Chapter 8: Conclusions, Recommendations and Future Direction of Research

Introduction

This study was conducted in one engineering undergraduate classroom in one of the higher education sectors in South Africa but within the framework of a greater recognition from engineering education globally, over the last two decades, that engineering education has to realize a new paradigm if it were to serve its stakeholders better in the 21st Century. The development of a new paradigm in engineering education was to focus on curricular reform in terms of how the engineering curriculum could better be organized in terms of, “the innovative approaches to teaching and degree of involvement of students in teaching and learning” (Ernst and Peden, 1998: iii). In this sense, engineering education, over more than twenty years, has been attempting to reconnect with an old debate on the meaning of engineering activities and how such understandings of what engineering activities mean shaped and guided the development of engineers within higher education. The discrepancy between what teachers in this study believed is the meaning of creativity which veered towards technological inventiveness and, what teachers pass on as teaching in their classroom, which slants closer to conventional problem-solving suggests an increasing awareness of the disconnect between engineering education and creativity.

In undertaking this study, engineering activities were understood to be based on the development of new knowledge in science (scientia), newly developed products or service (technē) based on this science and new means of working and doing (praxis) which meant that engineering activities were understood to be in a dynamic state of constant change. The embracing of the development and realizing of a new paradigm in engineering education has to, I argue, take consideration that engineering – ingenium – in its core essence is about technological innovation that subsists mostly on creativity.
In this study, engineering undergraduate studies were viewed as based on positioning students on both the “known, known” quadrant and the “known, unknown” quadrant which meant that undergraduates had to learn both on the individual and collective level.

The basis of students’ participation in the study was final-year undergraduate level, which means that there was greater understanding that creativity in a specific discipline of engineering has to be developed within the framework of competence in the discipline’s knowledge. Some competence in the disciplinary knowledge of engineering was thus seen as a prerequisite for participation in the study which was designed to develop students’ creativity through the development of an innovative pedagogy which was tested through an innovative research methodology – Designed-Based Research (DBR). DBR is about the search for appropriate pedagogies and learning theories to better serve new educational demands which, in the context of engineering education, involve the development of generic skills such as creativity, teamwork and communication alongside engineering disciplinary knowledge with more engineering contextualized science and mathematics in undergraduate curriculum.

I recount some of the salient points of the study because I am attempting to make better reading of the study’s conclusions, recommendations and the identification of research gaps that emerged as a result of this study. This chapter draws inferences based on the evidence developed in chapter 7 which adequately responded to the research questions, based on these inferences I make recommendations and provide direction for future research in engineering undergraduate curriculum and pedagogy as each relate to the fostering of engineering undergraduates’ creativity. It is expected that in presenting these conclusions, recommendations and research gaps that the constitution and transformative potential of creativity in engineering undergraduate studies will be illuminated as well as the study’s contribution to the ongoing efforts of engineering education to realize a new paradigm so as to attempt to enhance students’ experiences of learning and better prepare students for the unknown, increasingly complex future.
This study was essentially about initiating and growing final-year engineering undergraduate students into a particular creative problem-solving practice through the design and testing of a particular pedagogy that was more likely to develop learning environments where students’ experiences of creative problem-solving could be stimulated and enhanced. The study had to be designed in such a way as to ensure that pre- and post-measures of an experimental design were used without necessarily making use of a control group.

Design-Based Research encourages the design and testing of innovative pedagogies in “naturalistic settings” and without the pre-condition of a control group hence it was used as the study’s methodology. The Torrance’s Tests of Creative Thinking (TTCT) were used as measures of determining whether there was any significant difference in students’ creativity as a result of exposure to the learning environments that were framed in terms of invitational pedagogy and organized in the form of learnshops. TTCT is one of the few measuring tools of creativity that have been consistently tested for validity and have proved valid in most of these validity tests as expounded in chapter 5 hence their use in this study.

Conclusions

As discussed above, this study was about finding out current learning conditions in a specific engineering undergraduate classroom as guided by a particular pedagogic practice, eliciting teachers’ meanings of creativity as part of a bigger, global project on how teachers and students in higher education conceptualize creativity, determining whether the learning environments developed in the learnshops had a positive effect on students’ understandings of creativity and students’ generation of ideas, a variety of those ideas and their novelty.

The existing learning conditions in the engineering undergraduate classroom that was under investigation inclines, it can reasonably be inferred, towards narrowing students agentic and discretionary power as there is evidence that the professional authority of the teacher in the classroom is still very strong.
As indicated in chapter 6, learning environments that are mediated through professional authority significantly limit the agentic and discretionary power of the students and tend to accentuate the transmission and acquisition of existing, settled disciplinary knowledge which positioned students on this knowledge as deficit. In this sense, it can reasonably be concluded that the pedagogic practice that is illuminated in this specific engineering undergraduate slants toward mimetic pedagogy as described in chapter 1 as the pedagogy that pursues “copying” of existing knowledge.

Mimetic pedagogy is, as indicated in chapter 1, shaped and guided by a curriculum that emphasizes breath of learning content and is generally a textbook-driven curriculum which undermines the depth of engagement with learning content. Such pedagogy significantly limits teachers’ agentic and discretionary power (Runté, 1995) as it relates to committing to creating learning environments where students’ own agency and autonomy are foregrounded and meaningful classroom discussions can take place. It is also not unreasonable to suggest that such pedagogy positions students on disciplinary knowledge and thus defers to linearity in the classroom which significantly limits students’ aspirations to participate in some form of research and make some contribution to engineering knowledge base. Teachers lack of pedagogic expertise also contributes in limiting their potential to be creative, even within the strictures of the institutional curriculum and pedagogic culture, in terms of developing learning environments that could go some way in showing commitment towards preparing students for the unknown future with the use of mostly known, present knowledge.

The fact that more than ninety percent of students indicate that they rarely if ever gain opportunities in the classroom to engage in meaningful discussions and think creatively suggests that current learning environments in this engineering undergraduate classroom are inimical to creativity. However, a generalization of this state of affairs in engineering undergraduate classrooms in this sector of higher education and based on the general dissatisfaction with engineering undergraduate studies globally which have been marginalizing creativity, it can be concluded that creativity is a generally marginalized outcome of engineering undergraduate studies.
That teachers were generally unable to convincingly link the teaching of science and mathematics in engineering undergraduate curriculum and preparation of future engineers is also an issue that has been picked up globally and it can also be argued that the focus on science and mathematics teaching may have affected the development of students’ generic skills such as creativity because of pressures of time and a highly content-loaded curriculum. Of importance to note and conclude on is that the pedagogic practice revealed in this engineering undergraduate classroom commits more strongly to the transmission of disciplinary knowledge than on preparing students for the uncertain, more complex future. These learning conditions led to the design of an alternative pedagogy.

Teachers’ understandings of creativity reveal, as already indicated earlier, a propensity towards inventiveness which suggest that teachers have a fairly good understanding of the current direction of creativity within engineering, which also may be indicative of the limits set on the teachers by the institutional culture which the Higher Education Quality Committee (HEQC) report of 2007 on the institution under investigation indicated was highly authoritarian and top-heavy. The limits set on the teacher relate to what must be taught and how it should be taught in the engineering undergraduate classroom which, it can reasonably be inferred, set boundaries on what can legitimately be considered as genuine dialogue, transition towards healthy relativism (recognition that areas of legitimate expectations and diversity of ideas exists, Perry’s Intellectual Development stage 4, Perry, 1970) and that knowledge is not limited to textbooks and formal institutions only.

The interview data of students' post-learnshops show inclination towards imagination and resourcefulness as compared to prior to the learnshops when their understandings of creativity inclined towards originality. This suggests that students' meanings of creativity shifted away from defining creativity as emergenative (search for newness in its absolute sense, H-creativity) to understanding it as a tool for composing some new devices, processes and technologies (inventiveness which is closely associated with being imaginative and resourceful).
In this sense, it is not unreasonable to suggest that *learnshops'* learning environments had a positive effect on most of the students in terms of bringing them into a new understanding that creativity is accessible and can be developed within engineering education.

The TTCT results pre- and post *learnshops* showed that all the dimensions of TTCT – fluency, flexibility and originality – increased with statistic significance which implies that students’ creative abilities, as measured through fluency, flexibility and originality, increased as a result of being exposed to the *learnshops'* learning environments.

The learning environments in the *learnshops* were based on the idea that students’ creativity can be developed through guided creative problem-solving that is based on a specific creative problem-solving model. The TRIZ method framed and informed the creativity model that was used in the study. Three teams used the creativity model in varying degrees of sophistication and hence with different results.

Team B identified a real contradiction in the water technology which affected the quality and quantity of water supply and gave real prospects of developing some innovative product in the form of water leak detectors, the other teams focused on trimming and understanding the technology. Team A and C focused on cost-cutting measures (trimming) and made some attempts to understand the technologies each team was dealing with but failed to come up with innovative ideas that could result in the improvement of the technology. Based on this finding on how teams dealt with the inner logic of the TRIZ-based Creativity model, it can reasonably be inferred that guided creative problem-solving holds prospects of initiating and growing students into a specific creative problem-solving model or technique.

Case studies were designed in such a way as to be sufficiently vague to allow for the use of the TRIZ-Based Creativity model to trigger students’ problem-solving initiatives. It has to be remembered that the first step in the creativity model developed in chapter 4 is to make sense of the technology under investigation, followed by the question of whether the technology is working near-perfect and the identification of the nature of the problem that is hindering the technology from operating near-perfect as the third step.
These first three steps were designed to encourage students to gain more knowledge about the technology and be able to identify factors that compromised the optimal operation of the technology which we may call ‘the problem space’. The case studies, therefore, dealt with the problem space in the context of the TRIZ method. In this sense, it is reasonable to suggest that case studies served the purpose of delineating the basis of creative problem-solving and providing students with opportunities to actively and collectively engage a non-routine problem which shaped and guided their decision-making processes in a group context.

While the learning environments were designed to be sufficiently open-ended, it can reasonably be concluded that case studies and the use of the TRIZ-Based Creativity model set limits to the open-endedness of the learning environments so that there was some level of control and guidance over what was taking place in the learnshops.

Teamwork is based on the idea of consensus-making. In engineering, teamwork has been used mainly in expert teams with particular focus on shared mental models as described in chapter 2. The idea of shared mental models in the context of the study, that is based on non-experts, refers to how students develop common understandings of what they want to achieve as a team which boils down to decision-making. We have observed that non-expert teams focus on the tasks at hand which guide their decision-making processes and as a result, member swapping has very little effect on the overall functionality of the team. Task-oriented non-expert teams also show a propensity towards developing safe conversational spaces as we have observed very little use of verbal violations during the learnshops as a result it can reasonably be inferred that task-oriented, non-expert teams orientated themselves relatively quicker into safe conversations because the primary focus is the task at hand.

The teams’ visits to the relevant industries where the technologies they were investigating were being operated and the team members’ opportunities to meet, observe and discuss with the industry personnel on the existing industrial processes and the challenges of making these processes to operate optimally gave teams a sense of the real world as drawn from our observation of their report-back sessions.
Off-campus visits, it can reasonably be inferred, bring a strong sense of the real-world into the undergraduate classroom situation and serve to demystify the real-world of work in terms of students realizing that the problems are real and solutions hard to find.

Of all the challenges that the students faced in the learnshops, the transition towards relativism appeared to have been the most difficult. We observed that and students informed us during learnshops’ discussions that they were struggling to cope with both the demands of their actual disciplinary work which is still framed in terms of right and wrong answers and having to work in the learnshops where it is not demanded that they get the correct answers only that they struggle through the case studies as guided by the TRIZ-based Creativity Model.

It is as a result of this transitional struggle of the students during learnshops that I labeled this struggle to strike a balance between highly committed ways of knowing and ways of knowing that recognize that there are areas of legitimate uncertainty and diversity of ideas (stage 4 of Perry’s model) “recidivism complex”. In this sense, it is not unreasonable to conclude that the transition from basic dualism towards relativism in order to develop students’ creativity requires a broader and more systemic paradigm shift (to torture a cliché) within the institution.

It can also be concluded that in order to develop pedagogic practices that attempt to develop students’ creativity, it is important to create an enabling curriculum framework that strikes a healthy balance between the scope of coverage of learning content and the depth of engagement with the learning content with greater recognition of the value of deepened understanding of learning content as a precondition for developing students’ creativity.
Recommendations

The recommendations that follow are made in the context of attempting to find the constitution and transformative potential of creativity development within higher education.

- Creativity development initiatives that attempt to stimulate and enhance students' creativity in higher education could benefit from understanding the key features of a pedagogic practice and how they are shaped and guided by the entrenched curricular cultures within a particular institution or discipline.

In the case of this study, the curricular culture that emerged was the one that accentuated scope of learning content coverage at the expense of the depth of engagement with the learning content which resulted in students' experiencing recidivism complex. By the end of the *learnshops*, there was an understanding from the Teacher that students' creativity development could, potentially, result in the reconsideration of the current curriculum if it were attempted at a larger scale within the institution.

- The understandings of creativity from the perspective of research participants play an important role in determining whether innovative pedagogies are having any meaningful contribution to the growth of students' creativity and it is thus recommended that eliciting such meanings of creativity from the perspective of the research participants is vital in efforts on developing research participants' creativity.

- While the measuring of creativity remains a complex and controversial issue in creativity research and education, existing and enduring tools whose validity has been confirmed such as the TTCT should continue to be used until such time that alternatives are found especially when testing an innovative practice.
• Studies that involve the design and testing of an innovative pedagogy that attempts to develop learning environments that can stimulate and enhance students’ creativity are advised to choose research methodology that can have immediate effect on students’ experiences of learning.

• At an undergraduate level, the development of students’ creativity can benefit from considering students who already have some competence in any of the disciplines.

• Creativity development is generally resource intensive in terms of time and capital and efforts to such an end need to take this matter seriously.

**Future Direction of Research**

• Higher education teachers and students’ understandings of creativity may need to be further investigated in the form of a survey. This would help to contribute a South African perspective in the ongoing global project on eliciting higher education teachers and students’ meanings of creativity (Jackson and Shaw, 2006; Jackson and Sinclair, 2010) so that their views can contribute in the rich variety of perspectives on creativity as creativity remains difficult to pin down and elucidate with high degrees of certainty. This study has made some contribution in capturing the views of some of the higher education teachers and students on the meaning of creativity.

• The status and identity of Universities of Technology (UoTs) in South Africa remain problematic which affects the direction their curricular and pedagogic practices should take. The retention of the apartheid era curricular mission of these institutions (Ensor, 2004) and name change to Universities of Technology in 2004 was not informed by research-based evidence rather was based more on changing the name in keeping with international trends (Du Pre’, 2004).
For instance, in Germany the equivalent of a University of Technology (Fachhochschulen) focuses on providing qualifications that have a strong relevance to a specific profession or vocation as compared to traditional universities that focus on research and teaching and, in Netherlands the binary between universities that focus on teaching and research and Hoggeschole (equivalence of Universities of Technology in South Africa) that pay attention to career-focused courses is clear and unambiguous (Du Pre’, 2004). Both these institutions in Germany and Netherlands fall under the higher education band with a clear curricular mission of preparing students for a particular profession or vocation which may influence our own curricular mission. These international institutions are not chosen in any particular order except to make a point that importing models of higher education to South Africa without due consideration to our context poses serious challenges. These models of higher education provisioning, while clear and unproblematic remain problematic in the South African context because of the high unemployment rate of graduates from Universities of Technology as stated in the body of this thesis with reference to the works of Howitz, 2007, and Pauw, Bhorat, Goga, Ncube, Oosthuizen, and Van der Oosthuizen, 2006. I am of the view, in light of the findings of this study, that UoTs in South Africa will benefit more from adopting a curricular mission that is closer to providing higher technical education as compared to Further Education and Training (FET) band that is also underpinned by technology and knowledge transfer which accentuates the value of applied research and the *techne’* aspect of technology which refers to the practical application of useful and relevant knowledge to real, practical problems in society. The implication of the suggested curricular mission for UoTs is that UoTs in South African would play a meaningful role in preparing students not only to become innovative but also entrepreneurial both of which subsist on creativity. In light of this curricular mission, more research may need to be undertaken in terms of how the curricular mission will impact curriculum and pedagogy in these institutions.
More importantly, this thesis has made a case that curricular contexts and pedagogic practices that are based on replication of industrial processes would not necessarily lead to the development of students’ creativity and thus enhance their prospects of being employed or self-employed.

The suggested curricular mission for UoTs in South Africa may account for better articulation between UoTs and Further Education and Training institutions (FETs) in that FETs could focus on providing vocational programmes that develop students’ competences in specific disciplinary areas which are closer, in their general outlook, to a specific vocation or profession. UoTs can play a more meaningful role in developing students’ capacity to design, redesign or improve existing technologies which means a higher level of technical skills development. When the name change of these institutions was effected in 1977 from institutions that offered vocation-based, career-focused qualifications to Technikons, the idea was to develop these institutions into institutions that prepare students on creativity and innovation implied in the etymological meaning of Technikon derived from the Greek root *techné* which has the meaning of creativeness or ingenuity and the suffix “kon” which connotes academy (Du Pre’, 2004). When I started in this chapter I made the point that this thesis was about reconnecting UoTs education to the development of students’ creativity. The development of students’ creativity through reorganizing curriculum and pedagogy in a particular way, as demonstrated in this study, has to become an ongoing research project in South Africa which has to be linked to efforts on clarifying the identity and focus of these institutions with implications for current higher education policy on these institutions which is relatively unclear about the curricular mission of these institutions beyond the retention of the apartheid era mission.

The vertical articulation between FETs and UoTs education leaves a glaring gap in qualifications frameworks and research may need to focus on developing effective learning pathways between UoTs and FETs and create a greater synergy between the curricular missions of these institutions.
For instance, a student that comes from an FET college ought to have developed the necessary competences in a particular technology or field of practice in order to benefit from UoTs education which, I suggest, should focus on developing students’ innovate and entrepreneurial capacity within a particular technology for which a student has already gained some competence at FET level. This thesis showed that with greater emphasis on refocusing UoTs curricular mission, alternative pedagogic practices can be developed to encourage creativity which has the potential to lead to some innovative ideas and subsequent entrepreneurial opportunities. In terms of this approach to UoTs curricular mission, the relationship between UoTs and FETs will need to be further investigated and refined through surveys with key players in the UoTs, FETs and industry to improve on the articulation among these societal organs.

- The myth that changing the pedagogy will necessarily lead to desirable learning outcomes such as developed creative abilities of students was debunked through this study. The work of this study resulted in the design of an educational model that shows potential in developing students’ creativity will require further research (Figure 8.1).

![The Educational Model for Fostering Engineering Creativity](image)

*Figure 8.1. The educational model for fostering engineering creativity. (Pitso, 2010)*
• The refining of the features of a pedagogic practice may require further analysis and research, especially as they relate to the positioning of students’ disciplinary knowledge as creativity thrives on curricular conditions where there are greater freedoms and discretions for students to try out things without fear of punishment or failure. Creativity also thrives when there is border crossing among the knowledge areas and courses. The effects of the transition from basic dualism from which students have been orientated towards healthy relativism may need to be investigated through more qualitative instruments such as Design-Based Research to provide for the emotional support of students during those transitions.

Summary

This chapter attempted to draw inferences based on the empirical data collected and presented in chapter 7. Based on these inferences, recommendations and future direction of research were suggested. As part of the future direction of research more focus was placed on the curricular mission of the UoTs in light of the 21st Century job designs that value creativity and innovation but also that students prepared this way have the potential to become entrepreneurial. The vertical articulation between UoTs and FETs was also considered to be important and worthy of further research.