



# Career decisions of chemical engineers across their professional lives

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## COMMENTS

The reader is reminded of the following:

- The first and last chapters follow the editorial style format prescribed by the Programme in Industrial Psychology of the North-West University (Vaal Campus).
- The references and page numbers in this document follow the format as prescribed by the Publication Manual (6th edition) of the American Psychological Association (APA).
- This mini-dissertation is presented in research article format. The editorial style for qualitative research articles as specified by the South African Journal of Industrial Psychology is used in the second chapter.

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## **ABSTRACT**

Chemical engineers are expected to make a major contribution to the world's sustainability challenges, due to the nature of their training, their mode of thinking, and their understanding of key fundamental scientific concepts. Chemical engineering graduates can choose from a large number of employment options and career routes. The question arises: how, when and why do they make which career decisions? Such an insight can help facilitate the career growth of chemical engineers, streamline their career decisions from an early stage, and overall benefit the profession, and society.

A grounded theory study was conducted to investigate why chemical engineers make the career decisions they do throughout their professional lives. Twelve individuals who hail from diverse occupations in chemical engineering were interviewed on their career experience. The research participants were also diverse in terms of race, gender, and age. From these interviews a theory was constructed grounded in the data, and a model proposed, on how chemical engineers in this sample decide to make career decisions.

The theory constructed was that values dissonance after an event influences the decisions that chemical engineers take on their career path. A chemical engineer has a values system, and reality, such as working in a particular work life situation, will not match all their values. When an event precipitates the consideration of these values dissonances, the chemical engineer may make a decision that will minimise their overall values dissonance. The nature of the decision then depends on the person's particular values system.

The values-based decision-making system has commonalities with the protean career orientation, although the focus is on the minimisation of overall values dissonance, rather than being driven by values. Interview data revealed that older participant chemical engineers have been making career decisions in a manner found in this research from as early in their careers as the 1970s, more than 40 years ago, the protean career became popular in literature after 1990.

**Key terms:** chemical engineers, career decisions, values, value dissonance, protean career, grounded theory

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## CHAPTER 1

### INTRODUCTION

This study focuses on the career decisions of chemical engineers over their professional lives. The following paragraphs will elaborate on what chemical engineering is, what makes chemical engineers unique, and why their career decisions are important. Following on will be a brief discussion on careers, career theories and career decision theory in literature. In conclusion it will be shown that there is a gap in the literature on the career decisions of chemical engineers *per se*, and as it is important, this study will add value to the literature, chemical engineers themselves, their profession, and the field of industrial psychology, including career counselling.

Chemical engineering is defined as “the branch of engineering concerned with the design and operation of chemical plants” in the Oxford English Dictionary (Oxford Dictionary of English, 2020). Somewhat more broadly, it is the field of engineering involved in the design and construction as well as operation of such plants for the industrial scale production of useful products from the relevant raw materials (Gallego-Schmid, Rivera, & Stamford, 2018). The University of Minnesota’s website for Chemical Engineering and Materials Science (<https://cse.umn.edu/cems/cems-about>, 2021) elaborates that chemical engineering does the integration of mathematics, physics, chemistry and biology to create and optimise processes for the chemical, materials, energy, food and biotechnology industries.

Chemical engineers are trained to research and develop chemical processes, design, commission and operate such manufacturing plants, maintain existing plants, and perform economical optimisations in the design and operation of these factories (Engineers, 2014). Chemical engineering processes include chemical manufacturing (for example consumer goods, paper and paint), energy generation (power plants producing electricity, the petroleum industry producing fuels), the pharmaceutical industry (manufacturing of medicines and healthcare products), the food industry (manufacturing sugar, beer), the environmental industry (industrial and municipal waste water treatment, air pollution reduction, life cycle assessments and sustainability studies), water purification (for drinking water), the agricultural industry (producing fertilisers and pesticides) and the mining industry (the extraction of minerals and metals from mined ore) (IChemE, 2007).

They also perform risk studies on the safety of new and existing processes, for the people and the environment, and work with intellectual property (e.g. patents), investment firms, public administration and education (Kim I., 2002). Different jobs in chemical engineering can be technical, managerial or in project management, to name a few. The following section provides a background and rationale for this study.

Chemical engineering activities may be traced as far back as 1670 (Kim, 2002), but as a profession it is considered to have had its origins in 1887, when George E. Davis presented a series of lectures, introducing the concept of unit operations, at the Manchester Institute of Technology (Cohen, 1996). The definition of the profession is perhaps best captured by the United Kingdom's Institute of Chemical Engineers (IChemE) (2014), which describes chemical engineering as the branch of engineering that involves the design, building and operation of industrial processes where the state or composition of matter is changed. This was quoted as early as 1929 in that year's edition of the Encyclopaedia Britannica (Hinchley, 1929). In 2014, the definition was elaborated in the IChemE's Royal Charter to also include research and economic development in the field (IChemE, 2014).

As early as 1908 there were calls for an expansion in the education of chemical engineers to allow the chemical engineer to be a "larger, broader and more influential man" (Richardson, 1908, p. 89), expressing the need in society for what chemical engineers can contribute. Wood (2006) summarises criticisms of chemical engineering education, and later repeats his opinion that reform in chemical engineering curricula is not occurring (Wood, 2010). A need to equip chemical engineers better for their expected roles in society has therefore been repeatedly expressed. With the engineering curriculum already full, and similarly so in many countries (Byrne E. , 2006), it follows on that graduate chemical engineers should equip themselves in their careers (Samuel, Magwagwa, & Mazingi, 2020), and with their career decisions develop themselves with continuous education for the new roles that they occupy, and aspire to.

Byrne (2010) argues that the understanding that chemical engineers have of the second law of thermodynamics and energy and material balances uniquely allows them to understand how the earth is a closed system and that society and economics need to address it as such, and compels chemical engineers to lead in this regard. Shott writes in his preface to IChemE's (2007) publication of "A Roadmap for 21st Century Chemical Engineering" that the profession is playing a growing role in the needs of society, including in energy production, the supply of water, managing waste, the production of food, and the production of products from healthcare products to consumer goods. Kim (2002) explains that chemical engineers are involved in many emerging technologies. The point of interest therefore lies in how chemical engineers' career choices overlay these societal expectations.

Byrne and Fitzpatrick (2009) state that chemical engineers possess a set of competencies that are important to the sustainability of society, and indeed that they are ethically obliged to actively play a role in the development of a sustainable society.

Chemical engineering is at the leading edge of creating sustainable manufacturing processes, as well as addressing environmental, energy and health challenges as is stated by the University of Minnesota (<https://cse.umn.edu/cems/cems-about>, 2021). Engineering doctorates

in particular are expected to advance the technological progresses required to address society's most urgent priorities, on an international stage (Main & Wang, 2020).

John Perkins (2003) discusses the future of chemical engineering to be the "broadest and most scientific of the engineering disciplines". However, he raises the threat of overload of opportunities from the challenges of society, and that it could lead to dissociation of the professions very distinctive origins. It is therefore important to retain focus: how chemical engineers develop their careers into serving these societal challenges would be important.

Considering the above expectations for chemical engineers to have an ever-stronger education, university and afterwards, to allow for a wide range of technical and related professions and to take up various leadership roles in addressing the challenges of society, the question arises: what motivates chemical engineers during their careers to work towards different embodiments of the profession? Why are they making particular career decisions at particular times in their careers?

Clearly, there are many options to choose from, and many differentiations and specialisations that could be followed. University graduates start to encounter challenges such as less job security, ever-changing technology, more personal accountability, and also the onus for continuous development in their profession (Magagula, Maziri, & Saurombe, 2020). For a chemical engineer some options should be more attractive than others, and understanding this better could help facilitate this process for the persons themselves, but also their organisations, and then society, as was discussed.

This then creates more depth to the question of what personal motivations may exist for a chemical engineer in the shaping of his<sup>1</sup> career. For example, why and when does someone that has been in a technical role decide to work towards a managerial role? Following on will be a discussion on career theory.

Following is a brief overview of career theory in the literature, to serve as a context for this study. One may see a career as a journey through life: a career can provide purpose, self-fulfilment, identity and status, among other things, through work (Baruch, 2003). A career forms the connection between the inner self and the outer society, and this connection is the means by which many people pursue meaning (Parker, 2002).

The process of career development is influenced by situational, environmental and personal factors (Morris, Schindehutte, & Lesser, 2002). The traditional career is no longer the only career trajectory available. Concepts such as the protean career (driven by values and self-direction) and the boundaryless career (finding different career meanings and progress in multiple organisations) are alternative phenomena (Lyons, Schweitzer, Ng, & Kuron, 2012) that may

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<sup>1</sup> The personal pronouns he and she, and the possessive pronouns his and her are used interchangeably throughout this dissertation, and includes and represents all gender representations.

further frustrate a simple model to mapping careers. It follows that a single standard linear regimen of career development and drivers may not be representative anymore (Sommerlund & Boutaiba, 2007).

A generalised model, such as that of Super (1992) poses that people play several different roles in life, and over time these roles change. Many of these roles can be lived at the same time, with different strengths of commitment (the Rainbow model). Super (1992) continues that the characteristics of the person, including values, and abilities, as well as the environment within which the person functions, influences career development (the Arch model). If one considers different ages when engineers could engage in different technical, managerial or project responsibilities, it follows that many combinations of age and work roles are possible, and these will further combine with other life roles, for example parenthood. Such combinations may lead to different personal motivations for subsequent career choices that also depend on time and other personal factors.

In 1960 Wilensky described a career as a sequence of jobs, related, but increasing in prestige, which people will move through in a roughly predictable order (Wilensky, 1960). Such progress up a career ladder is the traditional or linear career trajectory. According to Sommerlund & Boutaiba (2007), the traditional “bordered” and the newer boundaryless career should be seen as co-existing, and not separate concepts as reported in literature – it is not always one or the other.

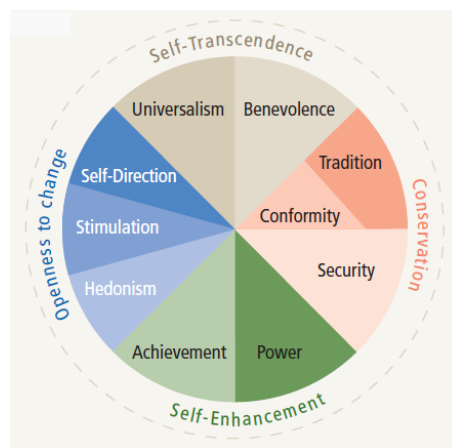
The protean career was coined by Hall in 1976 (Hall, 2004), but was popularised only in the mid-1990s (Hunter, 2016). According to the protean career model, the career process is self-driven by the person, not the organisation, and the person’s values constitute the driving force (Hunter, 2016). Vigoda-Gadot and Grimland (2008) states that psychological success is the measurement of the protean career.

The boundary career sees individuals navigate between organisations (Blanchette & Bencherqui, 2021). Hunter (2016) explains that the boundaryless career exceeds physical boundaries, for example moving between organisations, but also psychological boundaries, such as improving skills and networking beyond the current employing organisation.

A competency-based career perspective, which became known as the intelligent career, was proposed in 1994 by Filippi and Arthur (Parker, Khapova, & Arthur, 2009), using the terminology “knowing-why” (why you are in your current career environment), knowing-how (why you can perform in a current or future roll, your experience and skill-set) and knowing-whom (one’s overall circle of networks: mentors, colleagues, family and acquaintances, affiliations, etc.) (Hunter, 2016). These three cartegories (in short, why, how and with whom you work) of knowledge is a broad reflection of a person’s identity and motivation (Parker, Khapova, & Arthur, 2009). In the intelligent career, the person navigates their career by investing in relevant knowledge (Blanchette & Bencherqui, 2021), and benefiting from the options realised.

Bandura explored the interaction between behavioural, cognitive and social elements from the environment, posing that people are not merely a product of their past, but actively synthesise their future from elements in this field (Bandura, 1986). From this work, the social cognitive career theory (SCCT) developed (Lent & Brown, 1996). It focuses on the constant and complex interactions of goals, interest and abilities for the development of career interests, to advance aligned career decisions, reach a range levels of performance, and achieve persistence in career and further educational pursuits (Lent & Brown, 1996). SCCT research mostly concentrated on the fields of science, technology, engineering, and mathematics (STEM) careers (Medugorac, Sverko, & Babarovic, 2019).

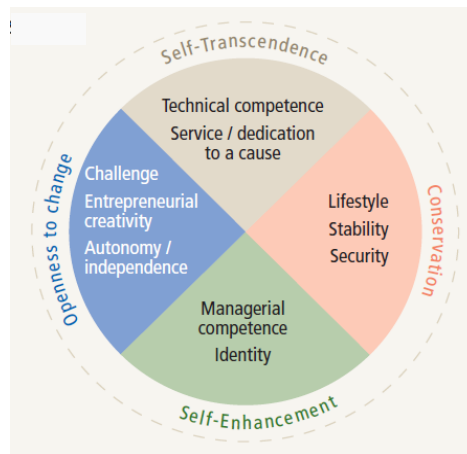
Schein (1990) describes the development of the term “career anchor” to be one’s constantly developing concept of what you are good at, what you need, what motivates you, and which of your values determine work choices (Schein, 1990). In his work, Schein (1990) discusses eight career anchors, which are security, autonomy, technical competence, general management, entrepreneurial orientation, service to a cause, pure challenge, and lifestyle. The initial concept was that one of these anchors would be governing, and hence determine the career direction of a person, but this was challenged in a study of engineers by Martineau, Wils and Tremblay (2005). They showed that multiple strong career anchors were not only possible, but common, and did not point to pathology as reported previously (Martineau, Wils, & Tremblay, 2005). Subsequently a model of values under opposing quadrants of self-transcendence and self-enhancement, and conservation and openness to change was developed by Schwartz (1992), as depicted in Figure 1 below.



Source: Schwartz (1992), in Wils, Wils and Tremblay (2010)

Figure 1. Schwartz’s Universal Structure of Values (Schwartz, 1992)

Wils, Wils and Tremblay (2010) proceeded to show that the career anchors from Schein indeed can be grouped under the same four quadrants, as depicted in Figure 2, below.



Source: Wils, Wils and Tremblay (2010)

Figure 2. The circular model of career anchor structure (Wils, Wils, & Tremblay, 2010)

It is interesting to note that the categories of the Engineering Council of South Africa's Code of Conduct were listed to include competency, integrity, public interest, environment and dignity of the profession as its elements (Cato, 2017). These correspond closely with the upper value quadrant of self-transcendence in the above models of Wils, Wils and Tremblay (2010), which include technical competence and service as career anchors, and Schwartz (1992), which include benevolence and universalism, among its values. The protean career, for example, has been linked before with benevolent citizenship (Vigoda-Gadot & Grimland, 2008).

The timing of career choices as a result of personal motivations will differ for different people. Lyons et al. (2012) conclude that cross-sectional studies of careers are very difficult to compare, despite much data, because of the varying definitions of generations and their time frames. It suggests that people's perceptions of a time frame may influence their perceptions of their careers at the time. How chemical engineers experience their own timeline, independent of external definitions or predetermined classifications, will prove insightful, especially when related to their career experience.

Lent and Brown (1996) describe how changes in a person's environment can lead them to revisit their interests from which they may derive reward, for example, becoming a father, or taking advantage of technological developments in the workplace.

Engineering in general is becoming more important in the globalised world (Martínez-León, Olmedo-Cifuentes, & Ramón-Llorens, 2018), and the management of such professionals and their careers too. Engineering has become powerful in advancing the economic and social advancement of countries (Grochocki, Guimarães, & Oliveira, 2018). The opportunities of chemical engineers, among all engineering disciplines, are increasing in fields such as

sustainability, because of the multidisciplinary skillset which they have (Gallego-Schmid, Rivera, & Stamford, 2018). The retention of engineers in organisations, and indeed in the profession, is important, and the insights gained from studying applicable career theory can assist in this endeavour (Hunter, 2016).

While a number of career theories have been described in literature, there is a gap in the literature in their direct application to chemical engineering. Likewise, the literature contains several career decision theories, but a gap exists on its application to chemical engineers specifically. Chemical engineers are unique in a number of ways. Their contribution to society is important. This study aims to address the noted gaps in literature by creating grounded theory. Following the development of a theory, a model which interprets the theory will be created.

## **1.1 Problem statement**

The course of professional chemical engineering development is formalised. The statutory Engineering Council of South Africa (ECSA) officially determines the specific requirements for registration for becoming a registered professional chemical engineer in South Africa (Cato, 2017). ECSA is the South African regulatory body regulating the engineering profession (Samuel, Magwagwa, & Mazingi, 2020) as legislated (South Africa, 2000). This includes an approved bachelors degree in chemical engineering. The approval occurs by means of accreditation, for which ECSA is responsible in South Africa. Further international accreditations of qualifications and professional registration processes among engineering organisations also occur, as has been described. Accredited university curricula have a regulated content, and specific competencies must be attained to allow for professional registration. Indeed, it has been found that the curricula in Australia, Canada, Singapore, the UK and the USA are as similar as among the universities in one country (Byrne E. , 2006). The core educational outcomes from the curricula should be global, to allow for chemical engineers' attributes to be globally on the same level, hence global accreditation is necessary (Patil, Nair, & Codner, 2008). Thereafter accredited continuous professional development is required (Mtshali, 2021). For international chemical engineering accreditation is achieved through the Washington accord, of which South Africa is a signatory through ECSA (International Engineering Alliance, 2017). There are many variations in the practice of chemical engineering in all its forms and roles and they need to live up to high expectations in a diversity of areas. Consequently, chemical engineers may choose a variety of career paths. The problem is that chemical engineers make career decisions at certain points throughout their professional lives, but it is not clear why and when they will make these career decisions. The process of career decision making is complex (Germeijs & De Boeck, 2003). The lives of chemical engineers, as with all people, are not uniform – different individuals' career stages and life stages can match up differently (Super, 1992), resulting in different needs within

seemingly similar life stages. This lack in understanding the career decisions chemical engineers make at which points throughout their professional lives impacts the individual lives of chemical engineers, organisations and the profession as a whole. Evidence has been presented on different career paths available to chemical engineers, possible reasons for career changes as well as the influence of changing career paths the profession, however why and when chemical engineers will make these career decisions has not been well described. This study aims to generate a theory to understand what career decisions chemical engineers make at which points throughout their professional lives.

## **1.2 Research questions**

This research study attempts to answer the following questions:

- How do chemical engineers experience their career development retrospectively?
- Why do chemical engineers make certain career? decisions?
- Why are the career decisions made at those particular times in their lives?
- How do chemical engineers experience the contexts within which they make career decisions?
- What theory, contained in a model, will explain the career decisions of chemical engineers across their professional lives?

## **1.3 Expected contributions of the study**

### **1.3.1 Contribution to industrial/organisational literature**

The knowledge and insight gained from this study will add to the literature available on this subject area. Insight into chemical engineers' perceived career change needs and decisions over the course of their professional lives will become apparent, as well as which criteria are involved in making such career decisions, and at which points in time. It will also add to career counselling resources. This means that, for example, when a chemical engineer presents to an industrial psychologist as a client with a career matter, the information from this study may inform the psychologist to better understand and navigate the matter.

### **1.3.2 Contribution to organisations**

Organisations may benefit in four ways. Organisations that employ chemical engineers may gain insight that they may use to structure their career development activities appropriately. If organisations can target development activities timeously, their chemical engineers' needs will be met more effectively, also, in terms of cost and time. Organisations that provide training and development to chemical engineers may benefit in understanding how they could tailor their

products and services more appropriately to the career needs of chemical engineers. The personal development of the chemical engineers in the organisation may also be aided, which in turn will benefit the organisations' career management. Lastly, professional chemical engineering organisations may benefit in understanding how to cater for the needs and developments of their members into reaching their potential, to the advantage of their members and society.

### **1.3.3 Contribution to the individual**

The individual chemical engineer will benefit from understanding how career needs manifest during the course of his personal career and life. Such insight will benefit his development plan in selecting development opportunities at the appropriate points. The dissonance of following a regimented development route versus a trajectory meeting personal needs will be reduced. A focus of collecting items in a curriculum vitae that will allow possible future options can be shifted to one of acquiring the development of competencies that allows for current growth.

The participation in the study effectively offered the individual a career counselling session, which improved self-insight, as was confirmed by most of the participants.

## **1.4 RESEARCH OBJECTIVES**

The research objectives are divided into a general objective and specific objectives.

### **1.4.1 General objective**

The general objective of this research was to understand what career decisions chemical engineers make at which points throughout their professional lives.

### **1.4.2 Specific objectives**

The specific objectives of this research were to:

- determine how chemical engineers experience their career development retrospectively;
- determine why chemical engineers make certain career decisions;
- determine why career decisions are made at those particular times in their lives; and
- investigate how chemical engineers experience the contexts within which they make career decisions.
- generate a theory to explain career decisions of chemical engineers throughout their professional lives, and represent it in a model.

## **1.5 RESEARCH DESIGN**

### **1.5.1 Research approach**

A qualitative research approach in the grounded theory tradition (Corbin & Strauss, 2008) was followed. The intention was to construct theory from the data to explain the reasons for career decisions, and how these fit in with career stages perceived by the chemical engineer, from the experience and perspective of chemical engineers. The research was therefore explorative in nature.

### **1.5.2 Research strategy**

The careers of a diverse combination of people in a diverse range of chemical engineering roles were studied. Several chemical engineers were interviewed individually.

The size of the sample was determined by data saturation. The original target was to interview at least eight people. Initially 15 chemical engineers were invited to participate. One person declined, and two did not respond, even after a reminder of the invitation. Ultimately, 12 chemical engineers were interviewed. Short follow-up interviews were conducted to clarify specific aspects of the first interviews. Saturation was reached, so no further participants were needed. Should further participants have been required, the technique of snowballing – gaining referrals from the first round of participants – would have been used.

For the purpose of this study, a chemical engineer is defined as someone who is, or who is able to be, registered as a professional chemical engineer. Such a registration in South Africa will be with the Engineering Council of South Africa (Engineering Professions Act 46 of 2000 see South Africa, 2000). Internationally such a registration will be with an organisation that forms part of any national engineering body that is recognised by the Washington Accord. The Washington Accord is an international agreement among engineering bodies that reciprocally accredit engineering degree programmes (International Engineering Alliance, 2017). Such a registration typically requires an accredited bachelor's degree level qualification (or equivalent) in chemical engineering as well as prescribed minimum relevant experience. For the purpose of this study, the definition of chemical engineering included process engineering, metallurgical engineering (and its sub-fields), biochemical engineering and petroleum engineering. Excluded from the definition of a chemical engineer are technicians, technologists, scientists, industrial chemists, and engineers from the other engineering professions, for example mechanical, mining, industrial, electrical and civil engineering. Potential participants holding any position as a chemical engineer qualified, for example production engineers, control engineers, managers, researchers, academics, technical specialists, entrepreneurs or unemployed persons with any of these

descriptions. Secondly, the delimitation was intended to practically limit the scope of the research for this study, being a mini-dissertation.

The participants were sourced by purposeful selection. The set of participants is comprised of chemical engineers of various ages, races, genders, disability status, nationality and sectors of the profession. Participants were approached directly in their personal capacity via WhatsApp. The potential participants were all known to the researcher as part of his professional networks, and therefore their mobile telephone numbers and email addresses were known to the researcher. Initially, an introduction notice was sent mentioning that a participation request would follow, and then a participation request was sent. Where the response was positive, a formal participation request was sent via email.

### **1.5.3 Research method**

#### **1.5.3.1 Literature review**

A complete review regarding chemical engineering career development was done. The sources consulted include searches in:

- Articles published in accredited scientific journals, whether in print or available electronically.
- Articles in chemical engineering publications.
- Relevant text in published books, encyclopaedias and dissertations.
- Relevant text available on the internet regarding the engineering organisations and the profession, for example definitions, charters, agreements, professional requirements and training-related material.

Key words in the search included: chemical engineering, process engineering, career development, career decision theory, protean career, values, values dissonance, career anchors, intelligent career life course, and grounded theory.

#### **1.5.3.2 Research setting**

The time and place (or electronic means) were arranged with each participant individually. This study was not specific to any employer. Where interviews took time during working hours, or at work premises, the participants were asked to clear this with their employers. Participants took part at their own discretion in their personal capacities.

Interviews were conducted by the researcher in suitable venues convenient to the participants, for example in a meeting room, office, or home, or electronically via Skype, or a telephone call. A suitable venue was arranged with each participant individually. If it was at the

participant's workplace, the person was asked to confirm that the interview may be done in work time and/or on the work premises.

The venue for the interview was required to have comfortable seating and be suitable for a private conversation. The venue had to allow for the digital recording of voice. The venue also was required to be closed from interruption for the duration of the interview. Skype interviews were done from the researcher's home office to participants' venues. The telephonic interviews was done from the researcher's home office as well, via speakerphone, to the participants' home or chosen location.

### **1.5.3.3 Entrée and establishing researcher roles**

Potential participants known to the researcher were provided with information on the study and were offered the opportunity to participate. The chemical engineers involved were known to the researcher through his own professional networks.

Each of the 15 potential participants was contacted via WhatsApp to alert them that they would receive an email with an invitation to participate in the study. The email, from a dedicated newly created address, was then sent to the participants identified for the first round. Twelve participants accepted the invitation to participate, one declined, and two did not respond. A reminder was sent to the two participants who did not respond. After no further response was received from them, they were not contacted again.

Informed consent was explained and was obtained in writing for those participants who were interviewed in person. The people who were interviewed via Skype or telephone received an explanation of the informed consent at the start of the interview. They then sent the signed consent forms via email to the researcher. Each participant received a detailed description with the informed consent information in advance as well. A time and place or method of an interview was then arranged.

The researcher conducted this research in his personal capacity as a student at the North-West University. He does not represent an organisation, although chemical engineering organisations have in principle supported the research within their membership.

The researcher was the interviewer. Each interview consisted of the researcher and the participant only.

### **1.5.3.4 Sampling**

The inclusion criteria, as stated earlier, was that the candidate should be a registered professional chemical engineer, or a chemical engineer able to register as a professional chemical engineer. Purposive sampling (Brink, Van der Walt, & Van Rensburg, 2012), was used to select individual participants. Individuals were selected who were likely to answer the research study (Tie, Birks, & Francis, 2019). In the case of this study, the individuals were selected to

demographically diverse within that potential sample to attempt to be able to build a representative theory of the population. Snowballing, where a participant is requested to recommend another (Staller, 2021), would have been used in saturation would not have been reached. Saturation is where the additional data reveals no new information (as codes or themes) (Braun & Clarke, 2019).

Individuals took part in the study in their personal capacity, and not in a representative role for an organisation or an employer.

#### **1.5.3.5 Data collection methods**

Data was collected by means of semi-structured individual interviews with the participants. The intensive interview has long been used in qualitative research for gathering data and allows for the in-depth exploration of an experience or topic (Charmaz, 2006).

The use of semi-structured in-depth interviews aimed to exclude possible bias from the researcher in pre-empting questions. Participants were each asked the initial question to describe their career in retrospect. Questions for probing and clarification were used to refine information.

A biographical questionnaire was verbally given to each participant at the end of the interview. This questionnaire included age, gender, race, type of current work (e.g. academic, management, production, etc.), qualifications, and current professional registrations. It allowed for some further reflection, connection, and elaboration to the content of the interview.

The final question was in which way the interview was meaningful to the participant, as a means of strengthening data reliability.

The interviews were recorded on a digital dictaphone and transcribed verbatim afterwards.

The researcher used a bracketing technique to identify his perspectives, and to avoid contamination (Brink et al., 2012) by writing a self-reflective statement. The self-reflective statement contains the researcher's own career experience as a chemical engineer, but also identifies various roles and perspectives from his career which may influence the way that he reflects on the data. This self-reflecting statement has been provided to the author's supervisor to monitor for bias. It contains information of a personal nature, and has therefore not been included in this document. It was also coded to once again monitor for bias.

Each participant is identified by a pseudonym and was not identified in the published materials, or to anyone who may have access to the research materials in the process of transcription, research, academic evaluation, or auditing. Names of people, places and organisations named in the interviews were changed to random generic names to further protect anonymity. In the South African context, with a relatively small community of chemical engineers, very few pieces of information could be used to identify a participant, hence extra care was taken to present even anonymous demographic information in unidentifiable manner.

### **1.5.3.6 Recording of data**

The interviews were recorded on a digital dictaphone.

The researcher made field notes during and after the interviews. During the interview, notes were taken on pertinent topics for further discussion later in the interview, as well as how the participant was seen to experience the interview process.

After the interview the researcher summarised the interview process and made notes on specific items of interest.

The data was downloaded from the dictaphone onto a computer, where it was saved in password-protected files. Field notes were typed into Microsoft Word, and the files were saved in an encrypted format. The voice recordings were transcribed by a professional transcriber under a confidentiality agreement.

The transcriptions were then sanitised in a manner where all names of people, places and organisations were substituted with generic and random names. The substituted names for organisations and places were used consistently, to allow for any significant relationships to be revealed during coding. The typed field notes were added to the transcriptions, for later coding.

Back-up copies of the encrypted files were made on a separate device and stored in a locked safe.

Paper copies of the field notes and transcriptions were stored in a locked file cabinet. The recording device was stored under lock in an office safe while the interview data was still on it. The notebook computer has electronic access control, and was stored under lock.

### **1.5.3.7 Data analysis**

Accepting that reality exists but may only be approximated by data and theory (“critical realism”), a postpositivist paradigm of inquiry (Lincoln & Guba, 1985), has been followed. By having collected data that penetrates beneath the obvious and subjective life, known as rich data (Charmaz, 2006), theory was constructed to attempt to describe the reality. This approach is known as grounded theory (Charmaz, 2006). Grounded theory is appropriate in cases where there is not much known about the field of study, the generation of an explanatory theory is desired, and the research is likely to explain the underlying process through the construction of the grounded theory methods (Birks & Mills, 2015).

Coding refers to the collection of data segments in categories that become themes. Codes clarify how data is selected, categorised and sorted to allow the analytical interpretation of it (Charmaz, 2006). Memoing followed as coding progressed. This process is described in detail in Chapter 2.

Coding has been done manually from the transcripts. An independent qualified researcher, under confidentiality agreement, repeated the coding and extraction of themes to ensure thorough analysis, and to minimise bias (Saldanha, 2009).

### **1.5.3.8 Strategies employed to ensure quality data**

Reliability and validity is also a requirement for qualitative research, and can be translated and interpreted in the following four areas: credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985).

#### **1.5.3.8.1 Credibility**

Credibility (validity) relates to the “truth value” (Lincoln & Guba, 1985) of the research. It is a measure of how close to reality the collected data is. Measures to ensure credibility in the research include the following:

- Promoting the chance of collecting credible data
  - Engaging sufficiently: the researcher must be familiar with the field to allow for understanding the field, be able to detect misinformation, and to establish trust with the participants. With the researcher’s background as described later, there was a high probability that the researcher was in a position to achieve these goals, although care was taken not to introduce bias, through bracketing.
  - Persistent observation was employed in engaging with participants from different demographics, which allowed various perspectives on the reality being investigated.
  - Triangulation, where additional data sources, methodologies and researchers may be used to add to the body of data from different perspectives, were used in two ways. Debriefing the participant’s experience of the meaningfulness of the interview was done (Flick, 2007), which indicated whether trust was experienced, and whether the participant had a meaningful engagement in the session. A second measure used was the use of independent coding by a qualified person not in the field of chemical engineering to allow for unbiased data analysis to be available to the study.
- Bracketing is where the researcher documents his experience and description of his perspectives beforehand. This was done in the form of a self-reflective statement. This allows for any bias to be documented ahead of the research.
- Referential adequacy (Lincoln & Guba, 1985) refers to having the opportunity to re-evaluate the generated theories against the data at a later stage. The use of recordings in the interviews allowed for this technique. After a theory was established, it could be compared against the recordings of the interviews.

#### 1.5.3.8.2 Transferability

Transferability (external validity or generalisability) refers to how the outcome to the research may compare to other similar settings. This requires rich data, or a “thick description” (Charmaz, 2006) to set a basis against which comparisons may be adequately made. In this study, the use of an interview together with the gathering of detailed field notes were used to create rich data.

#### 1.5.3.8.3 Dependability

Dependability (reliability) is provided by having the recordings and transcriptions of the interviews available for auditing. In addition, the research process is clearly described. Data saturation was achieved to ensure that all relevant themes were discovered.

#### 1.5.3.8.4 Confirmability

Confirmability, or objectivity, effectively means that someone else looking at the same data will reach the same conclusion. Triangulation and an independent co-coder, as well as proper data analysis techniques were used to achieve confirmability.

#### 1.5.3.8.5 Establishing the researcher’s background

The researcher is not independent from the field of study, and his relations to the field of the proposed study are declared here, in addition to the self-reflecting statement.

The researcher is a registered professional chemical engineer in mid-career. He is a senior manager in an industrial research environment, holding the roles of technical expert and line manager. In these roles, the technical and career development of chemical engineers form part of his work. He has been involved with research collaborations with academia for many years, and sits on the industrial advisory boards of two South African universities’ chemical engineering schools. In addition to the industrial experience, the researcher is extensively involved in the institutional aspect of the chemical engineering profession. He is a past president of the South African Institution of Chemical Engineers, and has represented South Africa at the executive of the World Chemical Engineering Council. He sat on the Engineering Council of South Africa’s Professional Affairs Committee for Chemical Engineers (which dealt with professional registrations among other things). He also sits on the Congress of the UK’s Institution of Chemical Engineers, being an international advisory body to the IChemE’s Board of Trustees.

He also mentors and coaches chemical engineers. As a line manager he was closely involved with the career development of chemical engineers in his group and in his wider

organisation. He holds degrees in management and industrial psychology, and is a registered psychometrist, all stemming from his interest in the development of people.

The researcher therefore holds an informed opinion on many matters regarding chemical engineering, especially in the South African context, in addition to his personal career experience. Care was exercised therefore to gather data in a manner that is not influenced by the researcher's background.

As stated earlier, analyses of interviews were repeated independently by a person who is not a chemical engineer, but who has experience of qualitative data analysis. This ensures that the data is mined thoroughly, and that bias from the researcher does not influence the outcome.

The self-reflective statement by the author will also serve as a means of identifying and excluding biases from the researcher's side. This statement is a reflection of the author's own career in chemical engineering, as well as the roles that he has held which may have influenced perspectives he could have on the profession, and career development.

#### **1.5.3.9 Reporting**

The report summarises the research for presentation in an article. The reporting is done in a narrative style. The post-positivist paradigm of this study requires critical realism. This implies relating the collated experiences of the participants close to the data.

#### **1.5.3.10 Ethical considerations**

Participation in the study was voluntary. Participants received written information on the study beforehand. A signed informed consent form was obtained from each participant before they took part in the study. The participants were anonymised, and were not identified in the research material or subsequent publications. The positions and employers of participants were also treated confidentially to protect the identity of the participants. The participants were interacted with in a professional and respectful manner. People assisting with transcription, coding and language editing were required to sign a confidentiality agreement.

Ethical clearance was obtained to perform this research. An application was made to the North-West University's Basic Social Sciences Ethics Committee (BaSSREC), who then approved the application, clearing the way for the research to proceed. The ethics clearance number is NWU-HS-2017-0126.

### **1.6 CHAPTER DIVISION**

The findings of the research objectives are discussed in the form of a research article, presented in Chapter 2. Chapter 3 contains the conclusions, limitations and recommendations of the study.

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## **CHAPTER 2**

### **RESEARCH ARTICLE**

## **Career decisions of chemical engineers across their professional lives**

### **Abstract**

**Orientation:** Chemical engineers' careers vary widely. While chemical engineers can make a significant impact on society, understanding how they choose and progress through their career choices is of interest to chemical engineers themselves, but also to their organisations and career counsellors.

**Research purpose:** The purpose of the research is to investigate when, how and why chemical engineers make career decisions.

**Motivation for the study:** An understanding of chemical engineers' career navigation strategies can help the individuals and organisations employing them to better plan career paths, and to tailor better development strategies.

**Research design, approach and method:** A qualitative research study employing constructivist grounded theory from a post-positivist perspective was utilised. Purposive sampling of 12 chemical engineers of diverse backgrounds, demographics, and careers was done. In-depth semi-structured interviews were conducted and the data was analysed based on constructivist grounded theory.

**Main findings:** A theory was constructed that explained how the chemical engineers' career decisions aimed at reducing their overall values dissonance. A model that represents this process was developed.

**Practical/Managerial implications:** A chemical engineer's career decisions pivots on their value system. Empowering the people to have a better perspective on their values, and which opportunities may suit them, may guide development and lead to improved career growth.

**Contribution/Value-add:** An understanding of the routes that chemical engineers take into the profession, and onward in their careers, contributes to the knowledge base of the profession. It may streamline individual's career paths and improve retention by offering suitable career opportunities. Career guidance professionals may use the developed model to help analyse and decide on appropriate career strategies for chemical engineers.

## Introduction

### Orientation

Chemical engineering offers various career options. Chemical engineers are expected to meet high expectations in resolving human sustainability challenges. As with all people, career needs coincide differently with various other personal needs over a lifetime. Factors leading to chemical engineers making career changes have not been well described in the literature. It would be valuable to have more insight into why, when and how chemical engineers pivot into various career directions.

### Research Purpose and Objectives

The general purpose of the study is to gain a better understanding of which career decisions chemical engineers make at which points over the span of their professional lives. The specific objectives are:

- To investigate how chemical engineers experience their careers in retrospect.
- To establish why they make certain career decisions.
- To find out why career decisions are made at a particular time.
- To explore the contexts within which chemical engineers make career decisions.
- To generate a theory to explain the career decisions of chemical engineers throughout their professional careers, and to represent it in a model.

### Literature Review

Chemical engineering as a profession is considered to have started in 1887 with George E. Davis's series of lectures. This introduction of the concept of unit operations was done at the Manchester Institute of Technology (Cohen, 1996). The Institution of Chemical Engineers (IChemE) (2014) of the United Kingdom describes chemical engineering as the engineering profession that encompasses the design, building and subsequent operation of industrial processes where there is a change of the state or composition of matter. This definition of chemical engineering was already provided in 1929 in the Encyclopaedia Britannica (Hinchley, 1929). In 2014, the IChemE's Royal Charter included economic development and research in the field (IChemE, 2014).

As early as 1908, there was a call for the expansion of the education of chemical engineers with the aim of allowing the chemical engineer to be a "larger, broader and more influential man" (Richardson, 1908). In 2006, Wood provided a summary of criticisms regarding chemical engineering education. In 2010, he repeated his opinion on the lack of reform in curricula (Wood, 2010). There are repeated expressions of the need to equip chemical engineers more for the expectations that society has of the profession. Students in chemical engineering need to be

enabled to work within complex, but poorly defined, problem-solving contexts (Wolff, Dorfling, & Akdogan, 2018).

Byrne (2010) reasons that the chemical engineers' understanding of the second law of thermodynamics, as well as material and energy balances, provide them with a unique understanding of the earth as a closed system, and that it needs to be so addressed by society and economics: chemical engineers are compelled to take the lead in this regard. In his preface to IChemE's 2007 publication "A Roadmap for 21st Century Chemical Engineering", Shott (IChemE, 2007) writes that the chemical engineering profession is fulfilling an expanding role in society's needs. This includes water supply, food production, waste management, the production of energy, and in production processes, ranging from consumer goods to healthcare products.

Kim (2002) states that chemical engineers are involved in numerous emerging technologies and positions, including, among others, for example: investment firms, intellectual property, public administration, and education. Byrne and Fitzpatrick (2009) report that chemical engineers have a competency set which is crucial to society's sustainability and state that they are ethically compelled to play an active role in establishing a sustainable society. The chemical engineering professional skills are necessary to ensure that chemical engineers can effectively address the current and future challenges of society and technology (Abegao & Glassey, 2018)

With the mentioned expectations from society for chemical engineers to have an even broader education, allowing for more latitude of technical and related professions and up to leadership in various roles to address society's challenges, the questions may be asked: what is it that motivates chemical engineers over their careers to become involved in different branches of the profession? Also, why are particular career decisions made at particular points in time in their careers?

A career may be considered as a journey through life: it can provide purpose, fulfilment, status, identity, and more, through work (Baruch, 2003). A career path can be defined as an objective description of a sequence of work experiences (Schreuder & Coetzee, 2006). The process of making decisions across a career is convoluted (Germeijs & De Boeck, 2003).

Much job satisfaction can be reached when the person's occupation corresponds well with his career anchors, especially if the dominant anchor could be identified (Ramaswamy & Kalkar, 2020), and such was the purpose of the development of the career anchors by Schein (Schein, 1990). However, it has been shown that the underlying values of career anchors can be grouped together (Schwartz, 1992). Indeed it was shown that multiple career anchors can be present (Martineau, Wils, & Tremblay, 2005), and that the career anchors can even be grouped similar to Schwartz's (1992) values circumflex model (Wils, Wils, & Tremblay, 2010).

The protean career (multiple career cycles) and the boundaryless career (finding different career meanings in multiple organisations) are alternatives to the traditional (linear) career (Lyons, Schweitzer, Ng, & Kuron, 2012) that may negate a simple model for mapping careers

(Sommerlund & Boutaiba, 2007). It was found that business professionals subjectively experienced more career success through both the boundaryless and the protean career orientations, embodied in career commitment and satisfaction (Kundi, Hollet-Haudebert, & Peterson, 2021). More recently people actively pursue careers that are meaningful to them, and therefore take a more active roll in their career evolution (Xin, Zhou, Li, & Tang, 2020).

The protean career has been described to be values-driven, where the person's own values provide the direction, and evaluation, of the person's career, rather than extrinsic motivators such as salary and job-offers (Segers, Inceoglu, Vloeberghs, Bartram, & Henderickx, 2008). In a study on millennial IT professionals, those who followed the protean orientation reported more objective success (in terms of salary), as well as subjective success (Kaushal & Vashisht, 2021). Although there is an increase in the number of studies into the protean career orientation, not much is known about how it is related to work values (Abessolo, Hirschi, & Rossier, 2017).

The boundaryless career exhibits mobility, both physical and psychological (Briscoe, Henagan, Burton, & Murphy, 2012). The physical movement is between organisations, while psychological mobility refers to upskilling for future options, and building networks external to the current employer (Segers, Inceoglu, Vloeberghs, Bartram, & Henderickx, 2008).

A model such as that of Super (1992), holds that people can be engaged in a range of life roles at the same time, and that these roles can change with time. He notes that one can be more committed to some roles compared to others, and that these levels of commitment may also change in time. He refers to this as the Rainbow model. He proceeds with the Arch model, where the person's environment, and the characteristics of the person such as competencies and values, influences career development.

The process of making career decisions does not hold easy answers. It continues through one's life, and is important for organisations' talent management (Hennessy & Yip, 2021).

The times at which career choices are made for various personal motivations will be different for different people: Lyons et al. (2012) concluded that cross-sectional career studies are quite difficult to compare, despite a large body of data, as a result of the diverse definitions of generations and their associated time frames.

This study therefore aimed to determine why and when chemical engineers make career decisions over the course of their career spans.

## **Research Design**

### **Research Approach**

A qualitative research approach, in the grounded theory tradition, was followed (Corbin & Strauss, 2008). The aim was to explain why career decisions were taken, by the construction of theory from the data, to explain motivations for making career decisions, and how this would

compare with career progress perceived by the chemical engineer, and from the chemical engineer's perspective and experience. This is therefore explorative research.

Little is known about what career decisions chemical engineers make at which points throughout their professional lives and therefore a grounded theory design was chosen with the aim to construct an explanatory theory that will uncover the career change decision process of chemical engineers. One of the characteristics of a grounded theory design is that the generated theory is grounded in the data. (Tie *et al.*, 2019:2). The researcher seeks to co-construct the experiences and meanings related to chemical engineering as a career choice with the study participants and therefore chose constructivist grounded theory as methodology.

The researcher purposively selected participants as data sources to answer the research question (Charmaz, 2006). Data collection and analysis was a concurrent process. Data collected from individual interviews were analysed by a process of constant comparative analysis. During the initial interviews, the researcher generated ideas inductively from the initial data (Sbaraini *et al.*, 2011). Idea after idea was compared in each code. In this initial coding process, the researcher generated as many codes as possible.

The researcher included memoing as a continuous reflective and interpretive process of writing down ideas and thoughts about codes, categories and relationships between categories contributing to a higher level of analysis. Tie *et al.* (2019) states that memos add more detail to the data, specifically it includes the researcher's thought processes, feelings and intuition regarding the subject in an attempt to co-construct meaning. As more interviews contributed rich data, more codes emerged. Initial codes were then compared with the new emerging codes. Several codes were then combined into categories. These categories were compared with previous ideas (Sbaraini *et al.*, 2011; Tie *et al.*, 2019). The initial coding identified the need for theoretical sampling of additional data, in the case of this study, from the same participants, to strengthen the development and saturation of theoretical categories (Tie *et al.*, 2019).

The research focused coding by pursuing a selected set of central codes throughout the entire dataset (Sbaraini *et al.*, 2011). The researcher and independent coder made decisions as the research team regarding initial codes that stood out and therefore considered important to derive meaning. Memoing were integrated and continued to provide evidence of thought patterns and feelings during this process. Focused coding is an iterative process that requires inductive and deductive thinking (Tie *et al.*, 2019). Consistencies and differences were sought out and reflected upon in a constant comparative process to refine concepts and theoretically relevant categories (Tie *et al.*, 2019). Core concepts emerged and the relationships between concepts became evident. The researcher was able to explain each category without the need to search out or add new data – thus theoretical saturation was achieved (Staller, 2021).

In the final stage of analysis, theoretical coding is the process of incorporating the core concepts to create a theory (Tie *et al.*, 2019). The results of this grounded theory study were

tabled as concepts related to each other and described as a substantive theory, a theory which interpreted and explained what career decisions chemical engineers make at which points throughout their professional lives.

### **Research Strategy**

Twelve chemical engineers were interviewed. Data saturation was reached, hence no further participants were approached.

For the purpose of this study, a chemical engineer was defined as someone who is, or who is able to be, registered as a professional chemical engineer. In South Africa, such a registration would be with the Engineering Council of South Africa (ECSA) (Samuel, Magwagwa, & Mazingi, 2020). Registration is not compulsory for chemical engineers in South Africa, and therefore not everyone who qualifies for registration is registered.

One requires an accredited bachelor's qualification (in South Africa), and sufficient experience in a range of prescribed areas of chemical engineering. This culminates in a specified list of competencies that must have been attained. For this study, the definition of chemical engineering includes process engineering, metallurgical engineering, petroleum engineering and biochemical engineering, and excludes scientists, industrial chemists, technicians, technologists, and other engineers, for example mining, mechanical, electrical, industrial, and civil engineering. Participants qualify regardless of the position they hold in chemical engineering, for example: technical specialists, production engineers, managers, consultants, academics, or researchers, among others. This study refers to the structured training and experiential learning that professional chemical engineers receive. The results may be applicable to other fields of engineering, science or even other professions, but that needs to be confirmed in separate studies. Secondly, the intention with the exclusion, is to limit the scope of the study to a practical extent.

Additional candidates were also contacted to increase the demographic diversity of the study. The intention was that, through purposive selection, more participants would be added to facilitate data saturation, if required. This was however not necessary.

### **Research Method**

**Research setting.** The participants in this study were requested to arrange the venue and time of each interview with the researcher. Participants took part in their personal capacity at their own discretion, and not as members of an organisation. Gatekeeper permissions were therefore not required. Where applicable, arrangements with their employers were left to the participants to organise (and they were so informed before the interview).

**Entrée and establishing researcher roles.** Fifteen chemical engineers were contacted to participate in the study. They were first contacted through WhatsApp to expect an email request to take part. The email request with informed consent and ethical clearance documents were then

sent to each of the participants. Twelve respondents agreed to participate, one declined, and two did not respond. The contact details of the potential participants were known to the researcher as a result of previous interactions through engineering society activities, or professional work.

The researcher conducted the research in his personal capacity as an NWU student. He was not acting as a representative of any organisation. The researcher conducted the interviews himself. Only the researcher and the participant were part of the interview.

**Research participants and sampling methods.** Potential participants were chosen by purposive sampling (Brink, Van der Walt, & Van Rensburg, 2012).

The initial set of potential participants were chosen from chemical engineers in the researcher's professional networks who are already, or who could be, registered professional chemical engineers. This initial set were chosen purposefully to cover a range of demographic and career diversities. If saturation would not have been reached, snowballing (Brink et al., 2012), would have been employed to invite further suitable participants via referral from existing participants. However, saturation (Braun & Clarke, 2019) was reached within the first set of participants. Theoretical saturation was achieved when emerging concepts were substantiated (Staller, 2021), and additional data did not add new codes.

The research participants took part in this study in their personal capacity. They did not represent an employer or organisation.

**Data collection methods.** Semi-structured one-on-one interviews with the participants were conducted to gather data. The interview started with a question for the participant to describe their career. Thereafter clarifying and probing questions were asked within the context of the participant's narration. The intensive interview allows for the in-depth exploration of an experience or topic (Charmaz, 2006), and has been in use for a long time in qualitative research. This generated rich data about chemical engineers' career paths and choices. At the end of the interview a set of biographical questions was asked. As the interviews progressed, and the researcher became aware of common themes, more probing and clarifications were asked on such themes, for example the decision to study chemical engineering.

Semi-structured interviews were used to limit possible bias by the researcher in pre-empting questions. As is the nature of grounded theory, analysis started concurrently with data collection and determined follow-up questions. In some cases, follow-up clarifications were held to enrich the data from relevant participants. In successive interviews the nature of the discussions was adapted to focus on specific matters that have previously been encountered, once again for focusing on more richer data.

A verbal biographical questionnaire was given to each participant at the conclusion of the interview. This questionnaire included demographic data, type of current work (e.g. production, management, academic, etc.), as well as qualifications. It was found that the biographical questions invited more information and discussion from the participants, enriching the data further.

The final question was whether, and if so, how, the interview brought new insight to the participant. This was done to strengthen data reliability through triangulation.

Subsequently the digitally recorded interviews were transcribed by a professional transcriber. The transcribed interviews, field notes, and the researcher's self-reflecting statement were all evaluated by the researcher and independent researcher.

Research participants have been assigned pseudonyms for use in the publications. The names of other people, places and organisations named during the interviews were also replaced with generic names.

**Data recording.** The interviews were digitally recorded on a dictaphone.

Field notes were made by the researcher during the interview, by hand, and afterwards. A professional transcriber was employed to transcribe the voice recordings, being subject to a confidentiality agreement. The field notes were typed, and added to the transcriptions.

**Strategies employed to ensure data quality and integrity.** Validity and reliability are requirements for qualitative research. This may be defined in the following four areas: credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985).

*Credibility.* Credibility is equivalent to validity. It refers to the "truth value" (Lincoln & Guba, 1985) of the research in the study. It is an indication of how well the collected data represents reality. The following measures were used to ensure credibility in the study:

- Increasing the opportunity of collecting credible data.
  - Engaging sufficiently: the researcher should be familiar with the field of chemical engineering. This allows for understanding the subject area, to detect misinformation, and for establishing trust with the participants. With the background of the researcher as described later, it is clear that the researcher did achieve these goals, although care was always taken against bias, especially employing a self-reflective statement.
  - Persistent observation, using focused methods to obtain relevant data (Hays & McKibben, 2021) was used during the engagement with participants from the different demographics. This allows for different perspectives on the participants' realities being investigated.
  - Triangulation, which is the practice of using additional data sources, methodologies and researchers, was used to augment the data set from different perspectives, in two ways. The participant's experience of the meaningfulness of the interview was debriefed (Flick, 2007), which will indicate whether trust was established, and whether the participant experienced a meaningful engagement in the interview session. Secondly, independent coding by a person who does not work in the field of chemical engineering allowed for unbiased analysis of the data to be available.

- The interviewer prepared a self-reflective statement before the first interview, which set out his experience and perspectives in the fields and professions of chemical engineering. This then established the position of the researcher in terms of the research interviews and subsequent interpretation.

*Transferability.* Transferability (generalisability or external validity) refers to how the research outcome would compare to similar other settings. This requires a “thick description” (Charmaz, 2006) to establish the basis from which comparisons may be suitably made. In this study the use of interviews, the biographical questionnaires together with collecting field notes were used to establish rich data.

*Dependability.* Dependability is equivalent to reliability, and is achieved by having the recordings and transcriptions of the interviews available for auditing. Data saturation was achieved, indicating that all relevant themes were discovered.

*Confirmability.* Also known as objectivity, confirmability effectively means that a different person looking at the same data will reach a similar conclusion. The use of triangulation, an independent co-coder, and good data analysis techniques contributes to the confirmability. Having the transcriptions done by a professional transcriber allowed for more accurate capturing of the data.

*Establishing the researcher’s background.* The researcher does not stand independent from the field of study. His interactions with the field of the research study are set out here.

The researcher is a registered professional chemical engineer. He is currently mid-career. He works in an industrial research setting. He is a technical expert with line management experience. The career development of chemical engineers, in technical positions and otherwise, form part of his work. He has been working with academia on research collaborations for many years. He sits on the industrial advisory board of two South African universities’ chemical engineering schools. Apart from his industrial experience, the researcher has been extensively involved in the professional aspect of chemical engineering. He is a past president of the South African Institution of Chemical Engineers. He has represented South Africa at the World Chemical Engineering Council. He was a member of the Engineering Council of South Africa’s Professional Affairs Committee for chemical engineers (dealing with professional registrations inter alia). He further is a mentor and a coach for chemical engineers.

The researcher therefore has an acquired perspective on matters regarding chemical engineering, particularly in the South African context. He also has his own career experience. While care was taken that the data was not analysed in a biased manner, the researcher’s immersion in the field also allowed him depth to analyse the data.

Independent coding of anonymised transcripts was done by a person with experience in qualitative analysis, but who is not a chemical engineer. This was to ensure thorough data mining, and to limit possible bias from the researcher to influence the outcome (Saldanha, 2009).

The researcher's also attempted to limit his bias by documenting his experience and perspective in the self-reflective statement.

Ethical clearance was obtained from North-West University's Basic Social Sciences Research Ethics Committee (BaSSREC).

**Data analysis.** A post-positivist paradigm of inquiry (Lincoln & Guba, 1985) was applied, accepting that there is an existing reality which may only be approximately described by data and subsequent theory ("critical realism"). By collecting rich data (Charmaz, 2006), theory was constructed in an attempt to provide a description of reality, an approach that is termed grounded theory (Charmaz, 2006). Grounded theory is suitable in instances where little is known about the field of study, an explanatory theory generation is considered advantageous, and the underlying process found in the research could be defined by employing the methods of grounded theory (Birks & Mills, 2015).

The collection of data element in categories (that become themes), is known as coding. Codes clarify the process of data selection, categorisation, and how it is sorted to allow it to be analytically interpreted (Charmaz, 2006).

Data analysis first employed initial coding (open coding), which generated several codes. Throughout the coding process, data was constantly compared between data transcripts, reflected upon, interpreted and notes made. Recordings were listened to several times, and transcripts read repeatedly to obtain a sense of the content. The grounded theory approach guided this constant comparative analysis. Inductively, concepts were identified and grouped into categories. For this process, the researcher required theoretical sensitivity to have insight in what is meaningful and significant in the data (Strauss & Corbin, 1990). The categories were further sorted to become themes and sub-themes. During this process memoing was used to theoretically distil the information further. After open coding, focused coding (selective coding) revealed the main concept, from which a conceptual model was developed. The next stage, also known as theoretical coding, guided the discovery of the relationships between concepts, which permits a comprehensive understanding and description of the emerging theory.

**Reporting style.** The themes and sub-themes found in the study are presented in the next section. Quotes from the participants are included to illustrate the relevant findings.

The research participants have been given pseudonyms to protect their anonymity. All companies, institutions and places have also been given random generic names, e.g. University 4, also to ensure anonymity.

This is followed by the proposed conceptual model and discussion. Relevant literature to the framework will be included in the discussion.

## Results

Three main themes were found during the grounded theory analysis of the data: "Why study chemical engineering?", "Career progression and aspiration" and "Reasons for career

changes”. These themes speak to the research objectives and questions. As mentioned earlier, further selective coding revealed the main concept.

Table 1

Demographic summary of research participants

Name	Age	Sex	Race	Nationality
Alley	39	F	White	RSA
Dean	66	M	White	RSA
Frank	67	M	Coloured	RSA
Greg	46	M	Indian	RSA
Hank	38	M	Foreign	French
Mary	32	F	Black	RSA
Nicki	44	F	White	RSA
Olaf	44	M	Foreign	Kenyan
Paul	61	M	Black	RSA
Quinn	47	F	White	RSA
Ursula	41	F	Indian	RSA
Wanda	37	F	White	RSA

Pseudonyms were used in Table 1. The following two paragraphs provide additional biographical information, but it was not added to Table 1 to limit identifiability.

Three of the participants are people living with disabilities, being sight-impaired, hearing-impaired and on the autism spectrum.

Positions which the participants held at the time of the interview include, in random order: entrepreneur, senior manager, senior university official, consultant, senior process engineer, unemployed (motherhood), lecturer, process engineer, research director and retired.

Table 2 summarises the themes and subthemes.

Why study chemical engineering? This theme includes the sub-themes of exposure to chemical engineering, personality and financial support.

Career progression and aspiration. The sub-themes that were found here are professional development, professional societies, industry, academic career, management and leadership, and entrepreneurship.

Reasons for changes. Financial security, challenge-seeking, finding meaning, life-long learning, individual and family focus, and benefiting society were found to be sub-themes of this theme.

Table 2

Summarised themes

<u>Theme</u>	<u>Sub-theme</u>	<u>Explanation of theme properties</u>	<u>Quotes</u>
Theme 1: Why study chemical engineering?	Sub-theme 1.1: Exposure to chemical engineering	Participants describe specific exposure to chemical engineering as a career option as the catalyst for considering it as a career.	Paul: "Therefore, there was that pull toward the medical profession for some time, uhm until I think my last two years of high school. I entered the Olympiad is it Science Olympiad?"  Ursala: "...expose me to people who actually were working in the sciences at Company B so I was able to speak to an engineer and find out a bit more of what engineers actually do."
	Sub-theme 1.2: Personality	People who are inquisitive, enjoy intellectual challenges, enjoy mathematics and science or who prefer critical thinking enjoyed studying chemical engineering.	Olaf: "I have always enjoyed uhm you know logical thinking and abstract thinking uh I like uhm I like solving problems." Greg: "So when you are in an engineering environment, I think you tend to get a lot more people who tend to think along the same lines; very logical in terms of the way they make decisions."
	Sub-theme 1.3: Financial support	Students need financial resources to study chemical engineering. Bursaries, scholarships, grants and other methods of funding allow people who are inclined to study chemical engineering to do so. Students without funding may not start studying engineering or have to drop out. Sometimes the offer of funding will induce someone to study further in chemical engineering, for example a Fulbright Scholarship, when they have not considered the option before.	Hank: "...they also told me that there was an opportunity of a bursary as well, a European bursary so that helped a lot. Paul: "I got that Fulbright Scholarship."
Theme 2: Career	Sub-theme 2.1: Professional development	Chemical engineers work in a very wide technical field, and university education focuses mostly on	Wanda: "Whilst I was there, I did my Master's degree in Process modelling."

progression  
and aspiration

fundamentals and theory. It means that further learning needs to happen in the work context in order for the engineer to become competent. Specific technical and managerial courses, post-graduate degrees, as well as exposure to fields of work are methods of increasing competence and expertise in a field. Internationally, continuous professional development is encouraged for chemical engineers. The corporate world also allows for career progression into management.

Frank: "Uhm when I was at American University 1 I was in a lot of professional development courses, some of them were academic courses in environmental planning, emergency response uhm and uhm assessment and remediation of contaminated lands, brown field redevelopment and so forth."

Sub-theme 2.2: Professional societies

Networking, the availability of membership to specialised technical communities, service to the profession and professional registration are all reasons why chemical engineers join professional societies. In the South African context, the South African Institution of Chemical Engineers (SAIChE) and the Engineering Council of South Africa are the typical professional societies which chemical engineers may join. The South African Institution of Mining and Metallurgy (SAIMM) is also where chemical engineer employees in the metallurgy fields and working in mining industries register. In South Africa the membership of these organisations is not compulsory. Chemical engineers may also

Paul: "...so I think that skill kind of convinced me to join SAIChE prior when I started engineering at the former University 15"

register with various international organisations such as the American Institute of Chemical Engineers (AIChE), the Institution for Chemical Engineers (IChemE) in the United Kingdom, the Engineering Council in the UK, and so forth. Some of these registrations are formal peer-reviewed professional registrations which adds credentials to a person's name. Professional societies offer continuous professional development courses. They are also involved in the institutional management of the profession, for example in university degree accreditation, and professional registration. The latter functions are most often done by volunteer members, and as such is a community service.

Frank: "So I'm a registered professional engineer, I have been one since 1983, I have been uh uh [stutter] a member of the Institution of South African Institution Chemical Engineers, UK Institution of Chemical Engineers, since 1977/1978 so I have been with both organizations for a long, long time and with ECSA."

#### Sub-theme 2.3: Industry

Industry refers to the work-place of chemical engineers outside academia. Stereotypically it would be in factories and mines, but also include consulting firms, design offices, equipment manufacturing and process modelling among many other facets. In large companies a chemical engineer may be exposed to many aspects of the field, such as the technical problem solving, the design of the solution, generating cost estimation and economic analysis, managing the risk and safety of the design, overseeing installation and commissioning, managing the project, and the operation of the process.

Mary: "I graduated then in 2011 and then started at Company N. Company N was uhm sponsoring my, my studies at University 4."

Paul: "And then I was recruited on a project to build a plant in uhm in uh what is that called? A Technology L plant."

#### Sub-theme 2.4: Academic career

Chemical engineering in academia refers to a career in university teaching and research. Some

Frank: "...I went into teaching – I was at a technical college. For a number of years I taught my pet subject Subject W."

chemical engineers perform laboratory assistant and tutor jobs during post-graduate studies. In chemical engineering the definitive qualification (on which professional registration will focus) is the bachelor's degree (in South Africa). Post-graduate degrees are focused on research skills development. Research is often done for, and funded by, companies in industry. An academic career will include teaching and research, as well as the university management positions such as head of school, research director for centres of excellence, etc. In South Africa the remuneration for academic chemical engineers are much lower than for chemical engineers in industry. The chemical engineers in academia are allowed consulting for extra income, but often find the workload at the university to limit the amount of consulting that they can manage. Some chemical engineers have a strong preference for the academic world, or a dislike in the industrial world, so that they work at universities despite the lower salaries.

Sub-theme 2.5:  
Management and leadership

In industry, a chemical engineer is in some ways considered a manager at the time when they start work after university. In a factory hierarchy, the position of a chemical engineer is senior compared to that of plant operating personnel. The chemical engineer will also have complex and high-level responsibilities, for example making sure that the factory operation is technically sound, and that production targets are met. Engineers do progress in levels of seniority through to levels of

Greg: "...the university approached me and asked me if I wanted to kind of getting involved in a bit of part time teaching in chemical thermodynamics."

Olaf: "So I have mostly worked in okay I have worked clearly in Academia. Where I worked, I have had collaborations with Company O."

Nicki: "...agt jaar later het ek na engineering management toe geskuif." (*Eight years later I moved to engineering management*)

Ursala: "So I then took an opportunity on the plant in Town C. Uh and so I moved into uhm a management position, so I was responsible for a team of engineers."

management. This may be leading a project team, a technical function, a production facility, research groups, and eventually business units and even companies. Leadership may also extend wider than the corporate world. The current president of China, Mr. Xi Jinping, is a chemical engineer.

Sub-theme 2.6:  
Entrepreneurship

Chemical engineers develop expertise which they may use to start and operate a business with. Such business can include technical or management consulting, manufacturing of chemicals or equipment, or research. The business can be started parallel to their current careers, or at retirement. Reasons for entrepreneurship includes the freedom to operate under their own responsibility and rules. Other chemical engineers want to augment their income, or to provide for additional future incomes.

Frank: "...And uh so I decided to leave and I went on my own and started doing a lot of consulting work. I networked with a lot of companies that I worked for before..."

Hank: "So uhm my own creation, having my own independence, the idea of starting my own business, uhm ja I have got some thought about what I what I could start, but uh uhm so this is the reason why I have done the MBA as well."

Theme 3  
Reasons for  
career  
changes

Sub-theme 3.1: Financial  
security

Financial security is important for many people, including chemical engineers. Even though some sectors of the profession pay well, people may have reasons for focusing on financial security. Family responsibility is a typical reason, especially where there are extended families, single-parent families, disabled people or illness involved. In such cases a solid dependable income will attract more value for the person. Other elements of the remuneration package such as a pension fund and medical insurance will also be important.

Frank: "...depending on our interests and also uh financial reward,"

Wanda: "To make sure she's always provided for."

Sub-theme 3.2: Challenge seeking	<p>Chemical engineers who are driven by challenge, whether technical, managerial or business, need to have a stimulating work environment where there are significant problems to engage with. Repetitive, administrative and routine work (for example plant operations) will not satisfy their need for a challenge for long.</p>	<p>Ursala: "I started to get little bit restless and looked around for other opportunities."</p> <p>Hank: "I think what uh I like and what I look for is uh challenging opportunities and working with people that can you know have the – entertain this challenge..."</p>
Sub-theme 3.3: Finding meaning	<p>Chemical engineers work as parts of larger systems, for example a factory interacts with the environment, and professional volunteers ensure competent future chemical engineers with university accreditations. The need to contribute to the bigger society in terms of services and knowledge is common among engineers, as they have unique skill sets to provide such services and knowledge. Engineers in search of meaning can find it in their jobs, or start businesses to accomplish it, or volunteer their services and insights.</p>	<p>Hank: "oh, I think it's very important in my view ja, adding value, helping someone, sharing the – sharing the knowledge and making it uh making it make a difference indeed."</p> <p>Frank: "And uh one of the things that I would really like to do, is to start putting you know uhm writing books and manuals on the experiences and the knowledge that I have gained."</p>
Sub-theme 3.4: Life-long learning	<p>Chemical engineers by the very nature of their work need to learn constantly. They need to gather the details of the technical work, process or equipment they are dealing with, or the newest technologies, or in order to evaluate a proposal from a supplier. They also need to learn computer programs that they use to do their work. Learning therefore is a continuous part of the career. Professional societies encourage and provide opportunities for continuous professional development. Learning can be obtained through coaching, job rotation, formal</p>	<p>Paul: "Yes uh I did mostly short, very short courses - a week or could have been – no one was uh a three months I think on [inaudible] technology, I have done that one. I have financial, under [project] finances, specifically project management uh and then I did a number of supervisory type courses over time."</p> <p>Wanda: "And so then I started studying law because just before that, I was asked to represent employees at a CCMA case."</p>

courses or academic study. Learning can also be done for personal enrichment and interests.

Sub-theme 3.5: Individual and family focus

Changes in a chemical engineer's personal life or family circumstances may influence their decision to make a change in their career. If the husband and wife work in different cities, one may decide to find a new job in the other city. Having a child and caring for small children may move a mother towards positions with more flexible work arrangements.

Mary: "And ja, I think that ja, so that was the work I did up until I got pregnant and my circumstances also changed. I was now far, my fiancée was – had been anyway this in City 4, but working in Place B for Company A."

Nicki: "Ek kon half dag gewerk het, waar ek baie, baie dankbaar was. Maar sy het vir my gesê "Uhm 'n stresvolle werk, plus twee klein kindertjies wat baie van jou vat, plus 'n fisiese gestremdheid – wat my oë was, is too much for one person. Something must go"." and "En toe kry ek die pakket." (*I could work half-day, which I very much appreciated. But she said: "Uhm a stressful work, plus two small children which can take much out of you, plus a physical disability – which was my eyes, is too much for one person. Something must go and then I got the package.*)

Sub-theme 3.6: Benefiting society

Chemical engineering combines a unique set of competencies that may be used to the benefit of society. In a simple manner chemical engineering can be described as a profession that allows science to be scaled up for use in society. Critical fields where this is necessary is water supply, sanitation and waste management, energy production, food, medicine and environmental management. Volunteering their time and knowledge to communities is rewarding and benefiting society.

Olaf: "I like voluntary work. I think it's it could also give back to the environ— to the community. And uhm I like that we are able to network, we are able to do work outside of the normal work environment and then meet with different people as well. Yes, so it's something I have – I enjoy very much."

## The Process of Theory Development

The generation of the theory in a practice discipline can be done with four steps (Dickoff, James, & Wiedenbach, 1968). They are i) concept distilling, ii) defining and classifying the central concepts, iii) model description and iv) the implementation and evaluation of the theory to practice. However, in this paper, only the first two steps will be presented.

The steps that Dickoff, James, and Wiedenbach (1968) put forward for model development was used.

**Concept distilling.** The distilling of the relevant concepts was accomplished in the preceding empirical stage of the research, as is summarised in Table 2.

**Central concept definition and classification.** The six items of Dickoff et al. (1968) are the agent, recipient, context, procedure, dynamics, and terminus. They are now described for this study.

The person who performs the activity is the “agent”. In the context of this paper, the agent will be the person who uses the model to facilitate the career change decision of the chemical engineer. This could be a career counsellor, psychometrist, industrial psychologist, mentor, coach or manager. It may even be the person self.

The person who is the “recipient of the activity”, being the career change facilitation, will be the chemical engineer, or the prospective chemical engineering student.

The environment in which the activity is performed, is the “context”. The context in this case would be any situation in which a potential chemical engineering student must finalise a study choice, or where a chemical engineer is faced with a career decision.

The outcome of the activity is referred to as the “terminus”. In the model to be presented, the terminus would in the short term be the making of the career decision, but holistically in the long term it will be satisfaction with the person’s career path.

The “procedure” is the decision on whether to change career path or not. The procedure is a repetitive activity which will involve the recipient and the agent over the career path of the recipient.

The “dynamic” which provides the driving force in this model, is the values dissonance that the recipient – the chemical engineer – perceived after an event has happened in his/her career path.

**Relationship statements.** Following is a narrative of how the above interacts when the model will be used to facilitate career development.

The recipient (chemical engineer) will experience an event (e.g. being offered a job opportunity). The agent (e.g. industrial psychologist) will investigate the dynamic (chemical engineer’s values) to arrive at the procedure (chemical engineer’s career decision making). The terminus then is the actual taking of the decision (e.g. accepting the job offer or not), which is then either changing the chemical engineer’s career path, or remaining on the current career path.

**Main Concept.** With the themes as presented in Table 2, the overarching main concept could be identified as: **Values-based career progression.** As per research objective, a model was constructed from the main concept to elucidate the derived career change decision process. The central concept for the model refers to the following statement: conflicting beliefs, aversive arousal and mental discomfort with important principles, moral standards, personally held judgements and mode of conduct after a significant occurrence, have a perceptible effect of inflowing exertion of action on the career trajectory and professional lives of chemical engineers. A person's values may be described as broad goals over a range of situations which becomes guiding principles for the person over his lifetime (Arieli, Sagiv, & Roccas, 2018).

Table 3  
Summary of themes and main concept

<u>Theme 1</u>	<u>Theme 2</u>	<u>Theme 3</u>
Why study chemical engineering	Career progression and aspiration	Reasons for career changes
<u>Example reference:</u> Young women's attitude may positively be influenced towards a career in engineering by being exposed to role models (Mishkin, Wangrowicz, Dori, & Dori, 2016).	<u>Example reference:</u> Becoming a registered engineer is reaching a benchmark which requires academic and work experience background, as well as professional development (Feijoo, et al., 2018).	<u>Example reference:</u> It is the development opportunities, tangible career growth opportunities and managerial support of their work-life roles which determine the decision of woman to remain or leave an organisation (Fouad, Singh, Cappaert, Chang, & Wan, 2015).
<u>Main Concept</u> Values-based career progression		

**Concept analysis.** Concept included the characteristics and attributes of the concept. The individual concepts therefore are "influence", "values", "dissonance", "event" and "career path".

From their attributes in the literature, essential and related criteria could be identified for each of the concepts. This is a necessary step to define the main concept attributes.

### The Conceptual Model

**Introduction.** A model has been crafted to represent the main theoretical concept derived from the concept analysis. The model presented is a graphic representation of the process of career decision making experienced by the research participants.

**Overview of the model.** A person will start a career in chemical engineering by deciding to study chemical engineering, and then deciding to take up a position as a chemical engineer. This starts the career path. Along the career path events occur. They are various and range from insignificant to serious. Such an event will be compared to the person's values system. If it is consistent with the values system, then the person will continue with his/her career path. However, if a values dissonance is realised, then the person will make a decision on whether to

continue with the current career path or not. The decision will focus on reducing the values dissonance, or in other words, to find a career path which is more congruent with his or her value system. The process repeats itself often. In a new career path events will once again occur which challenges the chemical engineer's value system. Figure 3 depicts this decision process in the greater context of career paths, and in the background of the chemical engineer's work life.

The purpose of this conceptual model is to provide a framework for career counselling professionals, mentors and managers, and chemical engineers themselves, with which to facilitate career decisions based on events that occur in their career.

The context of the model lies in the work life environment of the chemical engineer, within which the career, and career decisions of the person is made. The work life environment in this case would constitute the full combination of all personal and professional circumstances of the person at the time frame of the career decision.

**Model structure.** The structure of the model is represented graphically in Figure 3. It shows the flow diagram of a single event that may lead to a career path decision. A full career will have many such events in sequence, each with their outcomes.

The model is based in the work life environment, with the understanding that a person's career and career decisions is part of their work life. The flow diagram starts with a chemical engineer already in their career, or a prospective chemical engineer intending to study chemical engineering and to become a chemical engineer. A line flows from the start that represents the current career path. This career path, although shown linearly in the diagram, is the process of all previous career path decisions.

An event that happens in the chemical engineer's life is represented by a square. The event may be non-significant, for example receiving a good performance review, and the person may not even perceive it as an event. It may also be a major event, such as retrenchment or severe conflict with a manager. Effectively everything that happens with a person constitutes an event, but only some will be noted by the person as a significant event.

Once an event happens the line downward towards the decision diamond indicates that there will be an evaluation of the event by the individual. The individual will compare the event's implications and their perceptions about it with their value system. Should there be no dissonance with their value system (e.g. the person receives recognition for work that they did put a lot of effort in), the "No" line to the right is followed, and the person proceeds on his/her current career path. However, should the values dissonance be significant (e.g. the person is sexually harassed by the manager), the "Yes" line from the bottom to the career decision diamond is followed.

In the career decision diamond the person assesses whether and how to make a career change, with an outcome that will lessen the values dissonance experienced to an acceptable level. If the person decides that the dissonance against his/her values system is too much, the "Yes" line towards the right is followed, indicating that the person is going to make a change in

his/her career path. In the above example of sexual harassment, the person may decide to leave the organisation and to find a position at an alternative organisation. Should the person decide that he/she does not want to make a career change, then the upward “No” arrow is followed to where the person remains on the current career path. In this case the person may decide to use in-house support structures to address the sexual harassment.

Over time which-ever eventual career routes are followed, the person is expected to be at a career-end state of satisfaction with his/her career path, having constantly diminished values dissonance over his/her career life. This is represented by the circle at the right. In the simplest case, following the above horizontal line, the person studied chemical engineering, joined an employer, worked an entire career with that employer until retirement. In a more realistic case, the career line will have a few deviations over the person’s career towards retirement. The circle does not signify the end of the person’s chemical engineer career: many people proceed to work past retirement. The circle does indicate that the person is working very contented in their career path at the time.

As a chemical engineer’s career proceeds over time, this event-decision evaluation will happen repeatedly. If the person makes good decisions, it should lead to increased values satisfaction over time.

**The central theoretical concept:** the influence of values dissonance after an event on the career path of chemical engineers, is described by the model. An event leads to a test of values dissonance, which then influences a decision to remain on the current career path, or make a change.

## Discussion

### Outline of the Results

The objectives of this study is to, through grounded theory development, determine which career decisions chemical engineers make throughout their careers, at which points they make these decisions, and why.

When faced with an event in their careers, chemical engineers make decisions to stay in their current career path, or to make a change. The first relevant event is deciding to study chemical engineering. Subsequent events may include restructuring, job opportunities, or changes in personal circumstances. The decisions to stay or change will be to reduce the person’s dissonance with their values system, for example to leave an unethical company, to move to a more technical challenging job, or to start a business to gain more autonomy.

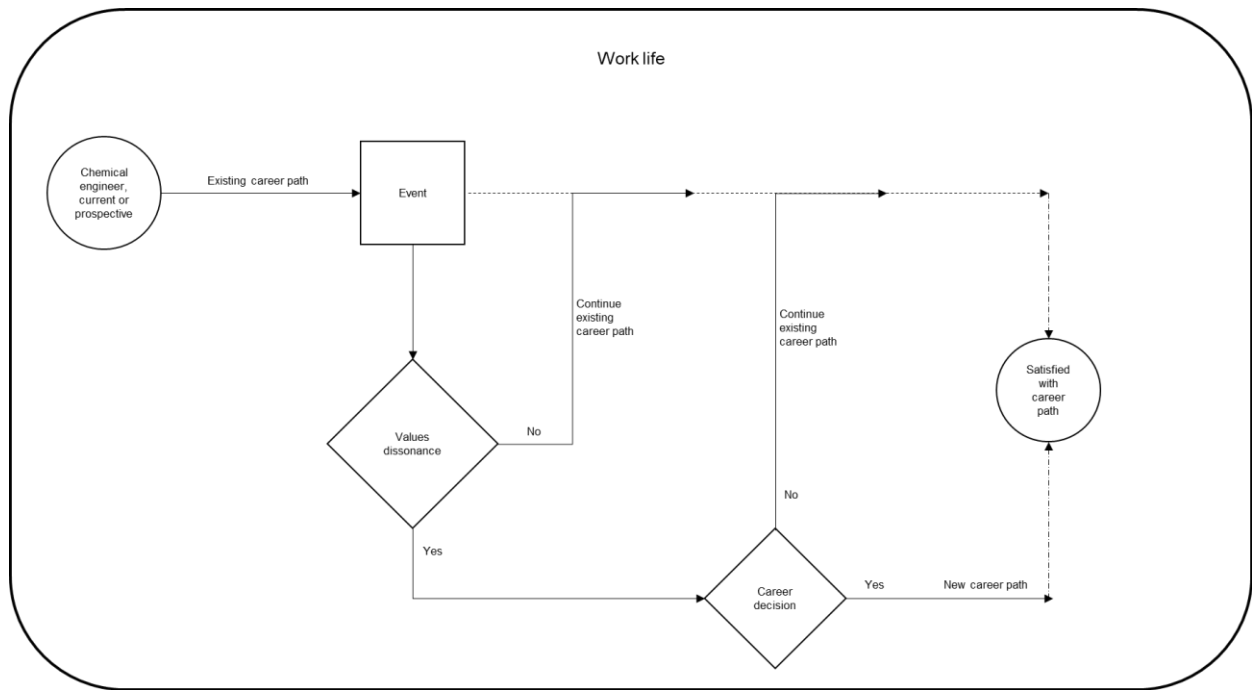


Figure 3. A conceptual model of values-based career progression

In short, a person will tend to grow closer to his/her personal value system over the duration of his/her career. At the time of selecting the profession, this value system may be less clear and defined, but by the time of reaching retirement age, it will be more crystallised, and the person will tend to have arrived at career activities close to their value system.

As for students who make the decision to become engineers, values have been found to be very important (Matusovich, Steveler, & Miller, 2010). Students who have been interested in chemistry outside their schoolwork tended to be more interested in chemical engineering than other engineering disciplines (Godwin, Sonnert, & Sadler, 2016).

The protean career path is also related to personal values, and seem to fit well with the results of this study. According to Hall (2004), a person's core values are driving career decisions in a protean career. It implies that the person, not the organisation, makes the career decisions. Li, Ngo, and Cheung (2019) found that career-decision self-efficacy was predicted by the protean career orientation. It also was predictive of career adaptability.

However it is important to note that this study found that chemical engineers make career decisions that minimise their overall values dissonance. Effectively every career decision is then made optimise their overall values realisation. The protean career is values driven, which implies that the person's values determine the career decisions. Thus, although the results of this study seem to match the protean career path, it does not exactly correspond. It is holistic of the collective of all values, and not only career-values. Alley for example wishes to pursue employment for her own career again, but recently her family, and before that following her husband's career was

more important to her. Frank chose to return and pursue his career in South Africa, from overseas, to be closer to his family, despite being subject to apartheid at the time.

It is noteworthy that the older participants, at and after retirement, applied the identified global values dissonance minimisation career pattern from the start of their career. At that time – some 45 years ago – the linear career ladder was considered to determine career paths, as the protean career concept was first introduced in 1976 by Hall (Hall, 2004).

### **Practical Implications**

For the individual chemical engineer, the lowering of values dissonance will lead to a greater enjoyment of his/her work-life. It however requires the person to be aware of their values system. An intuitive decision may not take the values into account in the same level as a purposeful values analysis-based decision. It places an onus on the chemical engineer to understand their values system from a young age already. In turn this implies that chemical engineers need to access resources such as career guidance teachers, psychometrists, industrial psychologists and mentors to help them assess and interpret their value system onto their reality. For many people these resources are not available, due to ignorance and socio-economic limitations, for example. Others will only seek guidance once the event has already happened, and at that time the event may be a poor performance review already. Lastly, some people may have difficulty assessing their value system due to trauma or a complicating life-experience (e.g. abuse).

Society-based norms, for example cultural differences and restrictions, may limit a person's options to make values-based decisions. For example, someone who has a values system congruent with chemical engineering may not have the funds to enroll. Various forms of discrimination based on gender, race, and other diversities will make it difficult for individuals to pursue their values-based decisions. However, as was the case with two research participants, perseverance, and possibly other personality traits, did allow them to eventually access and excel in a chemical engineering career. This study's design does not allow knowledge of how many people did have the aspiration to become a chemical engineer, but was limited by circumstances outside their value system. This imply people that did not have the funding, freedom or access to education due to, for example, socio-economic matters, poor schooling or discrimination.

Values were grouped into ten types by Roccas, Sagiv, Schwartz, and Knafo (2002), which include self-direction, stimulation, achievement, security, benevolence and power, among others. Schwarz (1992) lists similar values in his model.

Career counselling and coaching leads to increased clarity in career goals (Ebner, 2021). People and professionals who will act as the agents, need to be prepared to provide career counselling from a values-based perspective. It means that they will need to understand values, how it impacts a person's decision making, and how to guide a person through the procedure.

## **Limitations**

The study was relatively small, and utilised research participants known to the researcher. A wider study may be used to also investigate the efficiency with which career decisions are carried out, and how factors such as maturity, locus of control and clarity of values perception influence the actual career changes made. People with an internal locus of control are more adaptable, have high self-confidence, and are more likely to become involved in occupational activities (Kim & Lee, 2018).

The exclusion criteria of the study limit the resulting conceptual model to professional chemical engineers. It does not exclude that it may be of use for other professional people as well, but that has not been determined.

Data was only collected by interview and field notes. More methods of data collection may be employed, for example psychometric values assessments and focus groups.

This study's design does not allow to know how many people did have the aspiration to become a chemical engineer, but was limited by circumstances outside their value system.

## **Recommendations**

The personal development of chemical engineers is quite important for their career development and satisfaction. Such personal development may start at a young age (before making career choices), and continue through life. Personal development interventions may be a more streamlined method of facilitating career growth than providing young engineers with a wide spectrum of technical training with the intention of enabling them widely for career options.

Chemical engineers will be able to make their career progression more deliberate and rewarding if they develop and understand their value system well. Learning to evaluate events and opportunities will enhance their decision-making capabilities. Developing an internal locus of control will help effective action when taking career decisions.

Organisations should take note of employing values-based career coaching and decision-making as an alternative to the current fill-the-buckets-of-experience-to-fit-the-job-description approach, which is more characteristic of the traditional linear career. The proposed model does not negate the need of the necessary job skills in order to perform it, but the intention to make a career change in the future can be done, and then appropriate experience can be gained by the employee.

Chemical engineers, their employers, professional societies and industrial psychologists may assist the career flow of chemical engineers by empowering them to use their internal value system. The use of psychometrics, mentoring and coaching are all strategies which can be used in this context.

From the interviews it was very clear that exposure to chemical engineers and chemical engineering was crucial to school students learning about chemical engineering as a career option, and leading to them considering it as a future career. Chemical engineering societies, and

the wider profession, should heed this observation: a chemical engineering career choice requires contact with chemical engineers and chemical engineering.

The participation of individuals in chemical engineering societies' and public service activities corresponds with Schwartz's (1992) values of benevolence and universalism falling into the same self-transcendence category as where the career anchors of technical competence and service are grouped (Wils, Wils, & Tremblay, 2010). It is no surprise that the Engineering Council of South Africa include technical competence and public service as main points in their code of conduct for registered professional engineers (Cato, 2017).

### **Conclusion**

Chemical engineers make career decisions which at the time, and over time, will minimise their overall values dissonance, and which will lead them closer to their overall personal value system by the end of their careers. Each decision is made when an event, for example a restructuring, occurs, and results in whether the person changes their career or not.

The overall personal values structure, and the understanding thereof, will be particularly important in applying this finding in a chemical engineer's own career path, or in managing, counselling or mentoring chemical engineers.

Improving the flow of chemical engineers' careers will benefit society, as the profession of chemical engineering is able and required to address many of humanity's modern challenges.

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## CHAPTER 3

### CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

In this chapter the current study's conclusions will be presented according to the stated general and specific research objectives. Furthermore, the study's limitations will be discussed. Finally, recommendations will be made, for practical application, as well as for future research.

#### 3.1 Conclusions

The general objective of this study was to understand the career decisions of chemical engineers, specifically in terms of which career decisions are made, and at what point in their careers these decisions are made. The conclusions of this objective are described below under each specific objective.

The first objective was to determine how chemical engineers view their careers retrospectively. This was done through having several individual in-depth interviews with a diverse participant group, focusing on their entire careers. The research participants tended to start at what they consider the beginning of their career and would narratively talk through the timeline of their career until the present, and perhaps allude to future plans. The start of the career varied between the participants, from being at school through to their first or even second jobs. It indicates that some people see the sequence of events that brought them to their present career point starting early, before studying chemical engineering. Others only consider the starting point to be once they have a qualification, or a job title, as a chemical engineer.

The second objective aimed to find out why chemical engineers make particular career decisions. The scope of decisions can be elaborated on. Firstly, one may decide not to make a change. The decision may be between a current career path, and a new career path, for example when a chemical engineer receives a job offer from elsewhere.

A decision may be between more than two or more alternatives to the current career path, for example where a person decide to leave a position. The decision can be to change from technical to managerial, an industrial environment to an academic environment, or to start a new business. This study has concluded that a decision is made when a values dissonance is experienced. The specific value or values in which the dissonance(s) are experienced determine the scope of the decision to be made. For example, if a person realises that he/she is working for a company with unethical business practices, they may decide to leave the company, or to report it. If it is the manager of the chemical engineer that behaves unethically, the person may try to move to another manager – even if the job content changes, or also to report the manager. In this case ethical behaviour would be a core value that is in dissonance. The reason for making a

decision is therefore the person's dissonance of a core value that is created by the current work life situation, precipitated by an event which made him/her realise the dissonance.

The third objective was to understand why particular career decisions were made at particular times in chemical engineers' careers. The time at which a decision is made, is after the values dissonance is realised. In turn, the values dissonance is realised after an event happens which alerts the person to it.

The time between the realisation of the values dissonance, the decision, and the action following it, varies. If an event occurs that exposes values dissonance, for example overt conflict with a manager, the person may first take some time to interpret and understand the event. Then a decision may be made, for example to leave the manager. The opportunity to do so may only arrive later, for example once the person finds an appropriate job to apply for.

The event is however the precipitating step which will lead to a person evaluating values dissonance. Many types of events may occur. It could be a conversation with a mentor, a new opportunity being realised, a negative experience, a desire for job growth, and so forth. Changes in personal life also constitute events in work life. Becoming pregnant, going on maternity leave, and caring for a young child will let a female chemical engineer consider whether her value of caring for her family is strong to the point that it eclipses her value of career ambition.

Although many events will occur continuously over time, most of them will not lead to career change decisions. Whether a person detects a value dissonance after the event will determine whether a decision will follow. However, a person's maturity, emotional intelligence and insight in the event may determine whether it signifies a values dissonance. This study did not investigate how a person perceives an event: it was found that the realisation of an event is the start of the process in which values dissonance is assessed, which may then lead to a career decision.

The fourth objective was to investigate the context which chemical engineers experience when they make career decisions. The context would be the status quo at the time of the person's work life, as well as expectations of how things would progress. A single female chemical engineer with a young child would find the working conditions in a production role difficult, with aspects such as shifts and stand-by duty. The outlook is that the child will need care for a while still, and hence a change of career to a position which allows fixed or even flexible hours will be desirable. This is if the care for the child is a priority in the mother's value system. If career ambition is a higher value, then she may appoint an au pair for the foreseeable future and remain on her current career track. The context then evolves to the picture of values dissonances over the person's set of core values. In other words, when a precipitating event occurs, the person interprets his/her wider reality to his/her value system. That would result in a set of value dissonances. The person will decide which of these are acceptable, and which needs to be mitigated by a career path change.

The final objective was to establish grounded theory, represented in a model. This has been done. A model is proposed which represents the values-based consideration which a chemical engineer makes when an event precipitates a possible career decision. The model shows firstly that there is a start to the chemical engineering career, being the circle on the far right. A career path then follows. An event occurs, which prompts the chemical engineer to assess whether a values dissonance has occurred. If so, a decision is then made to change career paths or not. Eventually the career path leads to a point where a person is satisfied with the achieved career path, having lowered her overall values dissonance to a level acceptable for the person.

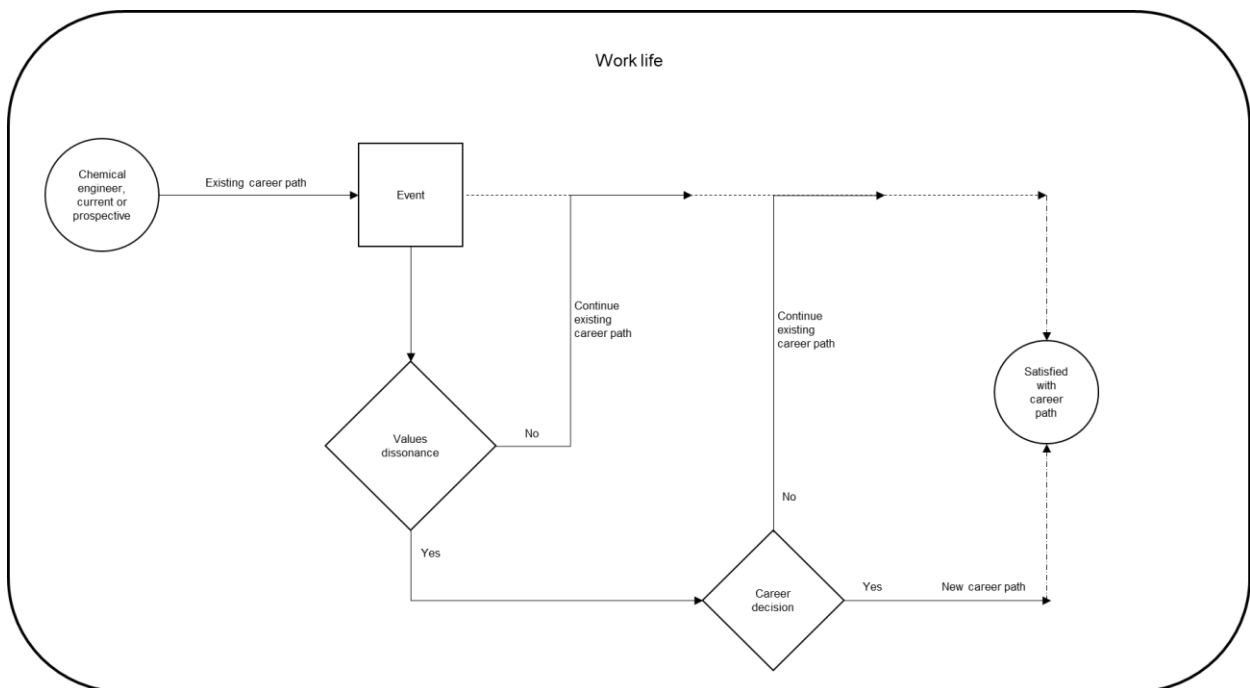


Figure 4. The proposed conceptual model of values-based career progression

Values have been found to be universal and stable, and achieving personal potential stretches over differences in, for example, gender and culture (Super & Branimir, 1995). It therefore provides a sound basis on which to base career decision making.

Wils, Wils and Tremblay (2010) has found in their study of 880 engineers' that a values-based multiple dominant career anchor structure is supported. Their careers are not driven by a single value. This correspond with the generated theory that an overall values dissonance minimisation is driving career decisions, and not the pursuit and fulfilment of a single value, or anchor.

### 3.2 Limitations

The study had some limitations. These should be considered when its results are interpreted.

The study was small. While it did cover a biographic diversity, and a diversity of job in the profession, and reached saturation of themes, a larger study may have provided more examples of career decision making in action, which in turn could have enriched the understanding of the dynamics. It may also have provided more material for literature comparison.

A wider study scope could have allowed for the investigation of how efficient career decisions were carried out. In effect, a decision is still an intent, and it may not even be a good decision. Therefore, career changes can be made that results in more values dissonance, instead of reducing it. The participants related their experience of pertinent career changes that they have made, as that was the focus of the study. They may have made career decisions that were not brought to practice or did not reduce their values dissonance. Decision theories may provide insight on the decision-making process, but a grounded theory study may study these dynamics in reality and provide insight in the context of chemical engineers' work life, as was the scope of the study.

The model and the theoretical concepts do not seem specific to chemical engineering: it does not contain a specific career. However, the data collected was from chemical engineers only, as stated in the exclusion criteria. The question is whether people in other careers, or indeed all people, use a similar decision strategy in their career decision making. This study's sample did not allow for such an elaboration. A study with a participant group from diverse careers may answer this question.

Data was collected by interview and field notes. More methods of data collection could have been used, but as this was a limited study, it fell outside the practical scope of execution. Psychometric values assessment to compare against the perceived values of the participants would allow to understand whether inherent values or perceived values were used as a reference for career decision-making. A focus group could have allowed for deeper discussion of key topics. A World Café exercise would have accommodated more research participants and allowed for focused discussions.

The study's design does not allow to know how many people did have aspirations to become a chemical engineer, but was limited by circumstances outside their value system, where a relevant career path decision was not an option for them.

This research study did not examine whether values judgement or career decisions were performed effectively or not. An individual participant may have had a skewed perception of the event, misinterpreted the value implications, or decided on incorrect or poor information. The participant may also have been unduly influenced by factors such as wellness challenges or poor

career counselling. The model represented in this study identified the process, including decision making, but did not examine the quality or efficiency of decision making itself.

Due to the limited scope of the study, the model was not reviewed by a panel of experts. Detailed guidelines for the application of the model were also not developed.

### **3.3 Recommendations**

#### **3.3.1 Recommendations for future research**

A future study could include a larger sample study. A future study may also use additional data gathering techniques. With the background of this study, the interviews may be more structured. For example, one can focus on specific instances of career decisions, and gain detailed examples from that.

Psychometric instruments such as values assessments can be employed to investigate the participants' awareness of their value systems. Decision making questionnaires can also shed light on the methods of decision making employed, and whether that would relate to chemical engineering specifically (referring to their thinking and analytical mindsets).

From another perspective, a future study may include participants from various other careers. This would shed light on whether the values-based trigger for decisions are experienced by people in other sectors of the world of work as well.

It would be valuable to find out more about people who aspired to be chemical engineers, but did not eventually become chemical engineers. For example, why they did not become chemical engineers, and what decisions followed that. It will add to the knowledge of whether people with the aptitude and inclination to become chemical engineers would fit into the findings of the study, or whether it is more the process of training and chemical engineering experience that results in the career decision behaviour of chemical engineers.

The decision-making process itself can be studied in more detail. In the interviews, participants reported their career in retrospect. In this perspective, a new career path outcome was preceded by a decision. The outcome is a past reality, and the aspects of the decision in retrospect cannot change that. One can theorise that, if a young chemical engineer understood their value system very well, that person could have the opportunity to make a very effective decision to reduce their values-dissonance extensively. Such a person will need less decisions to arrive at the same level of lowered values-dissonance that would take another person several additional career path changes to achieve.

For a continuance of this study, it is recommended that the model is evaluated by a panel of experts. It will allow for peer review and additional insight.

Detailed guidelines for the use of this model should also be developed before its use in practice.

### 3.3.2 Recommendations for practice

Individual chemical engineers may take note of this study, and increase their awareness of the importance of their value system to their future career decisions. Such awareness may also motivate them to actively understand their values system. Industrial psychologists and psychometrists will be instrumental in assessing and interpreting values. Chemical engineers should be encouraged to engage with such professionals. This is true for chemical engineers in careers, but also chemical engineering students, and learners who may wish to become chemical engineers. Career well-being requires career self-management (Wilhelm & Hirschi, 2019).

Organisations may take note of the importance of values when recruiting chemical engineers. Furthermore, they should heed the importance of chemical engineers' values when they plan their careers, redeploy them, or include them in succession planning. Values are important in organisations, as they are linked to career choices, and people's behaviour and decisions (Arieli, Sagiv, & Roccas, 2018). The individual may deviate from the career plan if it does not converge with his/her values. Mentors and coaches should also be made aware of the values-centric nature of chemical engineers' career path decisions. Organisations can also use psychometric assessments very fruitfully in the career counselling of their chemical engineering employees. It was demonstrated that people who take the responsibility of managing their careers along their values system may benefit themselves and the organisation (Sultana & Malik, 2019).

Industrial psychologists and psychometrists should note the importance of values in chemical engineer's work life environment. Chemical engineers may find great benefit in having their values thoroughly assessed and reported to them. Career counselling should allow them to clearly understand their values, and to keep doing so continuously over time. When chemical engineers seek counselling for career decisions, this should be done in the perspective of their values systems. A note of caution is that the values dissonance should be minimised over the long term. Taking a short-term assignment in a type of work that the person will not enjoy may prove useful in future when this will serve as good background experience for a management position, which would be the desired career path. There is a clear and continuous role to play for career counsellors in the development of chemical engineers over their career paths.

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