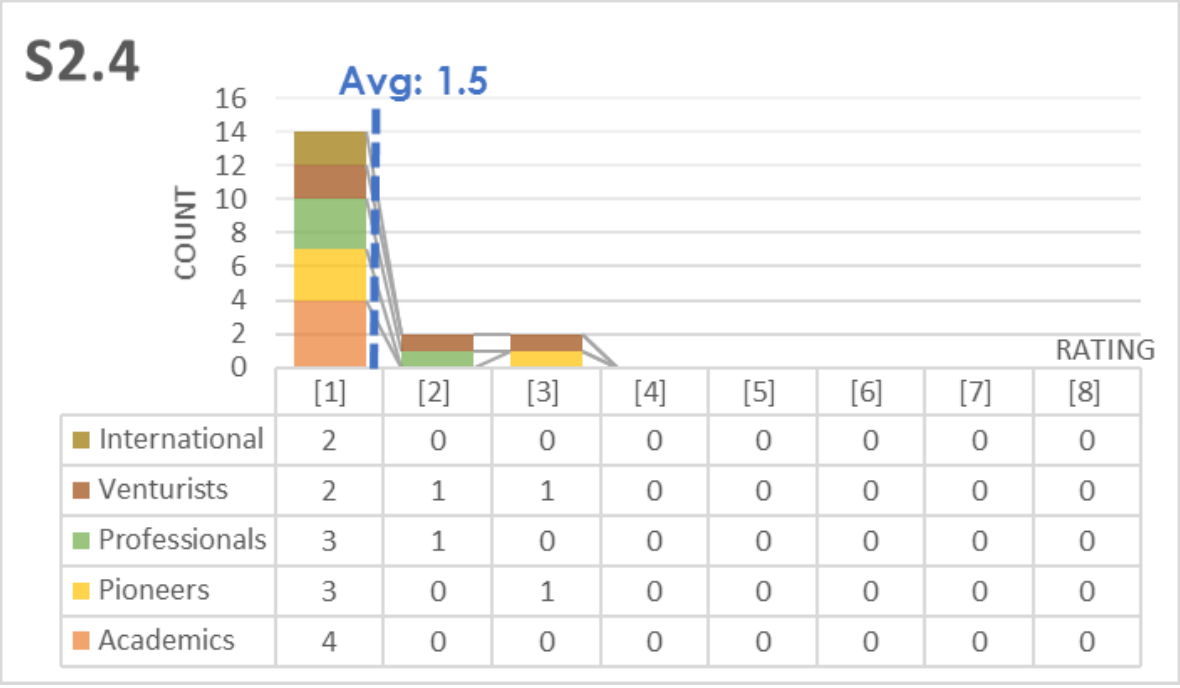
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Venturists	2	2	0	0	0	0	0	0
Professionals	3	0	1	0	0	0	0	0
Pioneers	3	0	1	0	0	0	0	0
Academics	3	0	1	0	0	0	0	0

S2.3: The Baader-Meinhof Phenomenon (see or hear something everywhere after initial contact) can be used to reinforce certain concepts within different contexts which can strengthen the recollection and application ability of students



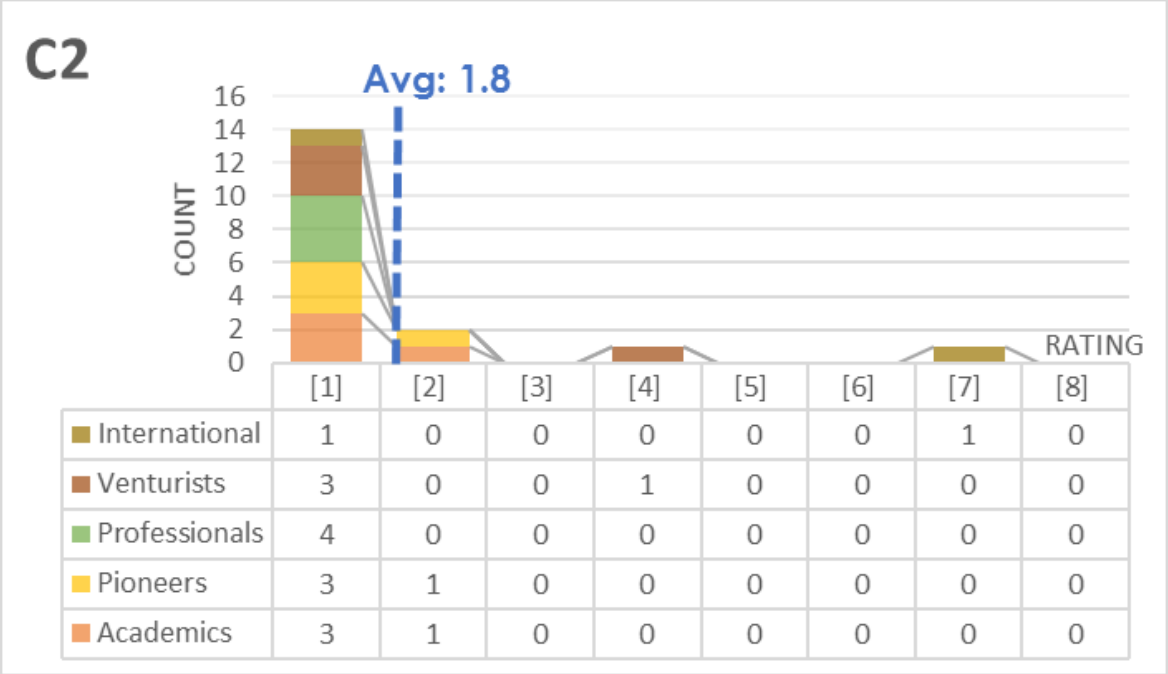
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Professionals	3	1	0	0	0	0	0	0
Pioneers	3	0	0	0	1	0	0	0
Academics	3	1	0	0	0	0	0	0

S2.4: The Industrial Engineering community works in various environments. Sharing insights and resources from the different environments (which are currently dispersed) can help in strengthening relationships throughout the profession



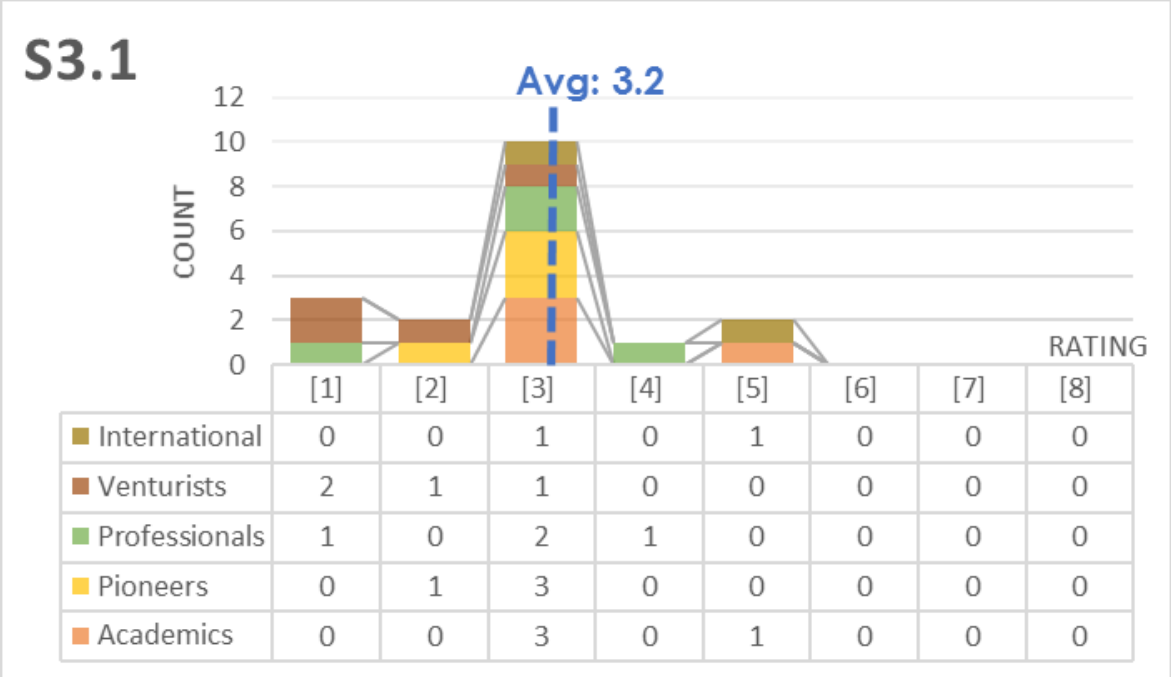
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Venturists	2	1	1	0	0	0	0	0
Professionals	3	1	0	0	0	0	0	0
Pioneers	3	0	1	0	0	0	0	0
Academics	4	0	0	0	0	0	0	0

Conclusion 2 [Desirable Systemic Change]: In the knowledge era, it becomes vital for professional communities to create knowledge & resource sharing platforms that act as incubators and places to congregate for initiatives that can further develop the profession and attract the next generation of entrants into IE



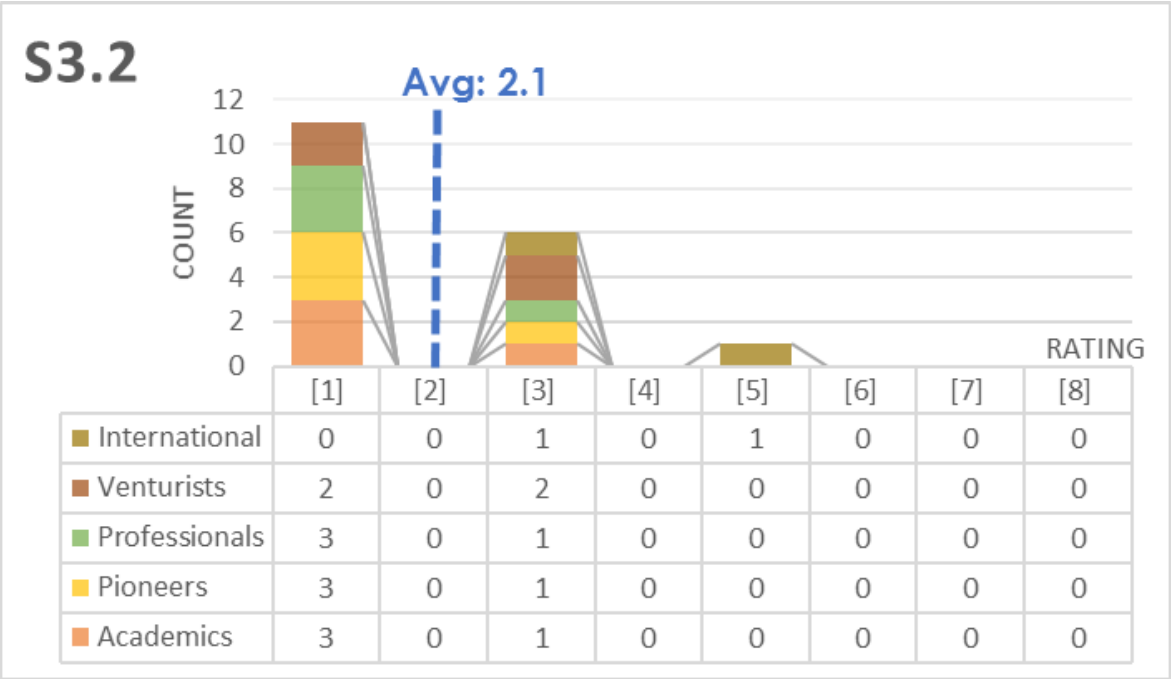
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Professionals	4	0	0	0	0	0	0	0
Pioneers	3	1	0	0	0	0	0	0
Academics	3	1	0	0	0	0	0	0

S3.1: Means of production are becoming decentralized and simpler due to 3D printing & additive manufacturing



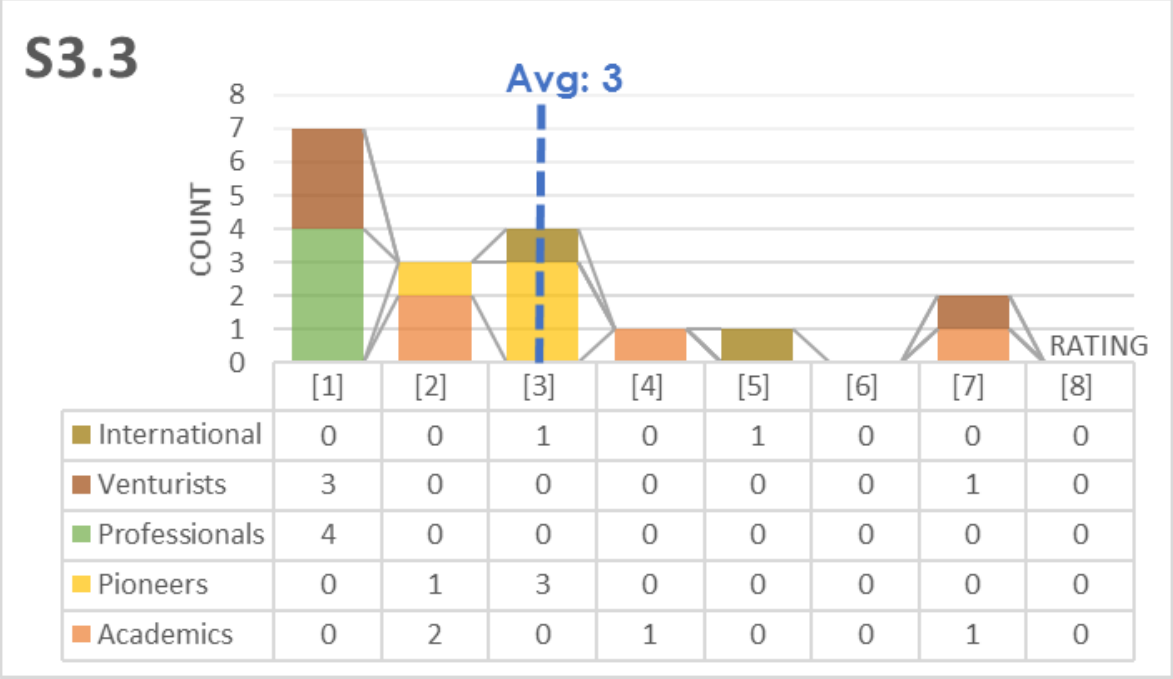
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Venturists	2	1	1	0	0	0	0	0
Professionals	1	0	2	1	0	0	0	0
Pioneers	0	1	3	0	0	0	0	0
Academics	0	0	3	0	1	0	0	0

S3.2: Employment mechanisms, corporate structures and customer behavior are becoming more network like due to the sharing and knowledge economy



	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	0	0	1	0	1	0	0	0
Venturists	2	0	2	0	0	0	0	0
Professionals	3	0	1	0	0	0	0	0
Pioneers	3	0	1	0	0	0	0	0
Academics	3	0	1	0	0	0	0	0

S3.3: Supply chains are becoming shorter due to transport technologies creating radically different supply/demand relationships



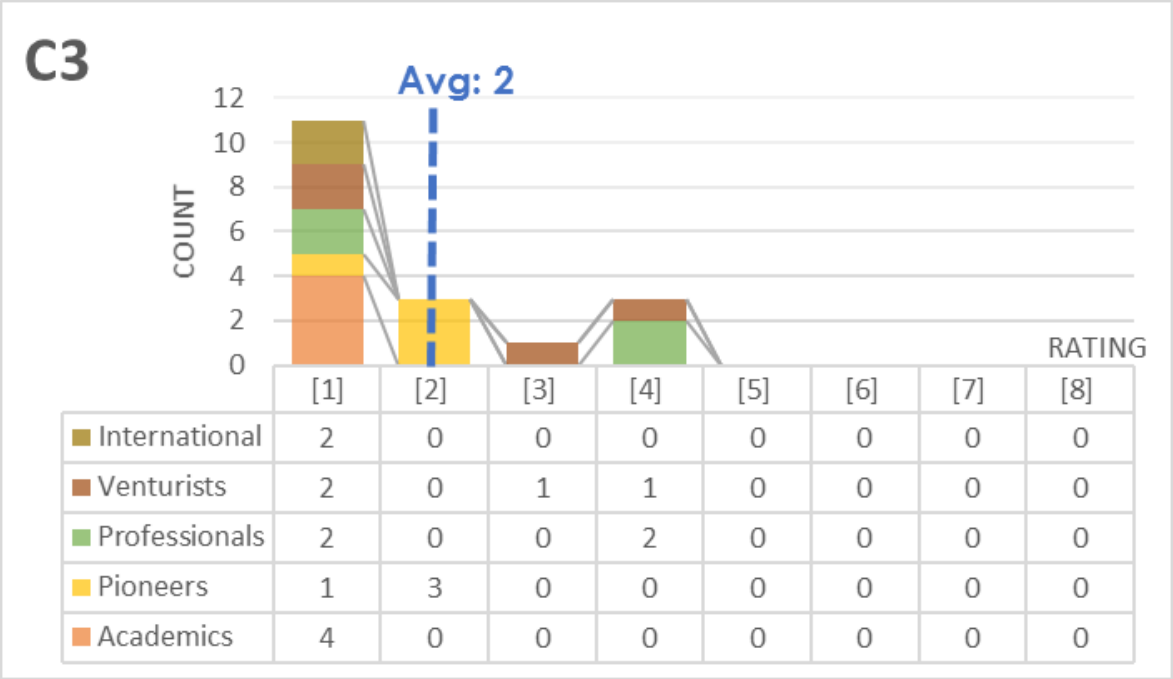
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Professionals	4	0	0	0	0	0	0	0
Pioneers	0	1	3	0	0	0	0	0
Academics	0	2	0	1	0	0	1	0

S3.4: Human concerns and values relating to education, health and other concerns are becoming more conscious



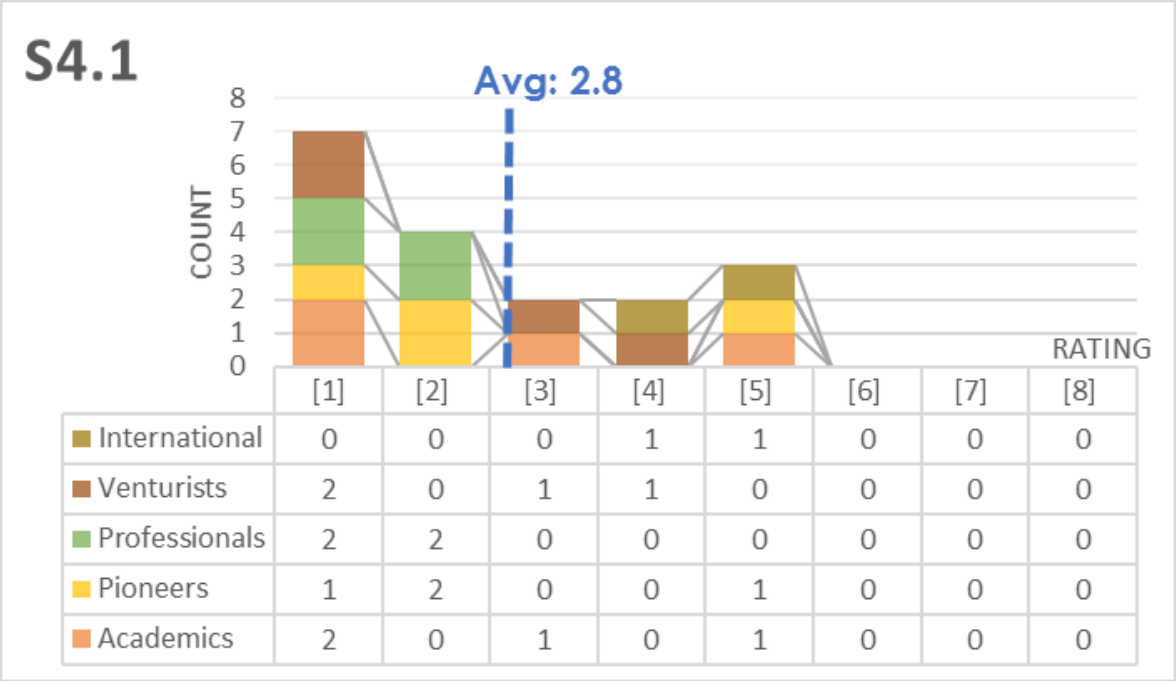
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Venturists	3	1	0	0	0	0	0	0
Professionals	3	0	0	1	0	0	0	0
Pioneers	1	1	2	0	0	0	0	0
Academics	2	0	1	0	0	0	1	0

Conclusion 3 [Desirable Systemic Change]: Since Industrial Engineering is deeply rooted in designing and managing the above socio-technical systems, transdisciplinary frameworks need to be created using Industrial Thinking to correctly evaluate the impact of macro-disruptors and successfully react to them.



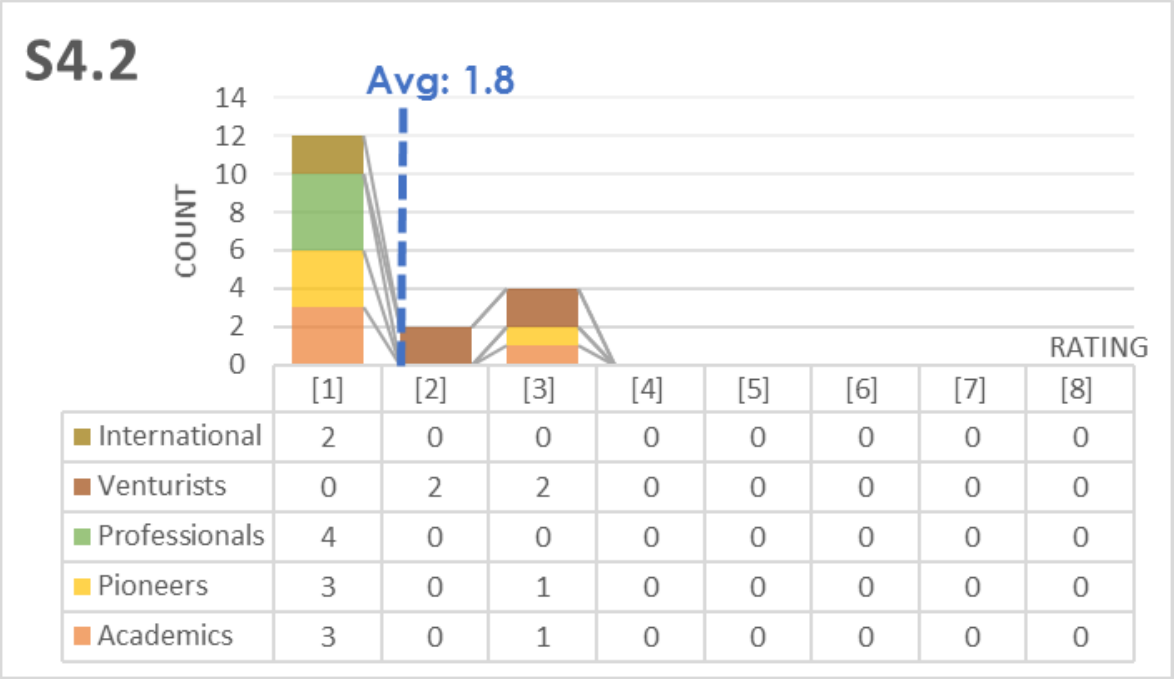
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Professionals	2	0	0	2	0	0	0	0
Pioneers	1	3	0	0	0	0	0	0
Academics	4	0	0	0	0	0	0	0

S4.1: The societal type currently existing in the knowledge era and experiencing the fourth industrial revolution is not post-industrial but post-post-industrial



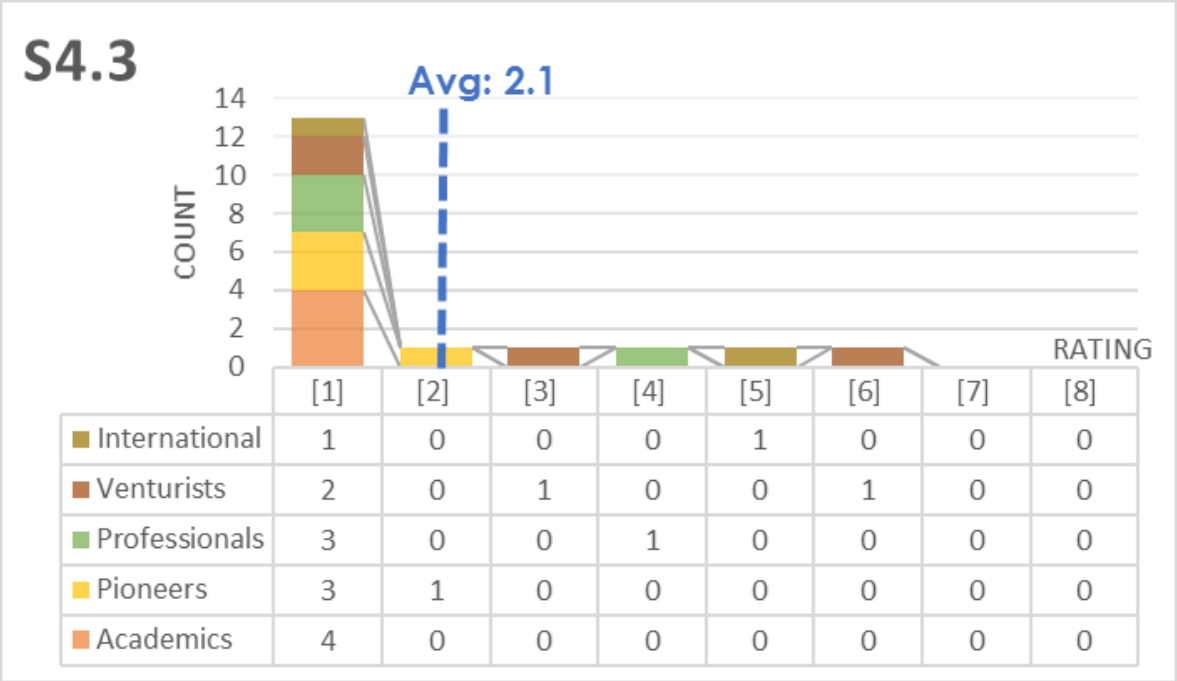
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International	0	0	0	1	1	0	0	0
Venturists	2	0	1	1	0	0	0	0
Professionals	2	2	0	0	0	0	0	0
Pioneers	1	2	0	0	1	0	0	0
Academics	2	0	1	0	1	0	0	0

S4.2: This society is better named the network society; its extraction of value mainly stems from an ability to be connected, collaborate and leverage networks (which has evolved as a cognitive function over 4 industrial revolutions)



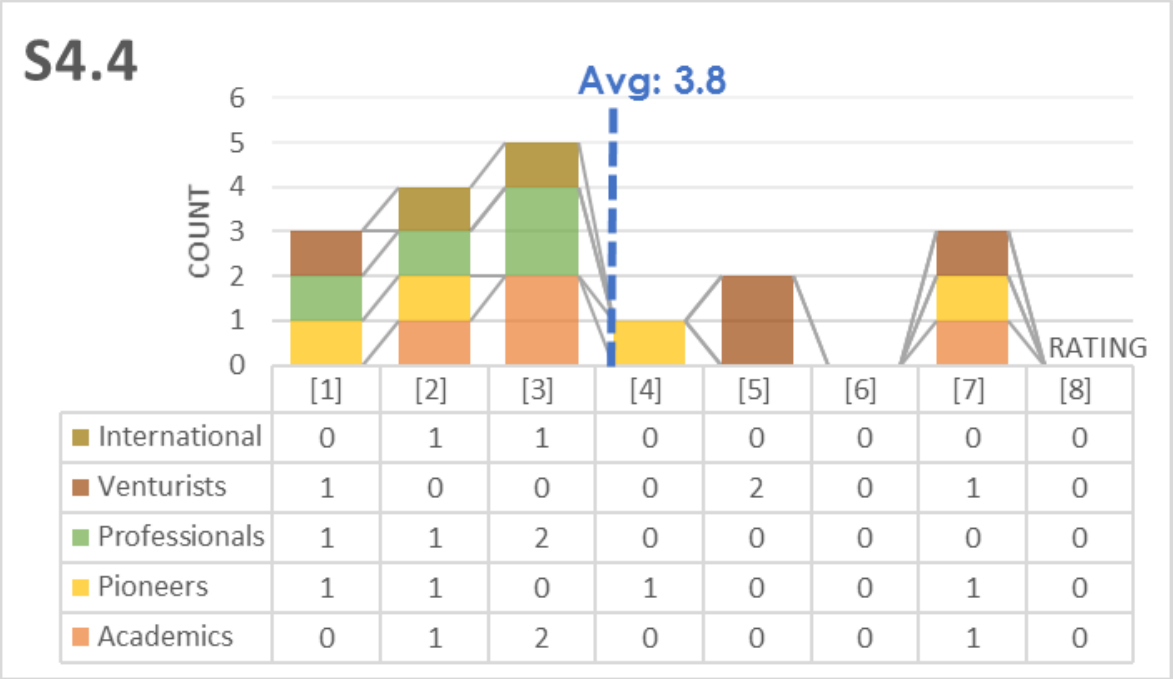
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Venturists	0	2	2	0	0	0	0	0
Professionals	4	0	0	0	0	0	0	0
Pioneers	3	0	1	0	0	0	0	0
Academics	3	0	1	0	0	0	0	0

S4.3: What was previously known as the bottom of the pyramid society is, in this scenario, the outer network society and rarely experience the full benefit and value added by Industry 4.0 and the knowledge era due to a lack of appropriate systems in place



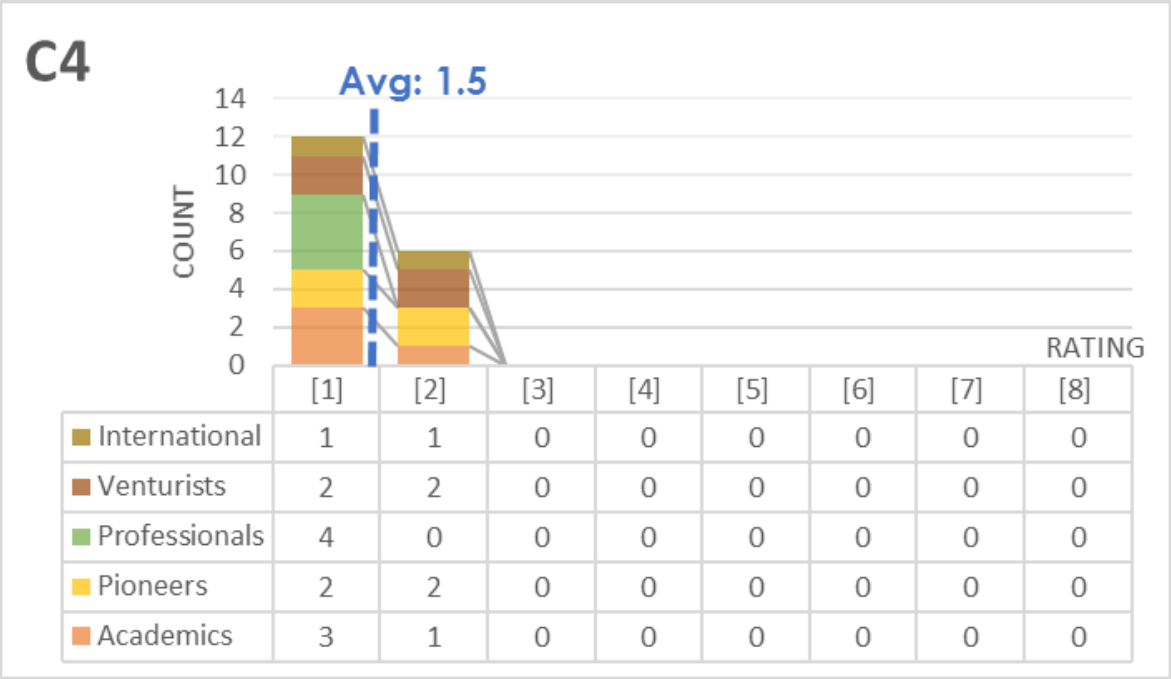
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International	1	0	0	0	1	0	0	0
Venturists	2	0	1	0	0	1	0	0
Professionals	3	0	0	1	0	0	0	0
Pioneers	3	1	0	0	0	0	0	0
Academics	4	0	0	0	0	0	0	0

S4.4: Industrial Engineering was founded on ensuring that all of society (from employees to customers) have a voice in shaping the products and systems that ultimately service them



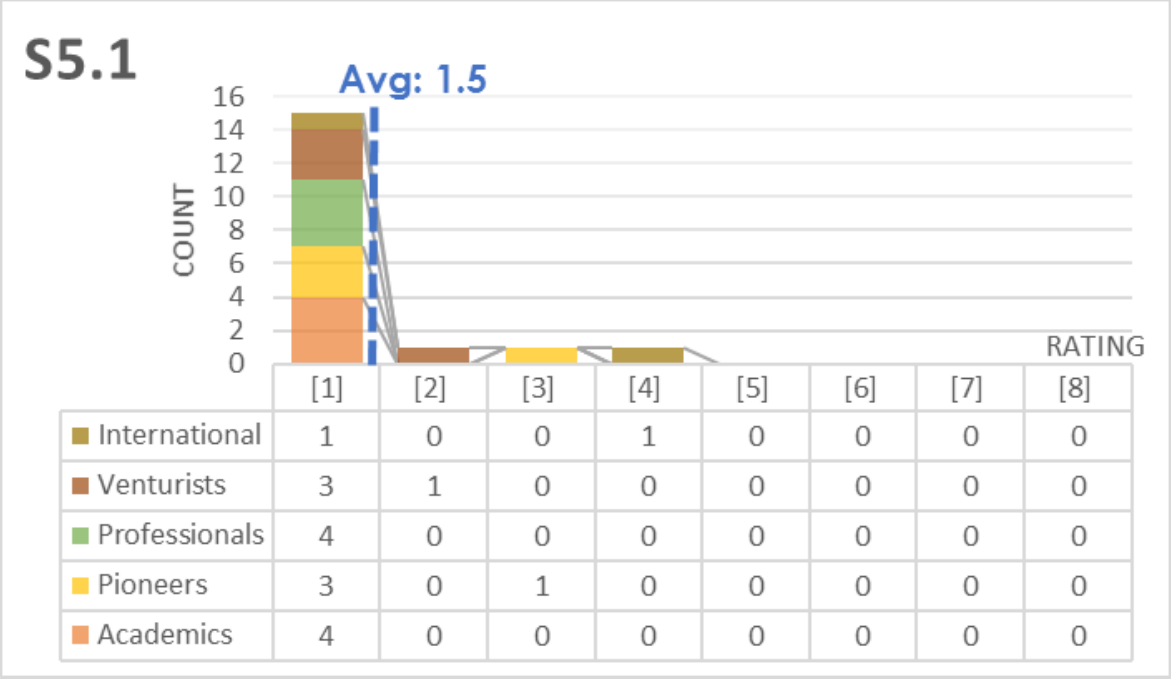
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	0	1	1	0	0	0	0	0
Venturists	1	0	0	0	2	0	1	0
Professionals	1	1	2	0	0	0	0	0
Pioneers	1	1	0	1	0	0	1	0
Academics	0	1	2	0	0	0	1	0

Conclusion 4 [Desirable Systemic Change]: Since the majority of society (80%) lives in the outer network, it is fundamental for Industrial Engineers to design new systems that connect them to resources (in the broadest sense) that can help them develop socio-economically and cognitively to be able integrate to global network society



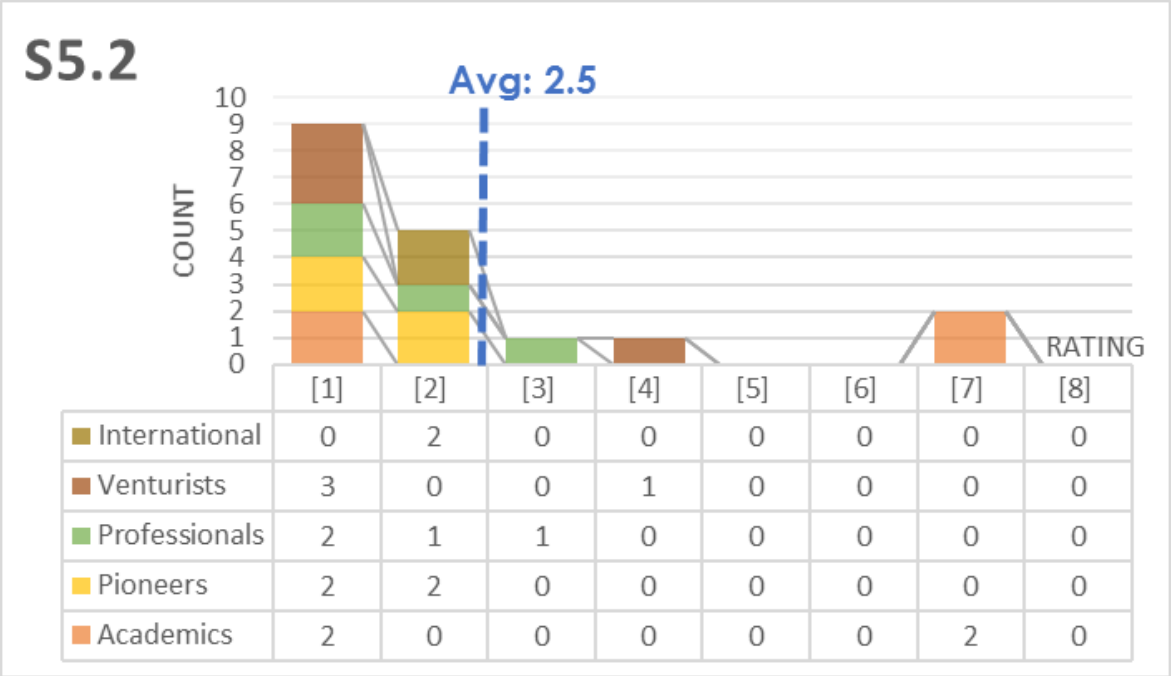
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Venturists	2	2	0	0	0	0	0	0
Professionals	4	0	0	0	0	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	3	1	0	0	0	0	0	0

S5.1: Beyond biological factors, various psychological factors form the identity of the modern human being which have led to the term Homo Industrialis; By virtue of being industrious, the human being wishes to adapt their environment to better suit their needs



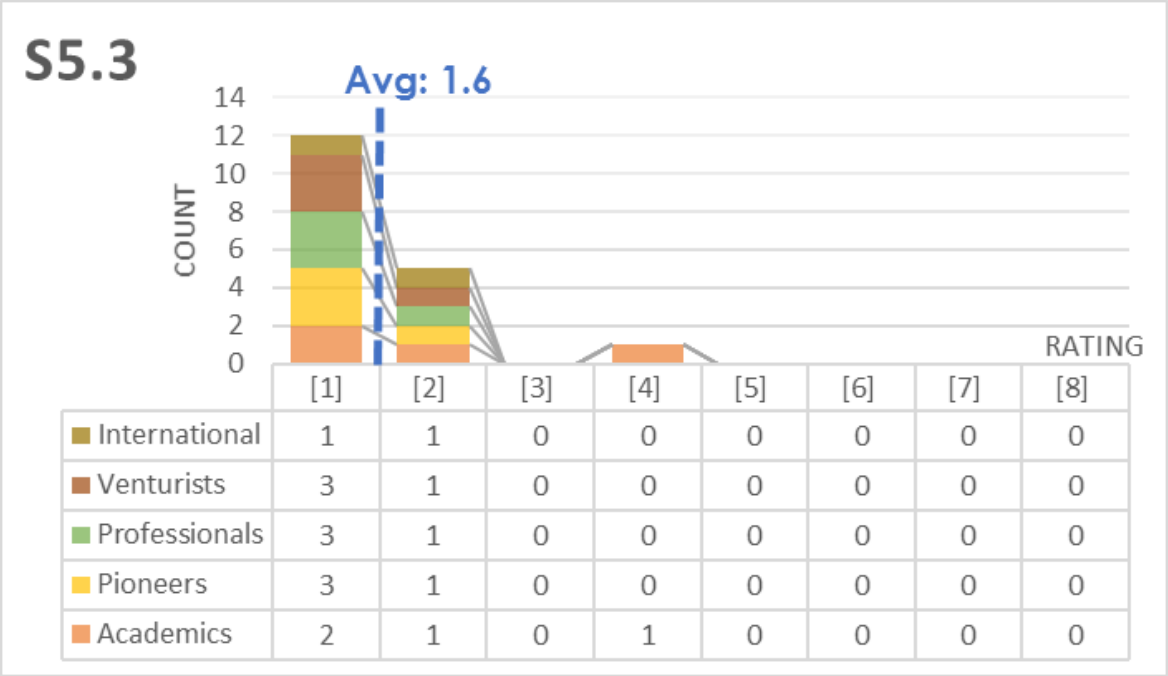
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Venturists	3	1	0	0	0	0	0	0
Professionals	4	0	0	0	0	0	0	0
Pioneers	3	0	1	0	0	0	0	0
Academics	4	0	0	0	0	0	0	0

S5.2: Even though this nature has existed for centuries, its professional function was only formalized relatively recently in the IE field since industrial engineers display more of this industrious behavior as well as understanding the systems perspective surrounding it



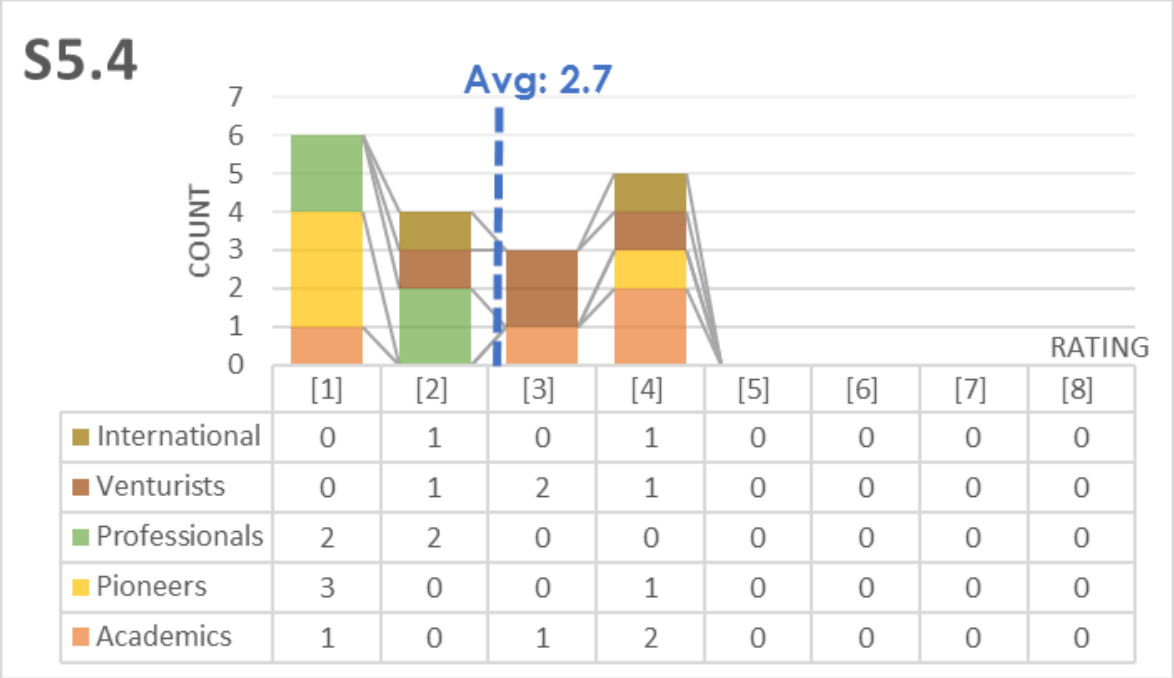
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	0	2	0	0	0	0	0	0
Venturists	3	0	0	1	0	0	0	0
Professionals	2	1	1	0	0	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	2	0	0	0	0	0	2	0

S5.3: However, this behavior can, if remained unchecked, lead to significant societal and environmental decay especially when the terminology used to describe it is value laden with growth as opposed to balanced measures



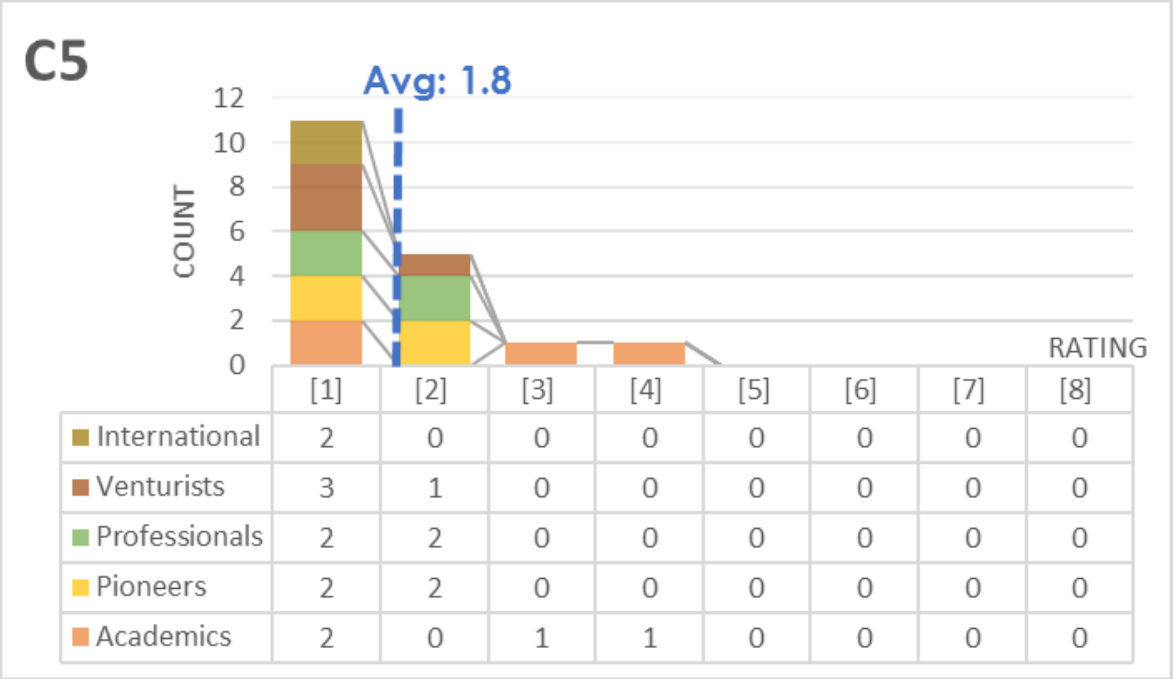
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
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Venturists	3	1	0	0	0	0	0	0
Professionals	3	1	0	0	0	0	0	0
Pioneers	3	1	0	0	0	0	0	0
Academics	2	1	0	1	0	0	0	0

S5.4: Yet, Industrialization is absolutely necessary for development, but its current form is environmentally and socially destructive which can be partially attributed to a slow integration of global developments into the terminology and philosophies taught in industry and educational institutes



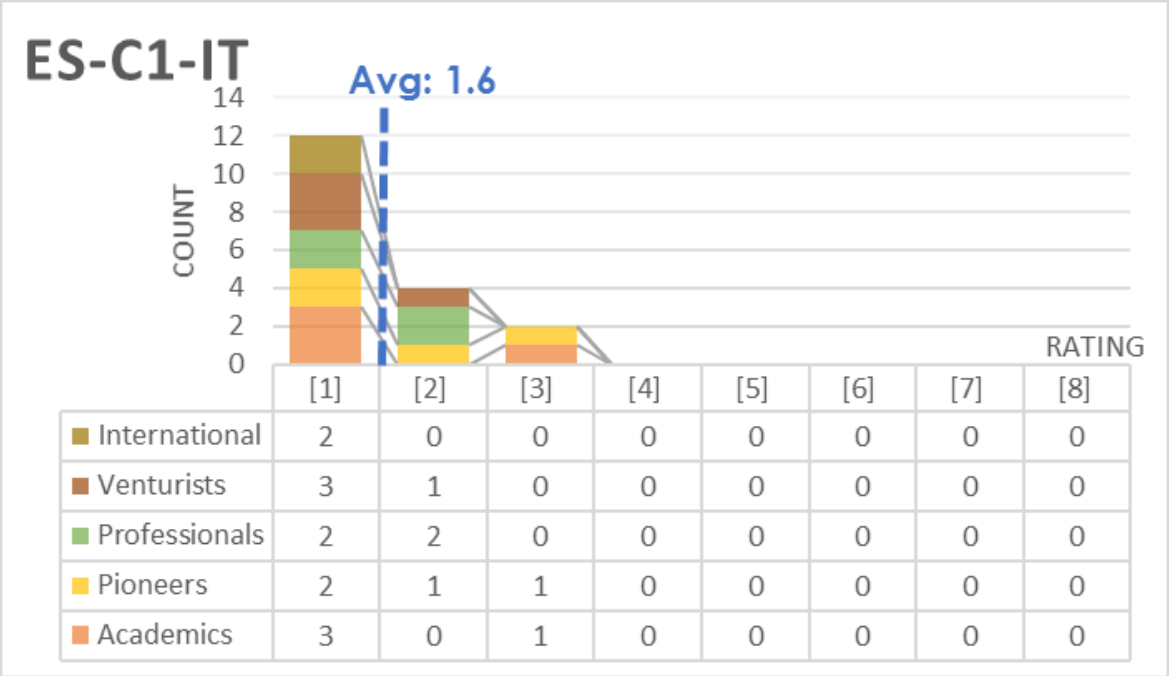
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Venturists	0	1	2	1	0	0	0	0
Professionals	2	2	0	0	0	0	0	0
Pioneers	3	0	0	1	0	0	0	0
Academics	1	0	1	2	0	0	0	0

Conclusion 5 [Desirable Systemic Change]: IE is one of the fields affected by this problem which can be largely resolved by adapting some of the IE body of knowledge to reflect developments in biomimesis and a modern understanding of human needs



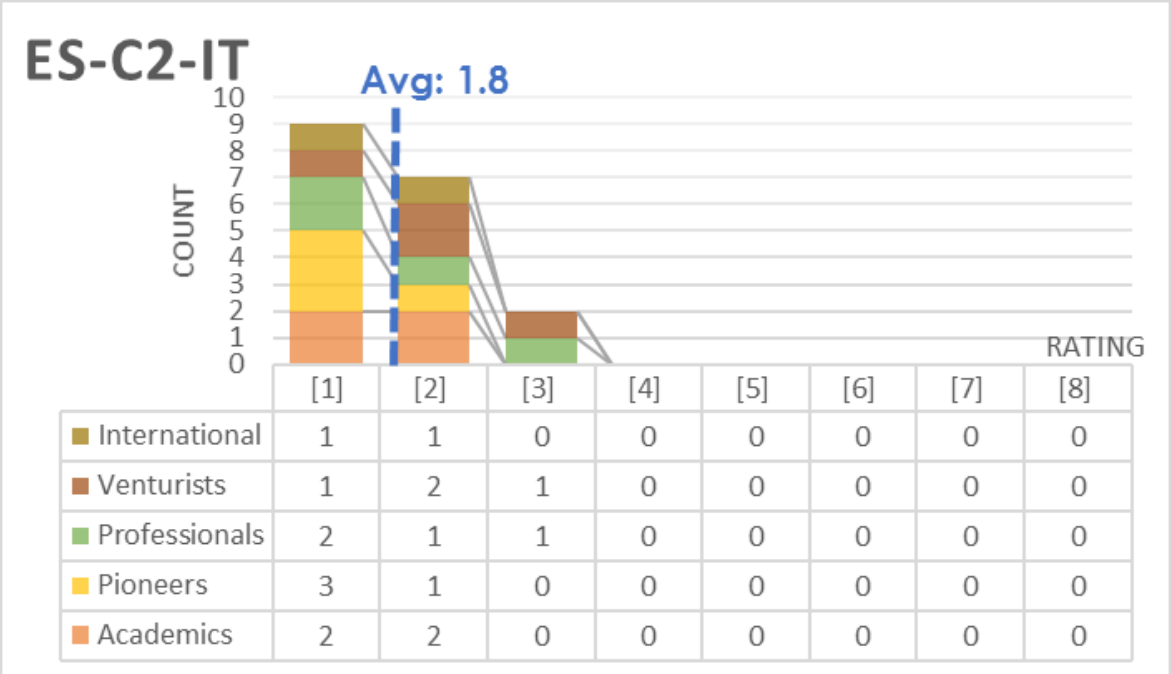
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Venturists	3	1	0	0	0	0	0	0
Professionals	2	2	0	0	0	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	2	0	1	1	0	0	0	0

[ES-C1-IT]: The associated thinking style of the Industrial Engineer must hold true to developments in the IE Identity **Thus:** Industrial Thinking must develop to be more focused on balanced solutions rather



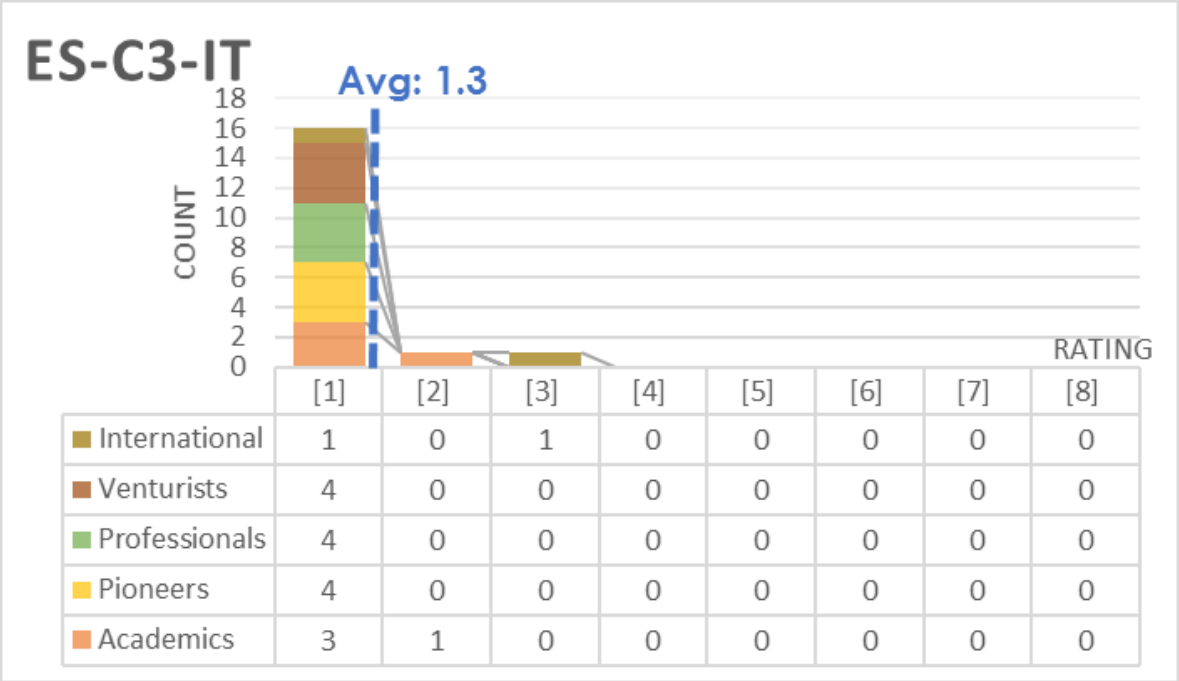
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	2	0	0	0	0	0	0	0
Venturists	3	1	0	0	0	0	0	0
Professionals	2	2	0	0	0	0	0	0
Pioneers	2	1	1	0	0	0	0	0
Academics	3	0	1	0	0	0	0	0

[ES-C2-IT]: It is important to collaboratively engage all stakeholders in shaping the future of a profession if one hopes to get their support. **Thus:** Industrial Thinking must develop strong transparent interfaces that echo the values of the profession.



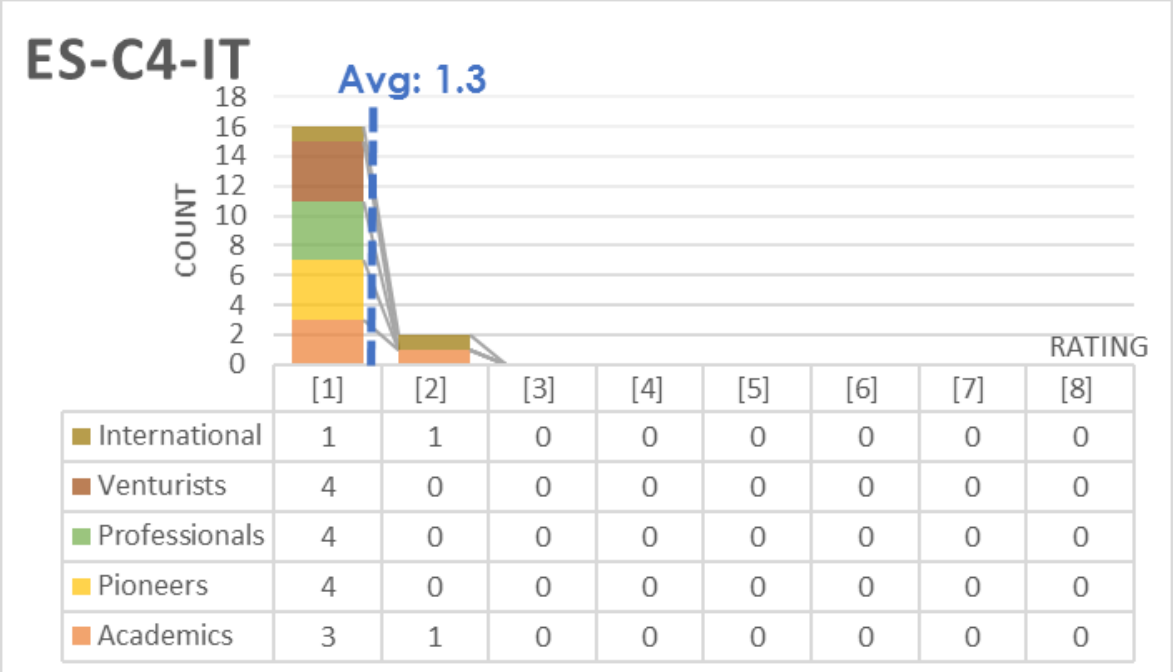
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	1	1	0	0	0	0	0	0
Venturists	1	2	1	0	0	0	0	0
Professionals	2	1	1	0	0	0	0	0
Pioneers	3	1	0	0	0	0	0	0
Academics	2	2	0	0	0	0	0	0

[ES-C3-IT]: The diversity of macro-tech disruptions requires lean and resilient nature. **Thus:** Industrial Thinking must entail strong management elements and abilities to leverage technologies.



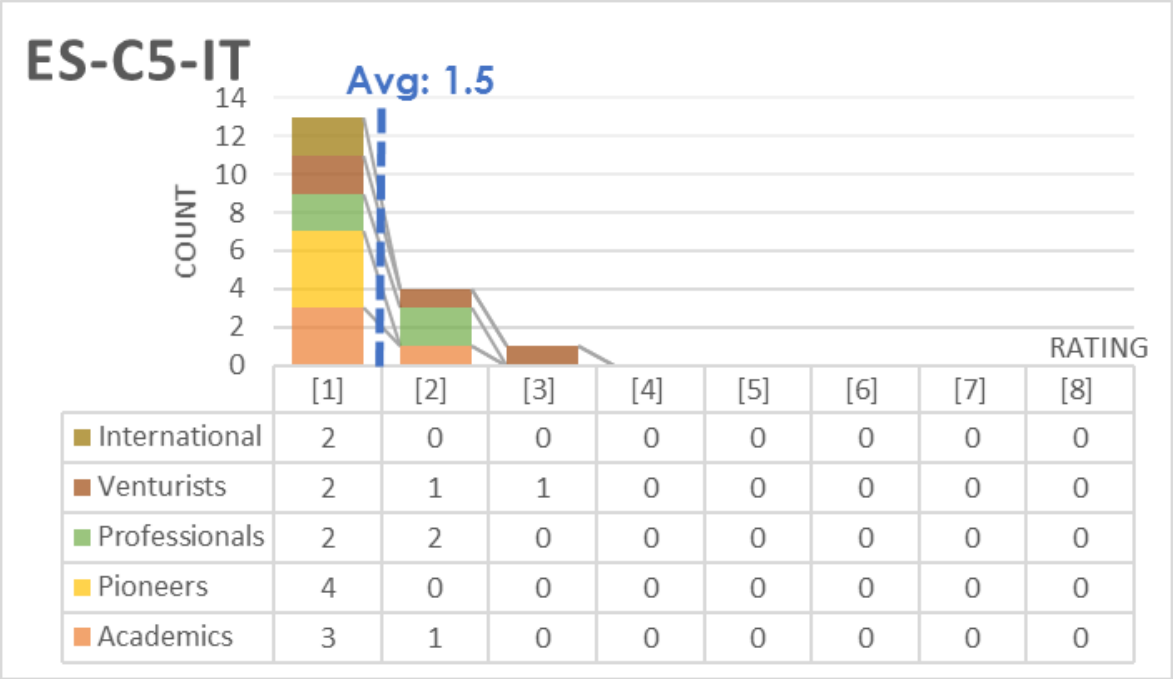
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	1	0	1	0	0	0	0	0
Venturists	4	0	0	0	0	0	0	0
Professionals	4	0	0	0	0	0	0	0
Pioneers	4	0	0	0	0	0	0	0
Academics	3	1	0	0	0	0	0	0

[ES-C4-IT]: The loss of diverse societies and ecologies is unacceptable in the knowledge era. **Thus:** Industrial Thinking demands a holistic understanding of possible negative consequences and must counteract them (possibly even contributing positively to the impacted ecology).



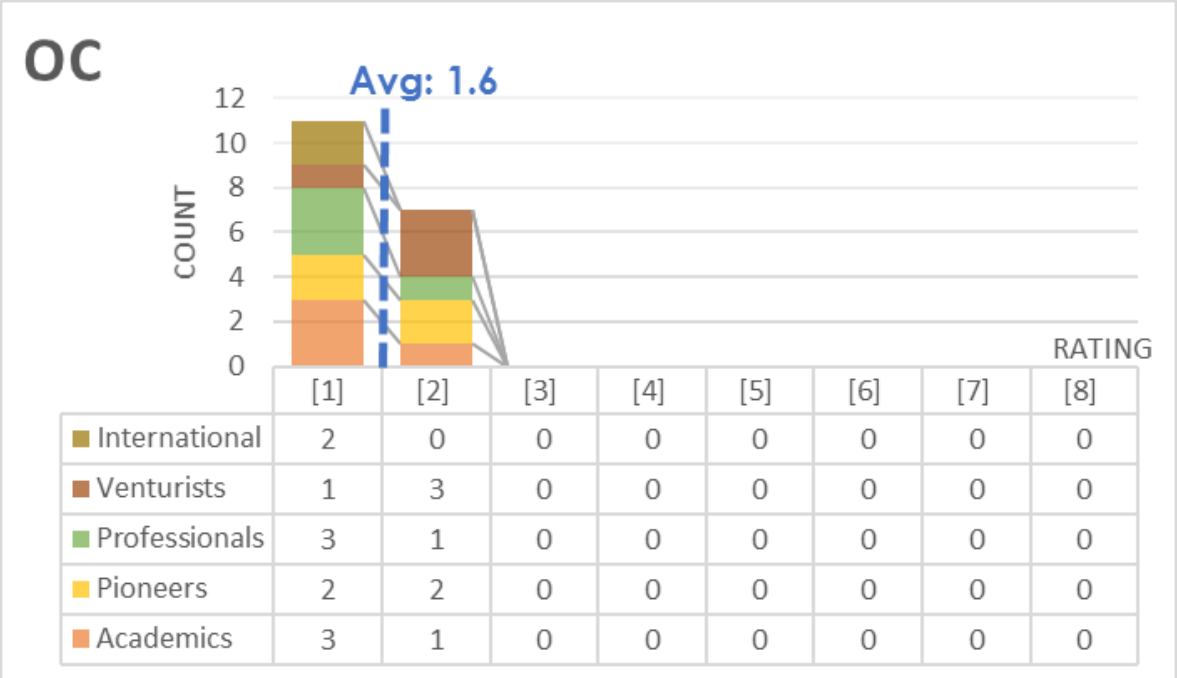
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	1	1	0	0	0	0	0	0
Venturists	4	0	0	0	0	0	0	0
Professionals	4	0	0	0	0	0	0	0
Pioneers	4	0	0	0	0	0	0	0
Academics	3	1	0	0	0	0	0	0

[ES-C5-IT]: Not catering for environmental and social needs can result in devastating scenarios. **Thus:** Industrial Thinking must inherently involve mechanisms to evaluate and promote the most feasible optimal course of action.



	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	2	0	0	0	0	0	0	0
Venturists	2	1	1	0	0	0	0	0
Professionals	2	2	0	0	0	0	0	0
Pioneers	4	0	0	0	0	0	0	0
Academics	3	1	0	0	0	0	0	0

OC: Industrial Thinking is the cognitive ability to conceptualize balanced industrious solutions which create value for all of society in an ecologically beneficial manner. This is achieved by uncovering optimal courses of action which guide the management of resources supported by technologies. Furthermore, using sound system design processes, progress is assessed and evaluated against expected impact on society and the environment. These elements work together like an industrial ecology.



	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
International	2	0	0	0	0	0	0	0
Venturists	1	3	0	0	0	0	0	0
Professionals	3	1	0	0	0	0	0	0
Pioneers	2	2	0	0	0	0	0	0
Academics	3	1	0	0	0	0	0	0