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Nurturing Creativity and Innovation Through FabKids: A Case Study

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Abstract This paper will report on a case study that was conducted involving Grade 10 learners who were exposed to a high-tech rapid-prototyping environment of a Fabrication Laboratory as part of a FabKids experience. This project must be viewed in the context of a global shortage of key skills placing a higher priority on the initiation and development of a pipeline to attract youth into science, engineering and technology careers. Creativity and innovation feature high on the skills agenda but more importantly preliminary results indicate that learners from a broad range of schools were able to operate effectively in this post constructivist environment. Participants had to apply their knowledge, skill, attitudes and values in order to produce a solution to the challenges provided. The fundamentals of the design process of investigate, design, make, evaluate and communicate were emphasized where the FabKids had to draw on their own collective knowledge using a range of technologies available to them.

Keywords Creativity · Innovation · Design process · FabLab · Net Generation · Knowledge workers

Abbreviations

AMTS	Advanced Manufacturing Technology Strategies
DST	Department of Science and Technology
FabLab	Fabrication Laboratory
FESTOC	Federation of Science, Technology and Engineering Olympiads and Competitions
FET	Further Education and Training (Grades 10-12)
GET	General Education and Training (Grades 0–9)
LED	Light Emitting Diode
MIT	Massachusetts Institute of Technology
N-Gen	Net Generation
NCS	National Curriculum Statements
NSI	National system of innovation
RNCS	Revised National Curriculum Statements
OBE	Outcomes Based Education
RFID	Radio-frequency identification
YESA	Young Engineers and Scientists of Africa
YiSS	Youth into Science Strategy
ZPD	Zone of Proximal Development

Introduction

What can be made in a Fabrication Laboratory or FabLab? While there are limits, especially for technical novices, the imagination drives the process. Currently the labs include computer controlled machines with spatial resolution down to microns, and electronics that have time resolution in microseconds. The ability to design and innovate in microns and microseconds puts powerful capabilities into the hands of FabLab users. Communication devices, sensing technologies, building structures, arts and crafts—all are within reach using the tools and materials in a FabLab. High profile projects made in FabLabs include: solar and wind turbines, wireless data networks, thin client computer interfaces, a press fit house (no nails, no cement), long-range antennas, and sheep sensing and tracking devices (Lassiter 2009, p. 3).

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Lassiter also shares a vision of the twenty-first century and strategizes around this “emerging economy where there are new skills, new kinds of knowledge, and new ways of knowing that will be required to compete in an economy based on digital media, communication, and information.”

> These labs are showing that “giving people the ability to make things for themselves can be the fastest way to solve their problems, particularly in communities with little access to education or technology” (Fab Central 2008). Some labs are on the verge of spinning off small businesses. “Fabs are now moving from experiments to becoming serious tools in addressing developing nations’ problems,” says Sushil Borde, executive director of the non-profit Fab Foundation, who has helped launch FabLabs in both India and South Africa. The deepest form of aid you can give a country is to allow them to design and make things (Mandavilli 2006).

The introduction of FabLabs into South Africa in recent years saw the focus on sharing these resources with the general public to empower both individuals and rural communities where the vast majority of users were university students and enthusiasts. The problem that was identified by the researcher was that even though access was open there was little or no emphasis on promoting the use of these resources at school level. The need to expose learners to the high-tech rapid-prototyping environment from as early as possible was also identified as a means of promoting creativity and innovation. This was perceived as being of benefit to learners entering tertiary education and potentially promoting Science, Engineering and Technology (SET) based careers.

> Reynolds in his statement of research and teaching interests recalls a turning point in his life when he knew from a very early age that he was a scientist and engineer at heart. His career effectively began as a 10 year old ham radio fanatic, on the day his father brought him his first oscilloscope. Twenty years later he was a qualified electrical engineer and computer scientist, designing, building, and characterizing complex systems of sensors, actuators, computation, and communication to solve real world problems (Reynolds 2006).

A critical component of Reynolds’ statement is that his focus was on real-world problems which were not limited to laboratory curiosities. Extrapolating this further, the knowledge that he generated was not restricted to the confines of textbook knowledge but resulted in a wide variety of innovative real-world applications.

Reflecting back on this scenario it could be argued that had he not had access to the opportunities that his education and upbringing afforded him he may not have found himself on the same career path. In contrast to this the vast majority of learners, especially in a multicultural and economically diverse country such as South Africa, have to rely on an education system to provide career guidance information. This is compounded by the fact that the social and economic fabric of many homes has been disrupted by the AIDS pandemic, resulting in an increasing number of teenagers as heads of households. Daily life for many youth is focused on survival with limited access to meaningful career changing opportunities. It may be argued that there are many learners with Einstein’s capabilities that are being lost by a society that is failing to address their basic socio-economic needs, let alone affording every child a meaningful education.

The main difference between the original intention embodied in Gershenfeld’s FabLab and the FabKids is that the latter approach exposes learners to a marginally structured process rather than relying on a more open-ended one. Details of the process will be elaborated on later in this paper.

This paper will report on the pilot project as a case study conducted with a range of learners from difference schools in the greater Tshwane metropolitan area. The research problem under investigation was to investigate whether learners would be able to operate effectively in such an environment given their different school backgrounds.

The FabKids intervention forms one of the corner stones of the Young Engineers and Scientists of Africa (YESA) project which was initiated by the Meraka Institute in 2006. Other programs which are associated with YESA include TekkiTots (pre-school), TekkiKids (Grades 4–7), Fab Teachers (for selected subject and all grades) and Digital Kids programs (all grades). There are also plans to investigate Digital Teachers and even Digital Parents. The aim of YESA is to initiate a SET pipeline by creating hands-on opportunities for learners to experience more key moments of exposure to SET in their school careers and to assist them in making more informed career choices.

The FabKids intervention supports the DST’s Youth into Science Strategy (YiSS), which relates, “firstly, to the promotion of science and technology literacy among the public, generally, and the youth, in particular; and secondly, to increasing the enrolment of a cohort of demographically representative youth with talent and potential into science, engineering and technology (SET)-based careers” (Mangena 2007). YESA is also an active member of Federation of Science, Technology and Engineering Olympiads and Competitions (FESTOC) which “aims provide a structured support to the affiliated Olympiads and competitions, and will be better able to get the thousands of youth with talent and potential to participate in such competitions" (Mangena 2008).

Science, Engineering, Technology and Outcomes Based Education

> Technology has been a determining factor in human history since time immemorial and in the twenty-first Century this will be so to an even greater extent. It is imperative that South Africa makes the right choices, sometimes difficult, to enhance our adoption and mastery of the technologies which will assist us in becoming a competitive nation. Basic science also has a crucial role to play in our country, not just because it is the platform on which applied science and technology are based, but because it has cultural and intellectual foundations as profound as those underpinning music, literature and other products of the human mind (Mabandla 1996).

'Creativity' and a 'national system of innovation' (NSI) are two critical elements of the South African government's White Paper on Science and Technology. It refers to

> Innovation as becoming a crucial survival issue. A society that pursues wellbeing and prosperity for its members can no longer treat it as an option. In practice innovation is the application in practice of creative new ideas, which in many cases involves the introduction of inventions into the marketplace. In contrast, creativity is the generating and articulating of new ideas (Department of Arts Culture Science and Technology 1996).

Naiman (2007) on the other hand defines "creativity as the act of turning new and imaginative ideas into reality. Creativity involves two processes: thinking, then producing. Innovation is the production or implementation of an idea. If you have ideas, but don't act on them, you are imaginative but not creative."

> A more elaborate definition of the term Innovation is the embodiment, combination, or synthesis of knowledge in original, relevant, valued new products, processes, or services. There are generally two types of Innovation: incremental and radical. Incremental innovation is generally understood to exploit existing forms or technologies. It either improves upon something that already exists or reconfigures an existing form of technology to serve some other purpose. In this sense it is innovation at the margins. A radical innovation, in contrast, is something new to the world and a departure from existing technology or methods. The terms breakthrough innovation and discontinuous innovation are often used as synonyms for radical innovation. More recently, Christensen has used the term disruptive innovation to describe a technical innovation that has the potential to upset the organization's or the industry's existing business model. In almost all cases, these innovations are radical. Disruptive technologies displace the established technology and precipitate the decline of companies whose business models are based on them. In many instances, disruptive technologies create new markets (Harvard Business School Press 2003, p. 3).

The establishment of YESA has provided an opportunity to encourage learners to allow their creativity to come to the fore especially through the FabKids and Digital Kids programmes. The intention is to demonstrate that over a period of time it is possible to nurture this creative spirit to the point where inidividuals are able to see opportunities for incremental innovation and ultimately move onto stimulate radical innovation in the different sectors that they may find themselves in.

In a teacher-centred education system there is very little scope for development of these types of skills where the main mode of "teaching is usually based on pure information transfer and where the teachers is regarded as a gatekeeper who authorizes knowledge" (Buckler 2004). This is in stark contrast to a knowledge society where people of similar interests try to make effective use of their combined knowledge and experience in their areas of interest, and in the process contribute to the body of knowledge.

In order for South Africa to draw benefits from participating in a knowledge economy the education system has to produce knowledge workers who are equipped with the necessary knowledge, skills, attitudes and values to do so. Creativity and innovation should be viewed as primary skills and attitudes in the toolkits of such workers who are able to turn creative ideas into innovative ones through the manufacture and delivery of physical artefacts or systems.

While individual creativity is important, exciting, and even crucial to business, the creativity of groups is equally important.

> The creation of today's complex systems of products and services requires the merging of knowledge from diverse national, disciplinary, and personal skill-based perspectives. Innovation—whether it be revealed in new products and services, new processes, or new organizational forms—is rarely an individual undertaking. Creative cooperation is critical (Leonard and Sensiper 2000).

The content-heavy education system of the apartheid era in South Africa has been superseded by a more skills-based learner-centred Outcomes Based Education (OBE) which attempts to embraces constructivism as a learning theory. Legislation is in place for the deployment of the National Curriculum Statements (Department of Education 2002) as entrenched in the Curriculum 2005 approach to education. The first cohort of learners who have been exposed to this new pedagogy exited the system in 2008. The new approach does not requires teachers to define in advance what they are going to teach as behavioural objectives but rather to assess the effectiveness of this process by looking for the evidence that teaching had taken place. In the former approach learners were assessed according to a predefined memorandum whereas OBE looks for hard evidence that learners are able to apply the knowledge acquired through the demonstration of key skills

Theoretical Perspectives

In conceptualizing the FabKids project it is relevant to ground the work in a pedagogical perspective. This project relies heavily on the theory of Piaget's constructivism.

> From his observation of children, Piaget understood that children were creating ideas. They were not limited to receiving knowledge from parents or teachers; they actively constructed their own knowledge. Piaget's work provides the foundation on which constructionist theories are based. Constructionists believe that knowledge is constructed and learning occurs when children create products or artifacts. They assert that learners are more likely to be engaged in learning when these artifacts are personally relevant and meaningful (Wood et al. 2008).

This theory forms an integral part of interpreting active learning and in the school of constructivism which has its origins in work of education reformer John Dewey and Russian psychologist Lev Vygotsky. In the case of the FabKids the technologies that are employed are not the focal point of the exercise but are used as tools to create artifacts through the design, manufacture and assembly of a solution to a given challenge.

The FabKids are able to combine personal experience and their existing knowledge in order to construct new meaning in solving the challenges that they are confronted with. This was evident in the diverse range of solutions that were produced as the physical manifestation of the individual's and group's collective creativity.

The Net Generation (N-Gen) is defined as "the population of about 90 million young people who have grown up or are growing up in constant contact with digital media" (Tapscott 1998).

> Born between roughly 1980 and 1994, the Millennials have already been pegged and defined by academics, trend spotters, and futurists: They are smart but impatient, expect results immediately and carry an arsenal of electronic devices—the more portable the better. Raised amid a barrage of information, they are able to juggle a conversation via Instant Messaging, surf the Web, and listen to an iTunes playlist while reading Twelfth Night for homework. Whether or not they are absorbing the finer points of the play is a matter of debate (Carlson 2005).

Most teachers in the classroom today, by contrast, grew up without computers in their homes, schools, or even at teacher training colleges and universities. As a result, some are trying to catch up with the technological innovations that are making their way into the classroom. In addition to acquiring new technical skills, teachers also must decide how to best implement these new teaching tools into the curriculum and their personal style of teaching.

> Real learning gets to the heart of what it is to be human. We become able to re-create ourselves. This applies to both individuals and organizations. Thus, for a 'learning organization it is not enough to survive. '"Survival learning" or what is more often termed "adaptive learning" is important—indeed it is necessary. But for a learning organization, "adaptive learning" must be joined by "generative learning", learning that enhances our capacity to create' (Senge 1990, p. 14).

Translating this into the school environment one would assume that the stakeholders are the learners themselves and not necessarily the parents. As learners in a constructivist environment they are not passive recipients of information but should be actively engaged in the learning process. More importantly, barriers to enabling all learners to maximise their potential need to be removed. It is imperative that interventions involving learning should take cognizance of the changing needs of the Net Generation within enabling learning environments especially where ICTs are employed in the classroom. This implies that educational institutions should be transformed into dynamic learning organizations that are preparing the youth for life in a technological world and not for the outdated society that their teachers grew up in.

The introduction of projects such as the Formula One in Schools Project (http://www.f1inschools.co.za) is a good example of "authentic learning where the learners become 'cognitive apprentices' to the experts while focusing on what happens in the real world" (Marra n.d.).

This is in stark contrast to the information transfer that has very little reference to the real world and which is prevalent in many schools in South Africa today. This approach stifles knowledge generation and ultimately limits creativity and innovation as necessary ingredients to nurture higher order thinking skills. “For many students, education has become nothing more than drill and response where there is no relevance for the materials the students are expected to learn” (Gardner 1991).

Authentic learning for FabKids is vested in the notion that there is very little information transfer via formal ‘teaching’ processes during FabLab sessions. Learners bring their own knowledge tool kits with them and are encouraged to apply this information to solve the problems using their collective wisdom.

It is relevant to consider an educational theory on psychology relating to the Zone of Proximal Development (ZPD) which was conceived by Vygotsky.

> ZPD is defined as ‘the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers’ (Vygotsky 1978, p. 86). In simple terms this can be viewed as ‘what the child is able to do in collaboration today he will be able to do independently tomorrow’ (Vygotsky 1987, p. 211). What is implied in this theory is that learning and development are interrelated. Learning is not the same as development but may lead to it.
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> Adult involvement in the process can provide the scaffolding of information in order to add greater meaning to the learning process. The term ‘scaffolding’ was developed as a metaphor to describe the type of assistance offered by a teacher or peer to support learning. In the process of scaffolding, the teacher helps the student master a task or concept that the student is initially unable to grasp independently. The teacher offers assistance with only those skills that are beyond the student’s capability (Lipscomb et al. 2004).

Group Demographics

The focus of the original pilot project conducted in 2007 and 2008 at the Innovation Hub in Pretoria, was to demonstrate proof of concept for the FabKids intervention. The information that was gathered was based on a course assessment questionnaire. Permission was granted from the Gauteng Education Department to interact with Grade 10 learners the following schools:

- St Mary’s DSG (12 Female—mixed races)
- St Alban’s College (12 Male—mixed races)
- Mamelodi High (5 Male and 5 Female)
- Gatang Comprehensive (5 Male and 5 Female)
- The Glen High (6 Male and 6 Female—mixed races)

A total of 56 learners participated in the pilot project with each school being involved for approximately 7 hours.

Summary of the Activities for the Day

After a brief welcome learners were introduced to the FabLab. This was followed by an introduction to such concepts as Gershenfeld’s “printing of a bicycle” (Gershenfeld 2005), to stimulate the thought processes and to encourage them to think outside the box.

A critical element of FabKids methodology is the application of the Design Process inherent in the Learning Area of Technology Education at the General Education and Training Phase (GET) for grades 1–9 (Department of Education 2002). The five steps include: Investigate, Design, Make, Evaluate and Communicate. These steps were contextualised in the challenge presented to the learners. For the purposes of the pilot project all schools were given the same problem of: ‘Designing a business card holder that would attract the attention of people walking past a desk’. The FabKids experience is based on the concept of teamwork which is essential for competing in today’s global arena, where “individual perfection is not as desirable as a high level of collective performance” (Stevens 2002, p. 24).

> It may be possible to differentiate between collaboration and cooperation with reference to a division of labour. In cooperation, partners split the work, solve sub-tasks individually and then assemble the partial results into the final output. In collaboration, partners do the work ‘together’. However, some spontaneous division of labour may occur even when two people really do work together (Dillenbourg 1999).

The net result of this approach is a “more efficient use of manpower leads to opportunities for informal and incidental learning” (Marsick and Volpe 1999).

The specific tasks assigned to each team included:

- Team Managers had to oversee all phases of the task.
- Design Engineers were responsible for the capturing of the ideas onto computer using Open Office Draw which were then printed to a laser cutter.
- Electronics Engineers had to assemble the electronic components using a 555 timer circuit and two Light Emitting Diodes (LEDs).
- Media specialists were responsible for the development of the group logos using Open Office Draw or the

completion of a report for the day which is published live on the internet via Google Groups.

The selection of the groups and the allocation of the responsibilities were left entirely up to members of each team in order to cater for individual interests. Once the groups were formed, they were tasked to pool their ideas by collectively producing a number of possible solutions as simple sketches on paper which included the dimensions of the different components. At a stage when the designs were nearing completion all the Design Engineers were extracted from the groups and given a rudimentary introduction to Open Office Draw for approximately 10 min. Their instructions included:

- launching the program in Windows or Linux (Ubuntu)
- defining the page layout size to accommodate the laser printer
- saving their designs regularly
- creating objects such as lines and shapes
- resetting sizes of object to absolute sizes
- rotation of objects and
- merging of shapes

On completion of this the Electronics Engineers were extracted from their groups where they spent approximately 3 hours with individual attention for the assembly and completion of the circuits. The training was conducted by an intern based at the FabLab.

The first phase of the activity lasted approximately 1–2 hours after which the Design Engineer transferred their designs to the computer in collaboration with the Team Manager. Their task was to accurately capture their sketches as two dimensional components which, when cut on the laser cutter, could easily be assembled as three dimensional objects. The first prototype was produced on a sheet of cardboard. This ‘cheap mistake’ is perceived as a critical step in the process as most teams discovered small inconsistencies which had been overlooked during the design phase. Teams were encouraged to ‘make mistakes’ and to learn from the process rather than be worried by a fear of failure. This is encapsulated in the English Proverb “He who never makes mistakes, never makes anything”.

After making the necessary adjustments to the designs the final models were cut out of Perspex using the laser cutter as shown in Fig. 1. By this time the circuits were either complete or nearing completion, depending on how efficiently the Electronics Engineers were at identifying problems such as dry soldering joints and the correct placement of components. The circuits and LEDs were integrated into the final models by the whole team.

Figure 2 shows a team assembling the final product including the electronic circuit into the base of the model. The Media Specialist was also responsible for a journal report for the day which generally included digital photographs to be posted onto a Google Groups web page.

Fig. 1 Two students and a teacher observing the laser cutter in action

Fig. 2 Shows team members assembling the final product including the electronic components

The management of the day was largely done through a process of “dynamic facilitation which worked with each person’s natural inclinations and genius, enabling the group to produce a better solution in faster time, while building trust and new levels of capability” (Rough 2008). The learners were free to ask for assistance when they encountered problems rather than the adoption of a teacher-led step-by-step process. In essence the Team Managers took full responsibility for the completion of the tasks and all teams did so successfully although two of the 16 sub groups were pressed for time.

Summary of the Findings

It must be emphasized that the pilot project was not aimed at doing an in-depth quantitative study but rather to establish proof of concept. The data presented thus provides an insight into how the participants experienced the FabKids sessions. The administration of the course evaluation questionnaires served to identify some important aspects that will need further investigation in order to draw more conclusive results.

The following points serve as relevant highlights:

- 78% of learners regarded themselves as computer literate
- 62% had not participated in any science or technology related competitions
- 84% would consider a career in Science, Engineering and Technology as a result of the FabKids experience

Responses to the question of what they did enjoy included:

- 94% enjoyed the design process
- 34% highlighted team work as being important
- 49% electronic enjoyed the electronics even though only one in four participants had hands-on experience of this section

Responses to the question of "What they did not enjoy" included:

- Approximately 94% were happy with everything
- 22% of learners reported that the laser cutter took too long to print especially with the more complex designs.
- Overall the 'negative comments' were of a minor and more personal nature and did not detract from the overall success of the day.

Responses to what the participants learnt from the FabKids experience included:

- The results were positive with a broad spectrum of learning taking place across a range of skills.
- In general approximately 30% highlighted the importance of team work in the completion of the task.

During a videotaped 'informal press conference with learners from the Glen High School, a student reported that it was the first time that they were able to experience and apply the design process rather than learning about it theoretically. Added to this the group agreed that there was very little information transfer that took place during the workshop as they were responsible for their own outputs. The opportunity that they were afforded allowed them to apply a range of skills such as lateral thinking, problem solving, creativity and innovation while working in groups in an environment where there were no right or wrong answers.

All groups produced a final product which represented a broad range of solutions. This concept is inherent in the learning area of Technology for Grades 1–9 which is contrary to the more traditional woodworking model where all learners produce the same final product according to the teacher's specifications. The fact that all the learners were actively engaged in the process meant that many of the groups did not break for tea or lunch time as they were totally absorbed in their work. The final solutions from the groups were all functional and of a similar high standard.

A final observation is that all learners who participated in the pilot project were able to operate at a similar level no matter what school they came from. This indicates that potentially all learners may benefit equally from such an intervention if the project were to be massified to all schools in the country.

Conclusions and Recommendations

In reflecting back on the learner-centred FabKids experience it is relevant to take stock of the outcomes achieved. OBE in a South African context emphasizes a learner-centred and activity-based approach to education. The Critical Outcomes of the National Curriculum Statements require learners to be able to:

- identify and solve problems and make decisions using critical and creative thinking;
- work effectively with others as members of a team, group, organization and community;
- organize and manage themselves and their activities responsibly and effectively;
- collect, analyze, organize and critically evaluate information;
- communicate effectively using visual, symbolic and/or language skills in various modes;
- use science and technology effectively and critically showing responsibility towards the environment and the health of others; and
- demonstrate an understanding of the world as a set of related systems by recognizing that problem solving contexts do not exist in isolation

(Department of Education 2002)

In reviewing the FabKids experience it is evident that all of these National Critical Outcomes are met within a single project although initial FabKids encounters were of a limited nature due to time constraints of a single session. The intention is to expose more learners to these types of experiences in order to develop a more positive attitude towards SET from a hands-on perspective which warrants further investigation. The process has been equated to 'lifting the lid of education' and allowing the learners to operate outside the confines of traditional classrooms and pedagogies.

The implicit assumption in selecting the types of learners drawn from a broad range of schools was that they would all cope with the challenges of a FabKids experience. This assumption was confirmed by the fact that all groups managed to complete the tasks by effectively using the tools available to produce realistic solutions, irrespective of their backgrounds. Another important issue is that all groups were working to their own design specifications and not according to ones supplied by the teacher as is the case in a more traditional woodwork or metalwork methodology.

There is a significant emphasis on computer literacy in most schools as they attempt to address issues such as access and bridging the digital divide. The dilemma is that the potential impact of this approach is severely hampered by limited access time to computer laboratories. Where computers have been deployed in schools, the access time for the vast majority of learners is severely restricted. In addition, the teachers may not be competent and confident enough to deal with large classes, let alone be able to deliver meaningful e-learning experiences.

The FabKids experience focuses on the use of computers as a tool to promote such concepts as teamwork, authentic and experiential learning by adopting a constructivist approach. This approach emphasizes the need "to create opportunities to use ICTs beyond just computer literacy which will empower the learners to operate much higher up the technological ladder" (Beyers 2008). Embedded in this approach is the notion of providing each learner with a meaningful experience which potentially could become a key SET moment in making a career choice. Long term impact studies are needed to clarify the effectiveness of this methodology.

The FabKids experience has the potential to provide an avenue for these Net Generation learners to express themselves in a more meaningful manner. Many were comfortable with using ICTs as the tools of their choice in solving the real world problems, irrespective of their backgrounds.

A significant outcome of the original pilot project is the need to support the learners when they returned to their respective schools. Many of the participants left on a creative and innovative 'high' and there is little support for them thereafter. As a result of the pilot FabKids intervention a Fab Teacher project is proposed where educators and even subject advisors for various learning areas and subjects would be exposed to the same processes as the FabKids. The only difference being the discussion of the pedagogy needed to assist the Fab Teachers to replicate the processes in their respective schools. It must be emphasized that the focus is on how technology can be used as a tool in education implying that teachers do not need to have access to a technology rich environment to implement the design process. The presence of a well-equipped technology-rich environment such as a FabLab can, however, greatly enhance the outcomes of such an experience.

To add further support to the Fab Teachers project, a process of curriculum mapping has been undertaken to link the design briefs to the NCS. This has been done effectively with the subject of Design at the Further Education and Training (FET) level. Distinct possibilities exist for synergy with Engineering, Graphics and Design, Science as well as Technology as a learning area at the GET level. The possibilities exist of linking up with languages, computer studies and Life Orientation, intimating the cross curricular nature of a FabKids intervention.

As part of the massification process a model of deploying a number of Fab Schools is envisaged for each of the provinces.

> The intention is to invest in a Hub School which could provide support to a number of satellite schools in the immediate community. Learners and teachers would be exposed to a Fab School experience and may be able to continue innovating in their own schools which are connected to the Hub School via a mesh network along the lines of the Ulwazi Concept (Beyers 2007).

This may also provide support to teachers and learners in their own communities while enabling a process of social transformation to take place through access to more community based information and other schools. Access to the shared resources could be increased where it is conceivable that learners will be empowered to translate their ideas into designs that are then emailed to the Hub School for digital manufacturing and collection, thereby increasing the returns on investments at such a Hub School.

Other aspects of the project that need further investigation include integrating the FabKids experience into science and technology Olympiads as well as SET competitions in association with FESTOC. This can be done by providing learners with the insight into how the FabLab resources could be used to translate ideas into physical artifacts. Adding an entrepreneurial aspect to this process could spawn a number of interesting small industries adding greater value to the economy as a whole.

With time and experience further design challenges will be developed and tested across a range of different grades matching the levels of interest and capabilities with the individual learners while developing additional 21st century skills. The option of integrating the FabKids into a number of other projects is certainly not out of the question. These may include longer term interventions where learners participate in collaborative projects with other schools integrating mechanisms to produce more complex solutions to challenges.

To increase the number of PhD graduates contributing to the goals of the National System of Innovation, requires a long-term investment. Given the necessary support and encouragement at the lower levels the SET pipeline can be initiated and developed from an early age with positive long term outcomes. The FabKids intervention has demonstrated that there is potential amongst our youth which needs to be channelled in the right direction for the benefit of the country as a whole.

The FabKids experience has given new meaning to the dictum of Confucius around 450 BC: “Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand.”

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