

Chapter 7: Results and Discussions

Introduction

In this chapter, I consider the current standing of a pedagogic practice in one sector of higher education in South Africa within the engineering undergraduate studies using the framework of a pedagogic practice as expounded in chapter 6. The purpose of consideration of such a context was to have better understanding of its existing learning conditions and, how such learning conditions limited, marginalized or enhanced creativity.

I, as the Design-Based researcher oriented towards investigating learning in its naturalistic setting and reconceptualizing and testing a new pedagogic practice that was likely to create learning environments that were to lead to the development of students' creativity, also used the data gained in this learning context to develop, design and test a new pedagogy. The developed pedagogy was tested for effectiveness in developing students' creativity through the use of TTCT as pre- and post-measures, and its role in creating meaning variations in how students understand creativity. This chapter, therefore, addresses questions 2 and 3 of the study and presents empirical data drawn from interviews with teachers and students, observations of *learnshops*, documentary analysis of final-year Process Instrumentation Learning Guide and TTCT to highlight key aspects of the developed conceptual framework.

The Engineering Undergraduate Pedagogic Practice

This section attempts to address the sub-question “*Which pedagogic practice is revealed and what curricular context informed such a practice in engineering undergraduate studies?*” In an effort to respond adequately to this sub-question, the teacher who took part in the main study, hereafter called “the Teacher” was requested to comment on what he considered as his and students' role in teaching and learning in his classroom.

This sub-question is at the heart of examining the pedagogic practice of the teacher because it relates to how classroom interactions map out the relationship between the teacher and the student and what count as legitimate expectations in terms of acceptable actions and behaviours in the classroom. At a more complex level, the question relates to interactions that take place among people within a particular social space (both physical and symbolic) and how the social space is negotiated at a physical and symbolic level. In chapter 2, I elaborated on how space in the classroom of a particular educational context can either stimulate or inhibit the development of students' creativity but also the teacher's creativity in terms of organizing the learning environment to meet prevailing educational demands which the institutional decision-making processes may not have yet considered relevant and important. I further indicated how time-space coordinates can be used to define what actions and behaviours are considered appropriate or anticipated in the classroom situation. These time-space coordinates affect both the teacher and students' agency and autonomy at an institutional and classroom level respectively and map out a particular relationship between the teacher and the students. Lack of classroom space, for instance, may affect how students are organized in the classroom and how such organization of students defines the parameters of classroom actions and behaviours.

Time constraints can also limit the degree and type of dialogues that take place in the classroom, the kinds of transitions that students could make and what passes as legitimate knowledge at that point in time. For instance, the allocated time for the completion of a module affects the trade-offs between the breadth of learning content coverage and the depth of engagement with such learning content. Less time and more content coverage is likely to veer classroom interactions toward focus on content coverage completion and compromise the depth of engagement with such learning content which may also pressure the teacher into an overly active role and students into an overly passive role because the commitment is on the completion of prescribed learning contents rather than on preparing students for the unknown and uncertain future. Questions on the role of people within a particular social space are thus questions on the expansion or narrowing of individual expectations and aspirations which affect individuals' experiences of the social space.

In the context of this study, such questions relate to how existing learning environments have, over time, impacted the engineering undergraduates experiences of their learning and how such experiences have set limits on their expectations, aspirations, actions and behaviours.

In responding to the question on his role and that of his students in the classroom, the Teacher focused on a hypothetical and idealized role of the teacher in teaching and learning (“...*must be able to...*”) as conceptualized within the framework of Outcomes-Based Education and based, by his own admission, on what he picked up in the Academic Development workshops he attended since 2004 when OBE was introduced in UoTs in South Africa:

“I must be able to create a climate conducive for discussion, integrate subject matter, acknowledge and interact with alternative forms of reasoning on the subject matter; all in all I must act as a facilitator”

In light of his idealization of his role in the classroom, I sought to elicit more information on what he considered to be the teacher’s role in his practices. I requested him to describe what he would consider as his consistent teaching actions in the final-year engineering undergraduate classes. He responded thus:

“Introducing the topic and find out whether the students have knowledge about the related topic by asking them questions, then explain the content of the topic, then we do the example (calculations) and they have to solve the problems”

The discrepancy between the idealized role of the teacher and his actual teaching actions in the classroom indicates the gap between his intentions and what actually takes place in the classroom. While his intentions are to attempt to develop classroom conditions that value students’ discussions and their active participation in their learning, revealing an expanded role of students in the classroom activities which potentially would improve students’ agentic and discretionary power as well as map out a balanced relationship between the teacher and students his description of his actual teaching practice indicates classroom conditions that are highly controlled and centred around the teacher which, in turn, moderates the teacher’s intentions.

The actual classroom actions of the teacher illuminate his professional authority as teaching is mostly single-voiced “*introducing topic, find out...asking questions...then explains*”. In the Teacher’s own description of his general classroom actions, the students’ voice as the second and legitimate voice, from the perspective of this study, in the project of classroom interaction and dialogue receives some recognition “...*then we do the example...*” but there is little evidence to indicate that the teacher enters into a genuine dialogic engagement with the students’ voice in his teaching.

The implication of this approach to teaching is that students’ agentic and discretionary power is significantly curtailed; the goal of teaching appears to be largely knowledge acquisition and conventional problem-solving as the classroom actions of the teacher inclines toward explaining, modeling problem-solving and letting students solve problems related to the modeled problem-solving approach. This approach to teaching reveals learning environments that mostly position students on existing disciplinary knowledge and conventional problem-solving. There is little evidence to indicate that the Teacher’s efforts also include attempts to push students not only towards attending to given knowledge but also towards considering the relevance of this knowledge to overriding abstract principles, allowing them to frame hypotheses that they can potentially investigate as an approach that could better prepare students, I argue, to apply these gained skills in situations of the future which are currently unknown. Furthermore, the teacher’s approach reveals a deferment to linearity as the intention of teaching appears to focus on taking students from the state of not knowing this already known disciplinary knowledge (quadrant 1) to a state of knowing the prescribed disciplinary knowledge (quadrant 2) and thus illuminates reproduction of existing knowledge consistent with the UoTs’ curriculum framework that has been accentuating replication of industrial processes and skills training discourses (McKenna and Sutherland, 2006).

On students' role in the classroom, the Teacher once again resorted to the idealized and hypothetical role of the students:

"Responsible for their own learning, solve problems, must be able to trace information, must be involved in class discussion, integrate knowledge, since the learning is much more learner centred"

I have already indicated that his actual classroom actions indicates a different role for the students which limits students' agentic and discretionary power as well as the expectations of what count as legitimate actions and behaviours in the classroom.

Both the Teacher (who took part in the main study) and a teacher who took part in the pilot phase were probed on their pedagogic expertise as defined in terms of formal qualifications in education specifically on curriculum and pedagogy. I assumed that teachers grounded in educational theories and the complex variations between them would be able to analyze and interpret their classroom practices as mediated and moderated by the entrenched institutional decision-making processes and were more likely to participate in efforts that were designed to improve classroom practice. I also assumed that such teachers would be better prepared to read the distal and proximal factors such as the prevailing economic paradigm and their impact on what takes place at a classroom level.

In responding to the question of training in education, the pilot phase teacher indicated that he has received no training at all and the Teacher referred to Academic Development initiatives that the institution initiated since 2001 which he has been attending and where he learned about the importance of learner-centredness in classroom practices and more about educational theories such as constructivism.

In order to facilitate the cross verification of the pedagogic practice described by the Teacher so far, I elicited the views of students on the consistent classroom activities they have often been exposed to and how these classroom activities relate to creativity and meaningful classroom discussions.

By meaningful classroom discussions I mean classroom discussions that are predicated on extensionalism which, in the context of this study, refers to the ability of students to grow collectively into individuals who can identify, distinguish and disambiguate a pattern of critical features of some phenomenon so that such phenomenon is seen in a new way. Within engineering, extensionalism even assumes a higher level of relevance as it involves discernment of some critical aspects of the problem and as Bowden and Marton (1998: 9) suggest:

“What was not seen before is now able to be seen and what was seen before is now seen differently”

In a way the idealized role of the student, from the perspective of the teacher as shown above, inclines toward meaningful classroom discussions.

When requested to respond to the question on the frequency of their engaging in engineering classroom activities that encourage them to think creatively, 22 of 24 students suggested that they rarely or never engage in such classroom activities, representing almost 92% of the total respondents. The following samples of students' views on meaningful classroom discussions illustrate the point more clearly:

“In classes like laboratory class, we do what we've learnt in theory class. Because we do it practically we combine theoretical knowledge and practical knowledge”

“Most of the time I first think or understand the promblem (sic) and check what I have, from there I check the method to be used and I solve the problem”

“In communication studies we are sometimes required to work in groups and come up with our own creative approaches to the activities given to us”

In response to the question that attempts to find out the frequency of students involvement in meaningful discussions, 20 of 24 respondents indicated that they rarely or never get opportunities in the classroom to meaningfully and collectively engage on the learning content representing 83% of the total respondents.

The students were asked to elaborate on their response to this question because it was important to elicit more information on the quality of discussions that usually take place in this engineering undergraduate classroom to find out whether such discussions meet the criterion of being meaningful as elucidated above. The sampled views of students that commented follow below:

“Most of our subjects we don’t engage much on group work were (sic) we are able to discuss different ideas and combine our ideas”

“If an individual in my study group try to solve a problem and on the way he/she get lost. I take time to discuss and at the end some group members get involved in the discussions to correct the mistakes”

“If I am not clear with the subject being discussed, I start or formulate a discussing (sic) or debate about it”

These sampled views of the students indicate that while simple discussions take place outside the classrooms, meaningful classroom discussions, as I define them earlier, are generally marginalized in this engineering undergraduate classroom. There appears to be little effort to add something new or gain in new perspectives in the discussions and debates that students refer to. There appears to be a strong tendency to limit discussions and debates to understanding known, existing knowledge (“...correct mistakes,.. not clear with the subject...”).

In responding to the question of whether they have ever been trained on TRIZ or any creative problem-solving techniques, the students unanimously indicated that they have never been trained on any creative problem-solving techniques including TRIZ. Linked to the questions on getting opportunities to think creatively, engage in meaningful classroom discussions and training on creativity was the issue of self-efficacy which refers, in the context of this study, to students’ self-belief that they are capable of contributing new, improved or alternative engineering processes or techniques. 22 of 24 respondents indicated that they are sufficiently confident that they can make such a contribution to engineering processes or procedures given a chance representing 92% of the total respondents.

The students were also expected to elaborate on their responses and the following sampled students' views show that students have the self-belief that they can successfully contribute to engineering knowledge base given opportunities in the classroom:

"By designing something that is not existing and by adding more information in other design"

"I would like to be one of the people who changes the way electrical power is generated"

"When I am given all the equipments and good assistance"

"I am a kind of a person who like to do research about new information that I've never seen before"

"Because I also have the thing or ideas that are (sic) wanted to be researcher and invent in this field of engineering"

These sampled views of students indicate a discrepancy between the actual teaching practice at final-year undergraduate level in this engineering classroom and the aspirations of students in terms of how they think they should be positioned on disciplinary knowledge which also indicates their readiness to assume agentic and discretionary power in their own learning.

In an attempt to further make sense of this engineering undergraduate classroom, I focused on the general organization of the final-year engineering undergraduate curriculum in terms of what it sought to achieve and how such outcomes would be achieved. Based on the interviews I conducted with both the teachers that participated in the pilot and main study and the analysis of the final-year Process Instrumentation Learning Guide, teachers' interviews and Learning Guide planned outcomes and goals reveal that students are positioned on the knowledge of one or more industrial processes as well as science and mathematics knowledge.

I focused my next question on why science and mathematics were given such prominence in engineering undergraduate curriculum; one teacher responded that *“in order for students to develop analytical and interpretation skills”*.

When I asked why it was necessary for students to develop such skills when the classroom activities and actions rarely, if ever, give students opportunities to apply these analytical and interpretation skills since the focus is on acquisition of knowledge of industrial processes and being acculturated into them, another discrepancy emerged.

There appeared to be a lack of awareness on the part of the teachers on the relationship between teaching science and mathematics in Power Engineering and Process Instrumentation Engineering and the role of science and mathematics in developing future engineers in these fields of practice.

There is also lack of appreciation of the importance of developing students' generic skills such as creativity, critical thinking, communication and teamwork as captured succinctly by one of the twenty-four students that participated in the study:

“We usually despise learning communication skills 1 because we gate (sic) no credit for it”

The analysis of the final-year Process Instrumentation Learning Guide indicates that the expected outcome of learning is that students *“ought to improve your ability to understand the learning content and formulate your own assignments and examination answers”* (Process Instrumentation Learning Guide 2009: iv). The overall goal of the Learning Guide is captured as:

“On completion of this module you should be knowledgeable in the operation of pressure, flow, level and temperature measuring instruments and competent in the implementation, calibration and maintenance of industrial instruments in an industrial control environment” (Process Instrumentation Learning Guide, 2009: iv).

It is also stated in the Learning Guide that students should consistently receive excellent results in science and mathematics to enhance their chances of proceeding to the next stage of learning (Bachelor of Technology).

The focus of my investigation refocused on the Teacher and I elicited his views on why engineering industrial processes knowledge as well as science and mathematics knowledge were emphasized and the development of students' generic skills such as creativity were so underemphasized, the Teacher responded that a particular engineering teacher has been appointed to investigate the possibility of expanding the development of students' generic skills beyond the current focus on communication.

However, I considered it necessary to broaden my understanding of the general organization of the engineering undergraduate curriculum in this sector of higher education in South Africa and how such organization shaped and guided certain pedagogic practices. The study conducted by McKenna and Sutherland (2006), which formed the basis of undertaking this study and is the only study ever conducted post-2004 when UoTs adopted OBE on creativity in this sector, provided more evidence on the general organization of the undergraduate curriculum from the perspective of both the teachers and students. The McKenna and Sutherland (2006) study interviewed both students and teachers on the value and role of creativity in the future effectiveness of students in the workplace.

The following quotations cited from this study from both the students and teachers (lecturers) paint a bleak picture of creative thinking in Universities of Technology in South Africa:

Student 1: *"...the UoT students have an understanding that is straightforward for the work"* (McKenna and Sutherland, 2006: 17)

Student 2: *"University graduates have become over-educated, um, they're taught to think a little too much, to think above your average Joe, they're taught to think way above the average Joe. They cause problems in society"* (McKenna and Sutherland, 2006: 17)

Lecturer 1: *“Our students are learning technical things like how to do a job, which buttons to press, how to fix something. They don’t (need to) do critical awareness and reflect on a process and write about it”.* (McKenna and Sutherland, 2006: 18).

Lecturer 2: *“Our job is to teach them to do the job, not to analyze the job. If they can even get a job with our unemployment they must be able to run with it. To do what is expected of them”.* (McKenna and Sutherland, 2006: 20)

This study, one of the only studies in South Africa to have been conducted at Universities of Technology on the status of the development of generic skills such as creativity, provides evidence of an education sector that is held captive by the training discourse of the industrial age. The emphasis of the curriculum mission of this education sector is on the:

“naïve transfer of technical or industry-based practices to students without the concomitant development of critical problem-solving abilities...UoTs exposes (sic) the emphasis that some lecturers place on skills training at the expense of critical and creative problem-solving...then UoTs may find it difficult to argue for space in the curriculum to develop higher order critical practices” (McKenna and Sutherland, 2006: 16)

Both the data collected in this study and the evidence from McKenna and Sutherland (2006) study reveal the curricular context that is generally trapped in the skills training discourse which, over time, has succeeded in marginalizing the development of high order abilities such as creativity as the focus has been on replication of industrial processes rather on extensionalism as defined in this study.

Investigating Students’ Development of Creativity

This section attempts to respond adequately to sub-question 2.2 and question 3 of the study. Sub-question 2.2 relates to students and teachers understandings of creativity pre-learnshops.

Question 3 investigates whether a reconceptualized and tested pedagogy has succeeded in developing students' creativity as well as in shaping students' meanings and relevance of creativity in improving classroom practice and their future effectiveness in the workplace.

Students' Understandings of Creativity Pre-Learnshops

The preceding sections focused largely on understanding a pedagogic practice within the framework of an institutional culture (entrenched ways of doing) as it relates to curriculum design and planning and how that expands or limits the teacher's potential to commit to students in the classroom. These sections further paid attention to current pedagogic conditions in one context of higher education and how it expanded or limited students' agentic and discretionary power in the classroom as well as the relationship between the teacher and the students. In this section, the focus shifts to attempting to understand students' meanings of creativity within a higher education context and how these students relate creativity to their future effectiveness and classroom improvement as ways of raising awareness about the topic that will be covered in the learnshops. In chapter 2, I refer to the extensive attempt that has been made, over many years, by creativity scholars and researchers to pin down the meaning of creativity which is as fluid and dynamic today as when those attempts were initiated by Francis Galton in the 19th Century.

The work of current scholars and researchers on creativity still testifies to the elusiveness of the meaning of creativity and how it remains difficult to make sense of and explain it (Jackson and Shaw, 2006; Jackson and Sinclair, 2010). I report on students' understandings of creativity prior to students' exposure to the learning environments that were designed and tested in the learnshops because the key issue, at this stage, is to find out how students perceive creativity in their own terms. I have indicated in the earlier sections, drawing from Bowden and Marton (1998), that teaching is but one of many ways students learn so that even within learning environments that restrict creativity, students are more likely to have accessed or have conceptualized their own understandings of creativity through other means that do not necessarily exclude their own learning environments.

Students' understandings of creativity are revisited after the learnshops to find out if there have been any meaning variations in their conceptions of creativity which may be attributed to the learnshops. The students' responses in the open-ended interview schedules pre- and post-learnshops have been categorized according to the four categories of the meanings of creativity I developed in chapter 5. There are even certain uncategorized responses which are presented as separate categories.

Category 1: Creativity and Imagination

My analysis of students' meanings of creativity focused first, on whether students are able to link creativity with generation of new ideas, thinking outside the box and seeing the world differently which is the meaning of imagination developed in chapter 5.

Four of the twenty-four students related creativity with imagination representing almost 17% of the total respondents:

"The ability to be able to think outside the box"

"ability to come up with new ideas"

"Coming with new ideas that other people haven't thought of"

"Imagining things"

Category 2: Creativity and Originality

Students' understandings of creativity were also analyzed in terms of the association students make between creativity and the quality of newness or the production of new things that other people have not done before; what Boden (1990) calls the H-creativity as described in chapters 2 and 5.

Ten of the twenty-four respondents made the link between creativity and originality which constitutes almost 42% of the total respondents. Of particular interest in this meaning of creativity is the fact that these engineering undergraduates draw strong links between creativity and new inventions. Such meanings of creativity that students link to creativity are shown by the following sampled statements:

“Design engineering equipment”

“Create or design anything”

“Make/design something practice” (sic)

“Make interesting things with little you have”

“Create and develop something that can impact the world”

Category 3: Creativity and Resourcefulness

The analysis of students' responses also shows a link between creativity and the search and use of knowledge to solve non-routine, unusual problems, improving existing technologies, sense opportunities or discern useful ideas as described in chapter 5.

Six of twenty-four respondents link creativity with resourcefulness, constituting 25% of the total respondents. Key to the association of creativity with resourcefulness is the fact that some undergraduates have a clear recognition that immense resources of time, capital and materials may be required to actualize a creative idea that can lead to some innovative products or service, and hence to some improvement on developing human conveniences. Statements on the creativity-resourcefulness nexus include:

“Being inventive and overcome many challenges”

“The ability to come up with new ideas, thoughts and suggestions...to do something or solve a problem on the environment/the place we live within”

“Something that is added to the original product, something that do extra to the original product”

“Make new things to solve a problem”

Uncategorized (new categories): Creativity and Personal Development

Prior to exposure to the learnshops; two students, 8% of the total respondents, made an association between creativity and personal development making statements such as:

“Able to start something”

“Start a new caree (sic) challenges”

The responses of two students on creativity veered towards a description of intelligence which is a highly convergent approach to thinking and the other response represented the current thinking in UoTs on conventional problem-solving. Both intelligence and conventional problem-solving are problematized in this study. The statements of the respondents follow below:

“Think fast, respond and take your thoughts to action”

“The information you have grabbed through education and using it to make sense in you (sic) project or practical work”

Students’ understandings of creativity, prior to exposure to the learnshops, show a marked inclination toward originality (42%), resourcefulness (25%) and imagination (17%) and will be compared with students’ meanings of creativity post-learnshops to seek variations in understandings of creativity with the view that learnshops may have been responsible for or contributed to such students’ meaning variations of creativity.

Teachers’ Meanings of Creativity

The two teachers who took part in the main and the pilot phase expressed meanings of creativity which are closely related to inventive problem-solving, which indicates that teachers’ value the kind of creativity that helps people to solve problems that are characterized by ill-defined goals, insufficient knowledge and time pressures. At the heart of the teachers’ understandings of creativity is the idea of usefulness which is at the core of engineering and forms one of the necessary conditions for an engineering activity to take place (Wankat and Oreovicz, 2007). This shows a clear understanding on the part of the teachers of the significance of creativity in engineering:

T1 (Pilot Phase): *“To introduce the new skills, idea and to improve what is already existing”*

T2 (Main Study): *“It’s the useful ideas that an individual or a group develop for themselves in order to solve problems. The ability to use your brain to produce useful things or information to make things simple or convenient”*

Improving existing technologies is the focus of TRIZ and this study in particular and defining engineering creativity in terms of developing and making things simple and convenient is in line with my definition of engineering as the use of science and natural resources to develop human conveniences.

Invitationally Reconceptualized and Tested Pedagogy for Developing Students’ Creativity

In chapter 5, I described the learning environments that I designed with the purpose of encouraging students’ creativity development. These designed learning environments were based on an invitational pedagogy that was conceptualized in order to reorganize the roles of the teacher and the students in the learnshops as a way of testing whether this role redefinition would not lead to different students’ experiences of learning as understood in terms of the number of ideas they would generate, the variety of those ideas and the novelty of such ideas. I argued, in chapter 2 where invitational pedagogy was developed, that dialogues that are based on persuasion even in the context of education presuppose certain roles between the rhetor and the audience ranging from conquest, conversion and advice forms of persuasion.

At the extreme end of persuasion is conquest persuasion with a clear active role for the rhetor who seeks to change the audience views and win them over to the rhetor’s point of view so that the audience’s role is mostly passive. There is an explicit expectation from the rhetor of the audience’s absolute submission to the dictates of the rhetor’s ideas (Foss, 1993). While conversion and advice forms of persuasion still seek to change the audience and win them over to the rhetor’s ideas, the expectation of audience submission to the rhetor’s position is benign.

The audience, under conversion and advice forms of persuasion, is allowed to participate in the dialogue with varying degrees of active participation with advice forms of persuasion providing more opportunities for active engagement in the dialogue. However, in all these forms of persuasion the rhetor's role remains dominant so that there is little role redefinition in these types of human interaction. Teaching is often associated with advice forms of persuasion although a case can be made that it veers closer to conversion persuasion in terms of how it positions students on committed ways of disciplinary knowing. The critical and most important aspect of human interactions organized around persuasion is that such persuasions proceed on linearity. Linearity in education refers to the positioning of students on disciplinary knowledge as deficient human beings seeking this knowledge and that defines students' roles in the classroom in very specific ways. The role of students, in pedagogies based on linear models of teaching, is based on the assumption that students react to learning environments as shaped and guided by these deficit-driven pedagogies. Such pedagogies ignore the fact that students react to the learning environment as it is experienced by them (Bowden and Marton, 1998).

Invitational pedagogy reconceptualized learning environments in such a way as to accommodate differences in how students approach learning, paying attention to the supposition that students approaches to learning are, in essence, dependent on what the students are focusing on, what they are trying to accomplish and how they go about doing it. For instance, in cases where students ignore the focusing on higher levels of cognitive engagement with curricular topics or text, it is because they may have concluded that it may not necessarily be tested or valued. In setting up learnshops, this lesson was foremost in my mind. It is a lesson that made me consider the linear model as unacceptable in the science of human experience and action. I considered the linear model in pedagogies, as aspects of the science of human experience and action, unacceptable because such a model undermines three mutually inclusive principles that indicate that the classroom milieu is the location of interdependence rather than linearity and individualism which affect the positioning of students on disciplinary knowledge in very important ways especially as it relates to students' agentic and discretionary power in their own learning.

The first principle postulates that experiential processes are seldom mechanisms which function in isolation (Jordaan and Jordaan, 1989). Experiential processes are always interdependent and thus it is impossible to understand one process without also understanding the other processes that together form an experiential Gestalt. In positioning students on existing disciplinary knowledge (quadrant 1) as deficient (unknowing beings in relation to disciplinary knowledge) who need to be placed at the knowing level, linear pedagogies foregrounds one aspect of the classroom experience (teaching) at the expense of another equally legitimate aspect of the classroom experience (learning). Research into teaching and learning has also suffered from this artificial binary between teaching and learning.

The second principle posits that experiential processes and actions are interdependent because experiential processes are mostly regarded as key aspects of actions (Jordaan and Jordaan, 1989). In the classroom situation, for instance, it is impossible to have a perceptual experience without the actions of listening and seeing (actions of sensory level).

The third principle postulates that people in interaction with one another and with the physical and symbolic world create corresponding inner worlds (intra-psychic inner worlds) which are intersubjectively meaningful. In this sense, peoples perceptual, dispositional, emotive and self-experiences and, their actions can be understood in the context of situations in which meanings are intersubjectively shared (Jordaan and Jordaan, 1989). Interactions between people in their physical and symbolic world within learning institutions as organized around pedagogies as aspects of the science of human experience and action, should be understood as entities that are actively and mutually influencing; what is done by one member has an effect on all other members individually and collectively. This is the experiential gestalt that I sought to encourage in the learnshops between the researcher, teacher, students and within students' teams.

Experiential Gestalt is about teamwork in the classroom where double-voiced dialogue is the essence of pedagogic practice, transition is from absolutized notions of knowledge to areas that still recognize existing disciplinary knowledge but also bring recognition that there are zones of legitimate uncertainty and diversity of opinion and knowledge sites are not restricted to formal learning institutions. Students' reactions to these learning environments were observed carefully in relation to how shared understandings were developed among team members, how the introduction of a new member affected the shared understandings (intersubjective meanings students have developed in a team). It is important to recall that these learning environments trained and attempted to initiate students into a particular creative problem-solving practice (chapter 4 describes this practice in more detail) which guided team members decisions and actions. It is equally relevant to remember that students' teams were exposed to three case studies as described in chapter 5.

The case studies were carefully developed to include the understanding of the science behind the technologies that students were to seek their higher designs, contextualized to their immediate environment without succumbing to the dictates of assuming that these technologies are uniquely complex, self-contained entities within the institution but has to be understood as part of the bigger technologies of developing human conveniences yet technologies that are experiencing problems in the 21st Century. Three teams consisting of six members each were established. Students were given the opportunity to join the team of their choice as each team was also given choice in terms of which technology in the case studies they wished to tackle. The general organization and leadership issues of teams were left to the teams to sort out. It is important to note that teams were made aware of the availability of resources such as access to the internet, transport and other materials including those of a technical nature.

In chapter 5, I describe the case studies and the task students were supposed to undertake in relation to the framework of the TRIZ-based Creativity model. In terms of the model, the first task that the team was expected to tackle concerned whether the technology they have chosen from the case studies was operating at an optimal level within the institution.

In terms of the TRIZ method this question is rhetorical because it has to be recalled that TRIZ is based on the philosophy of idealism which suggests continuous search for the near-perfect status of the technologies whatever those technologies are. Each of the three teams was able to reasonably work within the framework of this TRIZ axiom and thus launched themselves into the second stage of the creativity model which was to determine the causes of the imperfections in the technology.

Team A: Energy Technology

The team focused on the use of coal and water to produce electricity but later paid attention to the efforts of the Eskom Utility Company which was, at the time, involved in the project of replacing light bulbs in the country with energy-efficient ones.

This team worked within the framework of this project and arranged a trip to Eskom Lethabo which is located about 30 km South-East of the institution to work out its role in the project. Members of the team were distributed by Eskom Lethabo among two sub-projects that involved installing energy-efficient bulbs in one section of the neighbouring township and at the institution. There was a clear discrepancy between the initial task of the team which involved investigating how electrical energy is produced which led them to finding out about the existing energy mix within the company which was more than 90% coal according to the team's investigation and that efforts towards renewable energy were slow. The team's efforts, however, shifted to the project of installing energy-efficient bulbs after its visit to Eskom Lethabo. In reporting its findings from the Eskom Lethabo, the team indicated that interviews with some Eskom Lethabo personnel indicated some serious challenges on shifting the energy mix to renewable energy and rather the focus of Eskom Lethabo was to turn South Africa into an energy efficient country hence the energy-efficient bulbs project.

On our report-back sessions, this team was questioned on their initial tasks which they presented as focusing on energy mix and renewable energy as sources of alternative energy and the science behind any of the identified alternative energy sources.

The team was also probed on their role on the project of installing energy-efficient bulbs and the estimations they made on the amount of energy that was likely to be saved from this initiative and how that translates into saving coal and reducing emissions of harmful gases as it appears in their initial tasks which they presented to the whole class.

The team reported that, based on their interviews with Eskom personnel, it would take Eskom many years before it could really make a dent on energy mix away from coal and the team was advised to focus on the pragmatic projects Eskom has put in place in order to mitigate the challenges of Greenhouse Gas (GHG) Emissions. The team was unable to quantify energy savings that could accrue out of the Eskom project of installing energy-efficient bulbs and consequently could not make estimations on coal savings that may have accrued over a given time and thus on reductions of GHG emissions.

When probed on the science behind any of the renewable energy sources the team presented during the initial stages of its tasks, the team focused on solar technologies and indicated that the technology is based on the process of photosynthesis which allowed the green plants with chlorophyll to convert radiant (solar) energy from the sun into chemical energy.

The team also provided statistics on the amount of solar energy that was being absorbed by the earth's atmosphere, oceans and land masses which was, according to the team, estimated at 3, 850, 000 exajoules (EJ) per year, so that according to the team, in 2002, there was more energy in one hour than the world used in a year. The team concluded that this statistics shows that the amount of solar energy that reaches the surface of the planet was so vast that what was received in one year could be as much as the world would ever obtain from all of the earth's non-renewable resources such as coal, oil, natural gas and mined uranium combined. The team also provided information on the application of the solar technology.

According to the team, there are two forms of solar technology, one being active solar technology and the other passive solar technology. According to the team, the active

solar techniques use photovoltaic panels, pumps and fans to convert sunlight into useful outputs. The team indicates that passive solar techniques include selecting materials with favourable thermal properties, designing spaces that naturally circulate air and referencing the position of a building to the sun. The team ended by providing more technical information on photovoltaic cells.

Team B: Water Technology

This team focused its efforts on students' residences and the water usage at these residences. The issues the team raised as the initial foci of its tasks were on the lifespan of the water pipes that pumped water from Rand Water Board, the main supplier of water in the Gauteng Province, to the students' residences. Central to the team's presentation was the history of the institution especially as it relates to the number of students that were originally accommodated at the residences which the team indicated was sixty and the present situation where the students population has, according to the team, increased from 189 to about 15 000. The team considered the increased number of students in the residences as relevant to the extent that it relates to water usage as it impacts the pressure that would be experienced in the pipelines, the type of people that use the water as a reflection of consumer behavioural patterns and the current need as compared to the water needs when the institutions opened its doors for learning in 1966.

Another issue the team dealt with was the challenge facing Rand Water Board as the only water supplying company in the world, according to the team, that provided water to an industrialized region that is not situated on a major river and which has to pump water to this industrialized region from a dam situated almost 70km from the region at an altitude of above 375m. The team also focused on the material that was used by Rand Water Board to line the inside of the pipes that were transporting water to the consumers.

The team probed this issue on its visit to Rand Water Board offices (about 15km from the institution) and found that the company used bitumen to line the pipes which the team found problematic. The team found bitumen problematic because apparently,

according to the team, bitumen scaling off in the pipes affects the quality of water and has cost implications and, according to the team, insufficiently protected pipelines affected the flow performance of water from the company to the consumers. The team's hypothesis was that properly protecting the water supply pipes and investing in the technology that could result in such a protection to the pipes would increase the lifespan of the pipelines. The team also found out from Rand Water Board that it had never re-installed new or initiated any efforts designed to improve or replace the bitumen used in lining the pipes that pump water to the students' residences.

The team further focused on ways of reducing water within the students' residences and encouraging the development of water-saving initiatives. The team then focused on municipality water bills as they relate to water consumption in the students' residences. The team undertook to measure the sizes of the taps with a view of finding ways of installing water-saving taps as the team considered the institutional taps as generally old and water wasting. The team made some recommendations in terms of how water wastage could be reduced which include limiting water taps in the toilets, reducing width of taps and increasing pressure in the taps and the use of what the team calls 'grey water' from students' residences and laboratories for watering plants within the institution. The team also suggested the invention of water recycling technology within the institution.

However, the greatest discovery of the team was on the water bill where the team found an anomaly. The anomaly was seen due to the fact that the team selected two different periods during which water was being used at the students' residences. The first period was when students occupy residences during times when the academic calendar is in full swing and the second period was during off-peak periods when most students have gone home during academic recesses.

The team found that during periods when the students are occupying the residences, the water bill is less than during off-peak periods when students are mostly not occupying the residences which is a period when the water bill increases dramatically.

This anomaly challenged the team to refocus its discussion on water pipes and their lifespan. The team suggested that during peak periods in the residences, the water-supplying pipes from Rand Water Board are under less pressure as students constantly use water while during off-peak periods, the Rand water Board main pipes are under tremendous pressure because there is less demand at the residences. The team suggested that, because the main water pipes from Rand Water Board were installed about 42 years ago and bitumen is used for lining them then the pipes may be experiencing extreme pressures that were causing the water leaks which were exacerbated during the off-peak periods in the students' residences when water usage was low. This led this team and the teacher to focus their energies on water leakage detection which fell outside the period of the study; however, the team was able to provide a rough sketch of leak detection for a possible commercial use.

Team C: Paper Technologies

This team focused on identifying what the team called “paper wasting hotspots” within the institution – the library, administration block, SRC offices and lecturers. With regard to the library, the team paid attention to the photocopying machines, newspaper archives and general administration paper work, the SRC offices were targeted in terms of its paper-based “communiqués” and general administration work and, the lecturers were focused on because of the learning guides that were often given to students each semester especially in relation to surpluses that remain in their offices. The team made recommendations in terms of saving paper on campus. With regard to the photocopiers, the team suggested that a comprehensive instructional manual be placed next to the copiers to ensure proper use, educating of library users and the use of recycling bins.

The team suggested that the administration of the registration could be better organized to reduce paper use such as on-line applications which necessitated a visit by the team to the institutional IT department (interview with the IT Director) to make inquiries about online applications and registrations. The findings of which indicate that the IT department was already mooting such an approach to registration.

The team also visited Mondi Paper-Producing plant in Benoni about 60km East of Johannesburg and about the same distance from the institution to make inquiries on the production of paper. The team found out that a special tree called Eucalyptus is used to produce paper. The team also focused on the role of the tree on the environment in terms of its photosynthesis processes. According to the team, when boards are produced the tree goes through a process of debugging where all the bugs (insects) are removed from the tree because these bugs are dry and very hard to be of effective use in the machines. The next stage in the production, according to the team, is called chopping where the debugged tree is chopped then the popping process follows which involves the crushing of chopped trees which result in trees turning into a liquid form. The liquid then, the team indicated, undergoes the cleaning process where the undesirables such as dust and soil particles are removed.

The team indicated that the cleaned liquid goes through the process of digestion to remove all the chemicals present in the liquid. The idea of removing unwanted chemicals such as chloride, glue, is to avoid chemical reactions during paper or board production. The cleaned liquid, the team reported, underwent the process of bleaching which turns the brown colour of the liquid into a white colour. The team also indicated that it observed all the stages of using the different types of electrical machines such as induction motors to move the tree in its various forms from one process to another which included the process of drying up the liquid. The team also reported on paper loss within the company which the company estimated at 8%, the company's research on cost-effectiveness of production and safety issues.

Another point to make is that our own observation (that of the researcher and the Teacher) shows that the teams were too focused on the problem at hand that their decision-making processes tended to be mediated through the tasks intended to solve the problem. We also observed that the size of the team had little effect on the decision-making processes. Member swapping also had little effect on teams' decisions.

TTCT Results

As explained in chapter 5, Torrance's Tests of Creative Thinking (TTCT) were used pre- and post-learnshops as measures of determining whether the creativity of students that participated in the learning environments that were organized in the learnshops increased as a result of exposure to these learning environments. The pre- and post-learnshops TTCT scores were subjected to a t-test in order to establish statistical significance between these TTCT metric variables (fluency, flexibility and originality) that were collected pre- and post-intervention (Appendix B). The t-test was selected to determine statistical significance because in cases where inferential analysis has to be made in smaller samples (N=24), the t-test is a preferred option because small sample sizes do not always reflect a normal distribution rather provide a distribution curve which is flatter and known as t-distribution (Opie, 2004; Blaikie, 2003).

A t-test is defined as "*a statistic to measure the difference between the means of one sample on two separate occasions*" (Cohen, Manion and Morrison, 2000: 81). It is appropriate as a test in this study where one sample of final-year engineering undergraduates was tested on TTCT prior to and after exposure to the learnshops. The metric variables of each dimension of the TTCT were scored and then compared statistically to determine significance through the t-test. The results of the t-test are given in Table 7.1 below and indicate that students' fluency, flexibility and originality improved since the means of each creativity dimension show a marked increase post-learnshops and the p-values show statistical significance. That the standard deviations increased from pre- to post-test is a result of two of the students making no progress at all while several students made considerable progress.

Table 7.1: Mean, Standard Deviation, T-Test and P-value Results of TTCT Scores

	Pre-test		Post-test		t-test	p-value
	Mean	Standard deviation	Mean	Standard Deviation		
Fluency	47,83	8,65	58,25	20,32	-2,614	0,016
Flexibility	36,33	9,49	45,46	14,59	-3,291	0,003
Originality	24,08	7,57	33,71	12,18	-3,975	0,001

Students' Understandings of Creativity Post-Learnshops and Comparisons

When this study was designed there was an assumption that students' meanings of creativity may have been influenced by the undergraduate learning environments that have generally been marginalizing creativity although there was a recognition that teaching as it shapes and guides undergraduate classrooms is not the only means students come to learn about a concept. Given that students have now been exposed to learning environments that attempted to develop their creativity, I thought it useful not only to elicit their understandings of creativity post-learnshops but also try to compare them with those of the pre-learnshops. The purpose was to find out shifts in meaning variations on students' conceptions of creativity.

It was assumed that these meaning variations in the understandings of creativity by students may be attributed to their exposure to the learnshops.

Category 1: Creativity and Imagination

As compared to students' meanings of creativity prior to the learnshops, there was a marked increase in the number of students that made the association between creativity and imagination with nine of twenty-four students making such a link. Thus the number of respondents that associate creativity with imagination increased from 17% to 37, 5% of the total respondents after the learnshops.

Category 2: Creativity and Originality

There was a marked decrease on the association students makes between creativity and originality. Three students make such a link representing 12,5% of the total respondents down from almost 42% as compared to prior the learnshops.

Category 3: Creativity and Resourcefulness

The association students make between creativity and resourcefulness increased modestly after the learnshops as compared to prior the learnshops. The number of respondents that made the link between creativity and resourcefulness increased from 25% to 33,3% which represents about one-third of the total number of respondents.

Uncategorized: Creativity and Personal Development

There was no difference on the association students make between creativity and personal development after the learnshops.

Summary of the Categorizations of Students' Understandings of Creativity

The post-learnshops students' understandings of creativity show a shift in students' distributional percentages in the categories I developed in chapter 5 and also provide one unique category to understanding students' conceptions of creativity. Table 9 shows these variations in the students' responses on the meaning of creativity:

Table 7.2.: Students' Responses Distributional Patterns (Pre- and Post-test)

	Students' Pre-test Responses	Students' Post-test Responses
Imagination	4	9
Originality	10	3
Resourcefulness	6	8
New category (from data: Personal development	2	2
uncategorized	2	0

Students' Views on the Potential of Creativity to Improve Classroom Practice and Cognate Classroom Activities

As part of attempting to understand whether students could positively link creativity with improvement to classroom practice – thus indicating its signification as compared to the study that was conducted by McKenna and Sutherland (2006) which showed that students within UoTs in South Africa did not consider creativity relevant in their classrooms and future effectiveness – I elicited students' views through interviews. Five of twenty-four students associated the development of creativity in the classroom with possible individual benefits with statements such as:

“Chance to be able to develop new staff (sic)”

“In order to know how to develop new ideas”

Five other students of the total twenty-four that participated in the study linked creativity development in the classroom with their economic viability using statements such as:

“This helps to improve or bring complex and vital information on ideas to the industry”

“Give students a chance to come up with useful ideas...proving that they can practically come up with new ideas for industries”

“We must develop cheap and less expensive equipment”

Two students linked creativity development in the classroom with societal benefits with statements such as:

“Creativity can be very useful in all aspects of life and not only in one's professional life”

Four students linked the development of creativity in the classroom with the development of students' positive attitudes using statements such as:

“In order for students to be energetic all the time”

“Developed by inspiration by gaining extensive exposure”

Some students' views on the development of creativity in the classroom were difficult to pin down because each of such responses was idiosyncratically linked to one respondent. For example:

“because most of people they are not aware of their creativity, and once it is developed you can be aware of what I am capable of”

The classroom activities that students believed could develop their creativity include group discussions (seven respondents), problem-solving (two respondents), lab practice (two respondents) and research (three respondents) and the rest of the students did not respond to the question.

Students Beliefs on the Ability of Creativity to Improve Their Future Effectiveness in the Workplace

In relation to the link between the development of creativity in the classroom and undergraduates future effectiveness in the workplace only five students (almost 21%) made such an association.

The rest of the undergraduates did not respond to the question prior to the learnshops but post-*learnshops* there was a substantial increase in the number of responses to the question (17 of 24 respondents or almost 71%). The other important point to highlight is that undergraduates indicated prior to the *learnshops* that they have never been trained in the TRIZ method but post-*learnshops* there has been a growing appreciation of the role of the TRIZ method in assisting them to think creatively around existing technologies in order to search for their ideality. It may well be that the substantial increase in the nexus undergraduates made between creativity and their future effectiveness in the workplace, post-*learnshops*, may have been enhanced by explicit training in TRIZ and gain in experience in the use of TRIZ to generate new ideas.

It is important to note that the students' views that relate creativity with the improvement of classroom practice and students prospects of success in the workplace were solicited because the McKenna and Sutherland (2006) study based on interviewing lecturers and students within UoTs in South Africa found that neither lecturers nor students consider creativity as relevant in improving classroom practice or enhancing students chances of securing employment and becoming effective in the workplace. In this study, most students expressed that creativity can improve classroom practice which, in turn, could enhance students' own personal development, economic and societal viability. Students further expressed that creativity can contribute meaningfully in their future effectiveness in the workplace even though such an expression was formed post-*learnshops*.

Summary

This chapter attempted to provide empirical evidence gathered over a semester in one engineering undergraduate classroom in relation to the existing pedagogic practice in this specific classroom which was also contextualized to the broader context of UoTs in South Africa. The main purpose in finding out about the existing pedagogic practice was to better inform the reconceptualization and testing of an innovative pedagogy. Information was also elicited on the curricular context that shaped and guided the existence of such a pedagogic practice. Information on students and teachers understandings of creativity was presented and data on students' linking of creativity with classroom improvement and their future effectiveness were also given. The TTCT results were provided which show that learnshop had a positive effect on students' creativity.