Chapter 5: Research Design and Methods

Introduction

This chapter describes the research framework that informed the design of the study and the data collection methods that provided data that attempted to respond adequately to the study’s research questions. It further deals with how the data was handled and analyzed as well as ethical and validity issues the study posed and how they were dealt with. The study is conceptualized within the Design-Based Research (DBR) paradigm thus uses a relatively new, interdisciplinary research framework that attempts to create opportunities for educational researchers to, together with classroom practitioners, engage in theoretically informed research in authentic classroom settings. This accentuates the applied nature of educational research (Brown, 1992; Collins, 1992; Barab and Squire, 2004; Hoadley, 2004; Sandoval and Bell, 2004). DBR, as a research paradigm that draws from multiple practices within a variety of disciplines and research methodologies, differs in significant ways from existing approaches to research. First, DBR has one common goal of bringing into being, improving or refining learning theories by means of setting up “rich, theory-driven pedagogic innovations in authentic classroom settings” (Sandoval and Bell, 2004: 199). Second, the express goal of DBR is to impact classroom practice and contribute in advancing a learning theory that is sufficiently credible to warrant use by others.

Within this DBR framework; learning conditions that are enabled by invitational pedagogy were created in order to encourage the development of students’ creative abilities as measured in terms of the number of ideas students’ generated (fluency), the variety of those ideas (flexibility) and their novelty (originality). The Torrance’s Tests of Creative Thinking were used to measure students’ creativity. Invitational pedagogy is described in detail in Chapter 2 and the study involves students attending ten learnshops in which they use the TRIZ-based Creativity Model I developed in order to problematize, critique and attempt to achieve the higher designs of energy, paper and water technologies.
The students attempted to reveal the ideality of these technologies within their institution as part of a wider concern about environmental sustainability and issues related to climate change.

**Design-Based Research (DBR) as Study’s Framework for Design**

DBR, as a mode of inquiry, draws on multiple theoretical perspectives and research paradigms with the express purpose of building and establishing understandings of the nature and conditions of learning. In the case of this study, these understandings around the nature and conditions of learning relate to finding appropriate learning conditions that can result in the development of undergraduates’ creative abilities. DBR, as indicated in chapter 1, is intended to develop evidence-based claims from naturalistic investigations that can result in knowledge about how people generally learn (Barab and Squire, 2004). DBR work thus involves the development of learning conditions with a view to achieving clearly stated outcomes which, in the case of this study, entail improved undergraduates’ creative abilities and advancing a learning theory that can be used in engineering education to understand and support learning conditions that can lead to the development of creativity within the undergraduate curriculum. The fundamental essence of DBR is that knowing and context are “*irreducibly co-constituted and cannot be treated as isolated entities or processes*” (Barab and Squire, 2004: 2). In this sense, context matters in terms of learning and knowing so that as Brown (1992: 143) suggests:

> “Research paradigms that simply examine these processes as isolated variables within laboratory or other impoverished contexts of participation will necessarily lead to an incomplete understanding of their relevance in more naturalistic settings”

In other words, simply engaging in observing learning and knowing as they naturally occur in the world is inadequate as learning scientists almost always have transformative agendas in mind when conducting research as confirmed by Barab and Squire (2004: 3) when they write:
“Education is an applied field, and learning scientists bring agendas to their work, seeking to produce specific results such as engaging students in the making of science...as such, learning scientists have found that they must develop technological tools; curriculum and especially theories that help them systematically understand and predict how learning occurs”

The focus of DBR is on impacting local practice by means of appreciating the role of social context in shaping and influencing educational practices through designed artifacts and the resultant theory (Barab and Squire, 2004). The term “designed artifacts” refers to tangible products (e.g. professional development software) and programmes that can be developed and adopted elsewhere with clearly stated outcomes (Barab and Squire, 2004). In this study, learnshops were designed in such a manner as to create invitational pedagogic conditions with a view of achieving specific curricular outcomes which included the development of students’ creative abilities and other related social skills. The study thus had an explicit agenda of impacting local pedagogic practices in very specific ways and producing the learnshop as a design artifact.

First, the study intended to challenge the worksite approach to learning where learning is mediated through industrial images of strict timelines, efficiency models that are measured in terms of what Jardine (2008) calls “empty time” and rigid task management. I assumed that such an approach to learning is inimical to creativity development which often requires that students slow down on curricular topics and engage in deeper learning.

Second, the study had a specific goal of challenging replication as the critical pedagogic practice that informs learning in UoTs. Such pedagogical approaches to learning have tended to encourage mimetic learning that can hardly encourage creativity development, which essentially adds something new to existing knowledge and requires dealing with non-routine, non-conventional problems within an open-ended framework. DBR results are often validated through the consequences of their use so that they can provide consequential evidence or validity which can contribute in building learning theories (Messick, 1992).
In the case of this study, consequential evidence suggests that *learnshops* have to demonstrate that the pedagogical conditions that were created to encourage undergraduates’ creativity actually succeeded in doing so or show promise that such learning conditions can improve undergraduates’ creative abilities. Furthermore, *learnshops* have to show that such learning conditions can be recreated in other contexts to produce similar results.

DBR, as the study’s underpinning research paradigm, draws heavily on Dewey’s mode of pragmatism in which the value of a theory lies in its ability to produce changes in the world. Such a mode of inquiry often draws less from traditional positivist science or ethnographic traditions of inquiry and more from pragmatic lines of inquiry where theories are adjudicated not by their claims of truth but by their ability to do work in the world (Dewey, 1938). DBR is, in a sense, grounded not in claims of truth but instead in the viability of theories to explain phenomena and produce change in the world so that to DBR “*knowledge claims arise out of actions, situations and consequences rather than antecedent conditions*” (Creswell, 2003: 11). DBR is concerned with application – what works – and solutions to problems so that instead of methods being important, the problem is most important and researchers use multiple methodological approaches to understand and resolve the problem (Barab and Squire, 2004). The key aspects of DBR, it can reasonably be deduced from literature, include the recognition that each situation is unique, often entails degrees of vagueness and “*some intrinsic troublesomeness which disputes that nature has some ordered character that leads to natural laws*” (Creswell, 2003: 11). DBR, as a relatively new paradigm that is underpinned by pragmatism, has to ensure that it makes credible assertions that can be trusted. The sections that follow in this chapter take this matter further.
DBR Methodological Challenges

DBR has been confused with mixed methods approaches. This general confusion is not without merit as DBR shares the pragmatism and transformative stance with this mode of inquiry. DBR has also been criticized for immaturity and loosely organized set of methods (Kelly, 2004). At the heart of this section is the question of whether I could have used more established modes of inquiry such as the mixed methods approaches or the traditional methodologies (quantitative/qualitative) instead of DBR and thus why DBR?

DBR scholars posit seven major differences between traditional research methodologies and DBR methodologies (Table 5.1.). The aspect of DBR paradigm that is relevant to this study relates to where the study is conducted which, in the case of this study, is “in the real-life settings” (Brown, 1992: 144) of one engineering undergraduate classroom at one University of Technology within normal pedagogical arrangements that are informed mainly by mimesis and curricular settings that are framed within the replication of industrial processes and conventional problem-solving discourses (McKenna and Sutherland, 2006).

The study, through learnshops, created alternative pedagogical conditions that attempted to develop undergraduates’ creative problem-solving abilities and, at the same time, raise consciousness around the need for environmental sustainability. Students’ learning in learnshops thus went to understanding and attempting to unravel the messiness of real world problems.

Central to learnshops is the use of flexible design revision, multiple dependent variables that comprise the transferability and application of content knowledge that transcends disciplinary boundaries to contribute in the sustainability of the resources such as energy, water and paper as delineated in the case studies that were given to students as well as the capturing of social interaction so that “research participants are not treated as subjects that can be assigned to treatment rather are treated as co-participants in both design and analysis” (Barab and Squire, 2004: 4).
Thus, at the heart of the *learnshops* is the desire to impact local pedagogic and curricular practices in such a manner as to encourage the development of undergraduates’ creative abilities.

Table 5.1.: Comparison of Traditional and DBR Methods (Barab and Squire, 2004: 4)

<table>
<thead>
<tr>
<th>Category</th>
<th>Traditional</th>
<th>Design-Based Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of research</td>
<td>Conducted in laboratory settings</td>
<td>Occurs in the buzzing, blooming confusion of real-life settings where most learning actually occurs</td>
</tr>
<tr>
<td>Complexity of variables</td>
<td>Frequently involves a single or a couple of dependent variables</td>
<td>Involves multiple dependent variables, including learning context variables (e.g. learning of content, transfer) and system variables (e.g. dissemination, sustainability)</td>
</tr>
<tr>
<td>Focus of research</td>
<td>Focuses on identifying a few variables and holding them constant</td>
<td>Focuses on characterizing the situation in all its complexity, much of which is not now a priori</td>
</tr>
<tr>
<td>Untangling procedures</td>
<td>Uses fixed procedures</td>
<td>Involves flexible design revision in which there is a tentative initial set that are revised depending on their success in practice</td>
</tr>
<tr>
<td>Amount of social interaction</td>
<td>Isolates learners to control interaction</td>
<td>Frequently involves complex social interactions with participants sharing ideas, distracting each other, and so on</td>
</tr>
<tr>
<td>Characterizing the findings</td>
<td>Focuses on testing hypothesis</td>
<td>Involves looking at multiple aspects of the design and developing a profile that characterizes the design in practice</td>
</tr>
<tr>
<td>Role of participants</td>
<td>Treats participants as subjects</td>
<td>Involves different participants in the design so as to bring their differing expertise into producing and analyzing the design</td>
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</table>
The other aspect of DBR that is relevant to this study relates to whether these alternative pedagogic practices that are created in the learnshops that sought to encourage creativity development as an explicit curricular outcome can be used by others to achieve similar curricular outcomes. However, the greatest challenge that was faced in this study was the selection of methods of data collection that can be associated with DBR methodologies or even whether DBR can exclusively claim certain data collection methods as its own hence claim a stake as a credible educational research approach that is distinctive from the established ones.

DBR interventions encapsulate theoretical claims about what constitutes teaching and learning as shaped by either implicit or explicit curricular outcomes. In a sense, the design of learning practices and the development of learning theories are closely linked, and as Brown (1982), Collins (1999) and Design-Based Research Collective (2003) suggest that development and research occur through iterative cycles of design, enactment, analysis and redesign. Of particular importance to note in this section is the integrativism of DBR which emanates from:

“*The richness and variety of different theories, research methods and procedures from both qualitative and quantitative research...DBR utilizes mixed methods as a means to analyze an intervention’s outcomes and refine the intervention...the integrative use of multiple methods during the iterative cycles results in multiple sources and kinds of data, which increase the objectivity, validity, credibility and applicability of the findings*” (Wang and Hannafin, 2005: 9).

For this reason, data collection in this study has taken several forms. The researcher, lecturer as the classroom practitioner and undergraduates assumed the role of co-researchers. The researcher designed the educational intervention and invited the lecturer in the collection of data that assisted in the iterative analysis of the intervention’s outcomes that were constantly punctuated with refinement moments as the collected data dictated. The educational intervention, in the form of learnshops, was designed in such a manner as to ensure that students learned in a collaborative, research and problem-solving mode which are the essential ingredients of invitational pedagogy.
The researcher used invitational pedagogy and social reconstructivism as the overarching, collective theoretical lens that informed pedagogic and learning practices in the learnshops in line with what Creswell (2003) refers to as transformative procedures hence data collection and analysis methods were shaped by these theoretical lenses. Invitational pedagogy involves the rebalancing of classroom agency and illuminates collaboration, co-operation, active interaction and flexibility among classroom actors. Social reconstructivism attempts to reconnect learning with social reform initiatives. The data collection procedures are further elucidated in the next sections of this chapter.

Participants and Settings

Two final year undergraduate classes from two strands of engineering – Power Engineering and Process Instrumentation – in one UoT participated in this study. The Power Engineering lecturer and his 54 undergraduate students participated in the pilot phase. The Process Instrumentation lecturer and his twenty-four undergraduate students took part in the actual study.

Gender, race and age of the students were not considered relevant to the questions posed in this study. The classes were chosen because of the interest expressed by their lecturers to participate in the study as self-persuasion is sacrosanct in this study. The main purpose of the lecturers’ involvement was to make them co-researchers so that the research method and alternative classroom practices that are attempted in the learnshops could be transferred for further use and modification in their future classroom endeavours. Both lecturers have an Honours degree in their respective fields, more than ten years of teaching experience and the Process Instrumentation lecturer has five years experience of working in the power generation industry. He continues to be involved in industry work through part-time lecturing in the industry. The other lecturer (Power Engineering) has already attempted to be innovative through his systematic investigation of fuel cells technologies as part of his master’s degree studies.
Both these lecturers have received no formal training in education, curriculum or pedagogy. The lecturers appear to be fully aware of their pedagogic practices and the fact that they are heavily mediated through tests and examinations within the framework of replication of industrial processes. As one of the lecturers suggests:

“We are fond of over-testing. Testing develops a fear of learning, reduces real engagement, confrontation and encountering of the topics and leave students with very little experience, the actual experience is surviving tests and assignments, there is absolutely no deep appreciation of the topic.”

Lecturers also appear to be quite aware that change in curricular and pedagogic practices has become vital and need to go beyond conventional problem-solving. In this sense, the problem of creativity in UoTs, while still chronic, appear to be receiving attention because there is now some awareness that such a problem exists, and that creates opportunities to improve the situation.

**The Study’s Core Investigation**

The study attempts to encourage the development of creativity in engineering undergraduate curriculum through:

- Deconstructing and making visible the key features (micro and macro) of a pedagogic practice to enable possibilities of analysis as well as reconceptualization and testing of the existing pedagogic practice.

- Investigating current engineering undergraduate pedagogic practice from the perspective of both teachers and students and how such a practice enables or limits the development of students’ creativity as well as understand better the ways in which both teachers and students make sense of creativity.
Reconceptualizing and testing a particular pedagogic practice which attempts to develop learning environments where students’ creativity development can potentially thrive.

In order to deal effectively with this core investigation of the study, the transformative mixed methods procedures were employed with a view of collecting sufficient data to validate the investigation. Central to the use of transformative procedures in mixed methods approaches is the notion of the use of a theoretical lens as an overarching perspective “within a design that contains both quantitative and qualitative data” (Creswell, 2003: 16). The theoretical perspective serves as a framework that guides methods of collecting data and deciding on the possible outcomes of the research endeavour (Creswell, 2003).

In order to frame the questions of the interview schedule with pre-set themes as advised by Cohen, Manion and Morrison (2000: 271), I used the research conducted by Jackson and Shaw (2006), Jackson (2008) and Boshier and Huang (2008) as guides. The interview theme based on the Jackson and Shaw study entails eliciting the meaning of creativity. The study by Jackson covers the theme of the potential benefits of creativity while the Boshier and Huang study deals with the pedagogic theme. According to Jackson and Shaw (2006), key issues related to creativity include being imaginative, original, curious/growth-focused, resourceful and spontaneous. These issues form part of the pre-set themes of the interview schedules that attempt to elicit the views of the lecturers and students on the meaning of creativity. The Jackson (2008) study is used to frame questions related to the future effectiveness of students in the workplace and covers themes such as economic, societal and individual benefits. The work of Boshier and Huang (2008) covers themes that relate to classroom practices such as teamwork, research, technology, problem-solving, communication and off-campus learning.

Of particular importance to note is that South African studies on creativity in UoTs are few and do not cover the themes related to the meaning of creativity, relevance of classroom work to future effectiveness of students and appropriate classroom activities for developing students’ creativity that international studies that closely represent our context have been focusing on.
The standardized open-ended interviews were used for data analysis convenience, comparability and reasonable prospects for aggregation (Cohen, Manion and Morrison, 2000). According to Cohen *et al* (2000: 271), standardized open-ended interviews are characterized by “the exact wording and sequence of questions” that are determined in advance and which enable a situation where all interviewees are asked the same basic question in the same order. The fact that all the interviewees respond to the same basic questions increases comparability of responses and such an approach to interviewing tends to reduce interviewer effects and bias and, tends to facilitate organization and analysis of the data (Cohen, *et al*, 2000: 271).

I was fully aware of the limits of using such a method of data collection which contained the strong possibility that respondents’ experiences could be limited to selected themes on creativity, pedagogic reform and future effectiveness in the workplace. The information under these themes was, however, sufficient to have a sense of respondents' both prior and post-learnshops participation views on creativity, pedagogic reform and their future effectiveness in the workplace.

In order to reduce the impact of ‘swallowing up’ students’ meaning of creativity through pre-set themes, I also analyzed their responses qualitatively and looked for alternative themes that could emerge and thus transcend the pre-set themes. I followed up with one focus group interview schedule in order to deal with the language barrier challenges that may have compromised the students’ ability to define creativity more comprehensively.

Focus group interviews, according to Denzin and Lincoln (1994: 365), were coined by Merton, Fiske and Kendall in 1956 to refer to situations where the interviewer asks members of an assembled group specific question(s) about a topic once considerable research has been completed. However, this is not the direction I took in this study. The focus group interview in this study was used to deal with a unique problem that emerged once the interviews data were analyzed and students responses showed that the use of English may have hindered their ability to provide broader meanings of creativity.
Students, who are conversant in Sesotho which is the native language of both the researcher and their lecturer, were requested to participate in one focus group interview in which the meaning of creativity was discussed in Sesotho. I aligned the focus group interview with the meaning of focus group interviews that Kreuger (1988: 8) advances which is that the purpose focus group interviews “is to obtain information of a qualitative nature from a predetermined and limited number of people”.

In order to expose students to guided, systematic creativity as discussed in chapter 3 and 4, I used invitational pedagogy to guide decisions on the design of the educational intervention in the form of learnshops. As applied to this study, invitational pedagogy is used to create learning conditions where students engage in group conversations that attempt to contribute in not only raising awareness around prudent use of dwindling natural resources such as coal-based energy, water and wood-based paper but also in trying to find ways of ensuring that such resources are carefully managed within their institutional context.

It was anticipated that these students’ efforts would transgress traditional disciplinary boundaries and include off-campus learning which involved visiting industrial sites where such resources are manufactured and/or refined. During such visits students would interview, observe and determine whether these industries are seriously involved in the greening discourse which involves significant reduction of Greenhouse Gases (GHG) concentrations, halting of deforestation and over-reliance on water by industrial processes (Suzuki, 2009).

Data-Collection Methods

The first set of data collection entailed qualitative information elicited through standardized open-ended interviews with students before and after the learnshops, which were followed up by one focus group interview which was conducted post-learnshops. The interviews were intended to reveal the embedded meanings of creativity from the point of view of the students.
It is in this sense that the interview questions were pre-set but the interviewees’ responses were left open-ended so that they did not have to choose from pre-set responses as is the case in questionnaires and highly structured interviews (Appendix A1). The open-endedness of interviewees’ responses provided space for respondents to influence the pre-set themes of creativity and possibly bring out uncategorized themes.

It is important to note that the categories of Jackson and Shaw (2006) on creativity meaning are based on conducting interviews with higher education teachers but not with the students so that it was vital to make provision for possible variations in students meanings of creativity vis-à-vis teachers’ views of creativity. The possibility for the emergence of new categories of creativity was there and the type of interview to be used was crucial in making provision for such a possibility. The standardized open-ended interviews made such a provision. Students were also requested to comment on the value of creativity in respect of improving classroom practice and their future effectiveness in the workplace using the same instrument. The idea was to make a link between the development of students’ creativity and the rearrangement of classroom activities to reflect active, collective participation, inductive and creative problem-solving approaches to learning as well as establishing the link between acquisition of creative skills and better prospects of success in the workplace. The McKenna and Sutherland (2006) study showed that both lecturers and students in Universities of Technology did not consider creativity as relevant in improving classroom practice and students prospects of success in the workplace. Teachers’ views on creativity were also elicited through interviews.

The second set of data collection involved observation. When *learnshops* were designed to encourage students to actively participate in guided, systematic creativity in a collaborative form, it became important to make observation of a limited number of issues related to students' collaboration in respect of how it affects their generation of ideas.
Drawing from expert teams research as it applies to engineering as reviewed in chapter 2, I focused on examining the relationship between team formation and the quality of the team’s decision-making and how that affects students’ ideas generation and subsequent resolution of the problem at hand.

Team formation entails team size, task organization and itinerant membership. Team decision-making relates to the development of shared mental models (developing common understandings) that often facilitate tasks allocations and completions or lack thereof, role clarity and, search for solutions, all of which operate within the framework of uncertainty and high levels of vagueness especially in the initial stages of the collaboration. Quality in decision-making refers mainly to the degree to which decisions lead to effective tasks allocation and completion so that quality deals with the degree to which teams’ progress from the problem space to the solution space.

In investigating the relationship between team formation and quality of decision-making, some studied pay attention to team size and team’s development of mental models (Hare and Hare, 2003). Some studies focus on task organization and development of mental models or role clarity (Bonner, Baumann and Dalal, 2002). Other studies investigate itinerant membership and decision-making quality (Ancona and Caldwell, 1992).

This study was particularly interested in observing how a student team of six members facilitated the distribution of tasks within the team with interest in how each team selected those tasks and the matching of a task with a member as well as the degree of coordination of the team’s tasks. It is important to note that at the initial stages of team collaboration there are few reference points and teams have not fully developed shared mental models to guide decisions on tasks allocation and thus tasks identification and distribution proceed on the basis of hopeful conjecture. The lecturer and I (assuming ‘we’ henceforth) developed a focused observational protocol which concentrated more on aspects that were relevant to the research question which were how team decisions on tasks organization affected generation of ideas within a team. The observational protocol is based on interaction and team behaviour and how team interaction in the form of conversations leads to specific kinds of decisions on tasks organization.
How that leads to the illumination and marginalization of certain members of the team when trust, safe conversations and aligned intent become key factors in teams in relation to team’s ideas generation can be observed.

The observation of the relationship between team formation (team size) and team decision-making quality (effective tasks organization) as key in influencing ideas generation in the team is shaped by McGrath’s Task Circumplex Model of Group Tasks, Quadrant 11 (type 2 and 4) as described in Donelson Forsyth, 2006 (Figure 5.1). The McGrath theory (McGrath, 1984) is based on eight basic activities that can be undertaken by groups such as planning, creating, solving problems, making decisions, forming judgement, resolving conflict, competing and performing and they are organized into two dimensions of executing-choosing and generating-negotiating. Our observation focused initially on the interaction of each of the six-member teams in terms of how tasks were chosen and executed so that attention went to the conceptualization of tasks and behaviours associated with such tasks conceptualizations.

Towards the middle of the learnshops, we introduced one itinerant member in each team. It will be recalled that an itinerant member is a member who temporarily shifts positions from one team to another and then later return to the original team. We wanted to find out how that affects a team’s behaviour in terms of trust issues, apodictic safe conversational discussions and generation of ideas.

In a study conducted on itinerant membership it was found that itinerant members were not that influential in contributing towards the team’s generation of useful ideas but played a role in the team’s generation of novel ideas once the itinerant member rejoins the original team (Avnet, 2009; Cannon-Bowers, Salas and Converse, 1993). These studies also show that a carefully planned temporary switching of a member from the original team has some benefits. First, member switching deals effectively with the negative effects of rigid membership which can lead to groupthink and tunnel vision. Second, member switching can deal effectively with positional modeling which refers to gaining information and opportunity to observe and learn about the other team members’ roles and how that shape the sharing of knowledge as described more fully in chapter 2.
The third set of data collection involved quantitative information elicited through measuring students’ creative abilities by means of the standardized Torrance’s Tests of Creative Thinking (TTCT) that were conducted prior and post learnshop participation in order to determine whether students’ generation of ideas (fluency), variety of those ideas (flexibility) and their novelty (originality) improved as a result of exposure to learnshops.

TTCT in its original form (Torrance, 1990) consists of seven activities. Activities 1, 2 and 3 of the TTCT are called ‘Ask and Guess’ and refer to a single picture which students should analyze by way of asking as many questions as possible that are not only based on the picture but also include questions that fall outside the purview of the picture. Furthermore, students are expected to guess as many causes and consequences that are based on what they see and can infer from the picture. Activity 4, called ‘Product Improvement’, is based on a toy monkey and calls for students to think up as many ideas as they can generate and imagine to make the toy monkey more fun to play with.
Activity 5 is called ‘Unusual Uses (Tin Cans)’ and is based on tin cans that people usually throw away. It requests students to think of as many interesting and unusual ways they can use the tin cans as possible. Activity 6 was omitted in the revised TTCT because the validity tests conducted on the TTCT showed that Activity 6 plays no major role in measuring people’s creative thinking (Torrance, 1990). Activity 7, the last activity of the TTCT, is termed ‘Just Suppose’ and gives students an improbable situation which they must assume had happened. Students are supposed to imagine a great fog had fallen over the earth and all they could see of people were their feet. Students are expected to describe what would happen, the implications and consequences of life under such conditions. (Appendix B). The TTCT is conducted over a period of no more than an hour and no less than forty-five minutes.

Research Procedures and Pilot Testing

The study consists of three phases of implementation and data collection which are organized via learnshops (Table 5.2.) which is preceded by pre-study interviews with teachers and a brief analysis of one engineering undergraduate learning guide to set the scene for the study.

Phase 1: Pilot Testing (Learnshop session 1-7)

The Pilot Phase with one lecturer and 54 students was test the viability of using learnshops as both intervention and data collection strategy. The Pilot Testing was also intended to enhance the reliability of the interviews which Silverman (1993) suggests can be achieved by making sure that each respondent understands the question in the same way and by making use of as many standardized questions as possible. The latter may, however, lead to the misreading of infinite complexity and open-endedness of social interaction.
Furthermore, the Pilot Testing was meant to observe how students learn, use and react to the explicit training on creativity through the TRIZ-based Creativity Model. The Pilot Phase, similar to the first phase of the actual implementation and data collection, consisted of seven *learnshops*.

The *learnshops* were conducted within ‘naturalistic settings’, as students continued to attend their actual classroom lessons to ensure as little disturbance of the actual, real classroom atmosphere as possible. I interviewed 54 Power Engineering final year students in group form. Their lecturer played no role in the interviews. I gave each student an interview schedule and a pen. I then read out each question in the interview schedule and explained what the question expected of students in an attempt to ensure that each student understood what was expected of him or her in each question. Students were then given ample time to complete each question in writing.

Once the interviews were completed, the date of the next learnshop was set and students resumed their normal Power Engineering classes. It has already been noted that the standardized and open-ended interviews as outlined by Silverman (1993) have weaknesses but these were mitigated in the sense that themes were pre-set but students still provided their own understandings that could transcend these themes.

For example, interview questions asked respondents to give their own meaning of creativity, own understanding of pedagogic reform potential in light of creativity and role of creativity to enhance their future effectiveness in the workplace (Appendix A1). Furthermore, respondents were going to be given extended opportunities in the subsequent *learnshops* to demonstrate their unique ways of looking at the world and its problems. Students were tested on their creative abilities through the TTCT during the Pilot Phase but no analysis of that data was carried out as the idea was to find out how students coped with the tests so as to better inform the actual testing. The Pilot Phase students did not attend all the *learnshops* sessions because of resource constraints thus we conducted no further analysis on their TTCT data. The pilot phase was also used to improve our taking of observational notes and refining our observational protocol (Appendix A2) and comparing our scripts for iterative analysis and keeping the shape of the *learnshops*. 
We assumed observer status during the pilot phase *learnshops* and avoided showing students that we are seriously taking notes, to mitigate the possibility of compromising the naturalistic educational setting we sought to create and reducing students to research subjects as in laboratory settings. According to Creswell (2003: 186), when collecting data through observations, the researcher may assume the position of a complete participant where his or her role is concealed from the research participants or that of a complete observer where the researcher observes without participating. It was important that the researcher and the lecturer as co-researchers should assume the latter role to give students extended opportunities to take control of all aspects of the *learnshops*. I need to indicate that students who participated in the Pilot Phase *learnshops* reacted positively to the learning conditions that were flexible and open as demonstrated by their continued participation despite being reminded in every *learnshop* that their participation was voluntary and could be withdrawn anytime without providing any explanation.

The group interviews, giving each student an interview schedule to complete in writing and clarifying each question, proved effective. The issue of English becoming a barrier in responding to the questions was significantly reduced through this approach. Furthermore, this approach significantly reduced the apprehension often associated with assessment. The group interviews and the standardized nature of the questions substantially increased the reliability levels of the interviews as expounded by Creswell (2003) and; Cohen, Manion and Morrison (2000). Students also reacted positively to explicit training on creativity through the use of a creativity model and attempted to use the model to think about solutions to given case studies that dealt with sustainability of water, energy and paper within their own institution. However, students, through two focus group discussions consisting of five members each, suggested that the creativity model could be made more attractive and simpler especially with regard to its steps and terminology. Students also complained that more time than the four weeks of the pilot phase might be required to successfully come up with solutions to the problems in the case studies. These suggestions were taken very seriously and were worked into the next phase of the implementation.
Phase 2: Actual Implementation (Learnshop sessions 1-7)

The second phase of implementation involved 24 final year Process Instrumentation students and their lecturer and was conducted in the second and last semester of their studies before they went for Work Integrated Learning that involves being acculturated into a relevant industrial process mainly through the apprenticeship model of learning which is highly mediated through the epistemology of mimesis (Kalantzis and Cope, 2008) as argued in chapter 1.

The learnshops were conducted the same venue where the Process Instrumentation classes usually take place to ensure as minimal disruption of the naturalistic setting as possible. This second phase implementation was conducted in the same way as the pilot phase with the suggestions of the pilot phase integrated. For instance, the creativity model of the Pilot Phase was improved substantially and is that which appears in chapter 4, Figure 4.2. Students were interviewed in a group and in the written form in the same way as in the Pilot Phase. The main purpose of the students’ interviews was to elicit their views on the meaning of creativity, their classroom practices and whether they considered creativity as relevant to improving their classroom practices and future effectiveness in the workplace.

The lecturer was interviewed to find out his meaning of creativity, pedagogic training and practices, epistemic beliefs and how he conceptualized and understood teaching and students’ learning. The students were also pre-tested on their creative abilities through the TTCT for comparison with post-intervention results in order to determine whether learnshops based on invitational pedagogy, as an intervention strategy, had any effect on students’ creative abilities. Students were further exposed to data on the dwindling natural resources such as water, coal and trees and the implications of private and industrial heavy reliance on these resources as well as their unfettered use (information was elicited from Korten 1995, Suzuki, 2009, Peters 2003; Castells, 2001). Students were trained on an improved TRIZ-based Creativity Model and terms such as ‘transition’, ‘principles of integration’, ‘segmentation’ were elucidated and practical examples given.
The purpose of exposing students to a sustainability discourse is that institutions, organizations and countries are increasingly realizing the impact of unfettered use of these resources and the environmental impact of their unbridled use especially in the context of the capitalist mode of development and traditional technological focus (Pitso, 2008). As creativity is generally marginalized in UoTs, I considered it reasonable to explicitly train students on creativity plus there is general agreement in engineering education that such explicit training on creativity has some positive effects on the creative abilities of students (Chapter 2).

Students were placed in four groups of six members each and were given the case studies (Appendix F) that dealt with the challenges of sustaining any of the three resources – water, paper and energy. My intention in using teamwork as a basis of students’ creative problem-solving was to accentuate the fact that design problems are too complex to be resolved by one person as argued in chapter 2. Each team was expected to choose its own case study, figure out the problem, devise a plan and implement it within the context of their institution. My role and that of the lecturer was to observe and take notes on the evolving nature of ideas as undertaken by each team by means of the observational protocol (Appendix A2). In each *learnshop*, we focused our observations on how each team took decisions, how they managed tensions to sustain safe conversational spaces where members were not silenced through verbal violations. We also swapped one member from each team and observed whether such a change in team composition had any effect on each team’s decision-making processes and functionality levels. We (the researcher and the lecturer) took notes on our observations and attempted to reconcile them before conducting analysis of the observational data.

We then iteratively analyzed our notes on a regular basis and set up appropriate interventions, in the form of focus group discussions, with those teams we deemed to be threatening the invitational nature of the *learnshops*. Iterative analysis means that we attempted to feed our observation into the *learnshops* as soon as we deemed it necessary to do so, to keep them flexible enough to improve on the intervention and keep its basic invitational shape.
Phase 3: Actual Implementation (Learnshop sessions 8-10)

The students’ teams were now planning the next stage of their problem-solving processes which was the off-campus visits to industrial sites where relevant resources are manufactured and refined. I made my office resources such as the internet and telephone available to teams so as to arrange for these visits. Students do have access to computer rooms where these resources are actually available but working within time constraints meant creating some conveniences for the teams. The off-campus visits were intended for students to investigate how cognate industrial organizations were dealing with sustainability of these resources so as to better inform their own proposed solutions. Teams organized every part of the off-campus visits, including identifying the relevant industry, securing its address, finding the relevant people to arrange the visit with, setting up dates and securing transport from the institutional motor-fleet through my budget code.

Teams also prepared the questions they were going to ask and aspects of the industry they were going to observe to better inform their solutions. We (researcher and lecturer) observed as teams organized the visits without taking part or giving advice. It was important for teams to take control of all aspects of the organization and implementation of off-campus visits. Within the space of a week, the teams were ready to conduct off-campus visits and they gave the names of the organizations they were visiting as the Mondi Recycling Unit, Eskom Lethabo Energy Utility Company and Rand Water Board.

In our ninth learnshop, closer to the end of the semester, teams presented their action plans, the data they collected, their findings and possible solutions. It is after this session that we agreed that our next learnshop would be the last one where the post-intervention TTCT and interviews would be conducted. This agreement was based on the fact that students needed more time to prepare for their examinations and practicals (laboratory).
In the tenth and last *learnshop*, the TTCT was administered to all 24 students followed by written interviews as was done in the earlier *learnshop*. The students and lecturer were thanked for the effort they had put into the study. The work of the team, including each team’s report on the off-campus visit will be presented in chapter seven. In summary:

- Lecturer and students were interviewed pre-intervention in order to elicit their views on the meaning of creativity, its potential to impact classroom practice and future effectiveness of students. Main data: qualitative.

- The TTCT was administered to students as pre-test to measure fluency, flexibility and originality of ideas generated. Main Data: quantitative

- A series of *learnshops* were organized where students were exposed to statistics on the dwindling resources and why the unfettered use of these resources required arresting through rethinking existing technologies for sustainability and environmental protection. Furthermore, students were exposed to three case studies which involved one of these three resources for systematic investigation within campus and off-campus with a view to recommending solutions for improved use of these resources. Main Data: qualitative, observational notes

- Students were post-tested through the TTCT and interview schedules same as in the pre-test. Main Data: quantitative and qualitative.

The data collection is summarized in Table 5.2.
<table>
<thead>
<tr>
<th>Phase</th>
<th>Session</th>
<th>Research interest</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot</td>
<td>One: Reflecting on classroom practice</td>
<td>Assessing current environmental conditions for readiness to creativity: meaning, value and potential of creativity for future effectiveness</td>
<td>Interviews and Focus Groups Lecturer and students</td>
</tr>
<tr>
<td></td>
<td>Two: Pre-testing on fluency, flexibility and originality of ideas generated</td>
<td>Assessing current levels of creativity for comparison with post-tests results to determine whether intervention worked</td>
<td>TTCT data</td>
</tr>
<tr>
<td></td>
<td>Three: Disconfirmation data (textual and statistical data on graduate employment, dwindling natural resources, etc.)</td>
<td>Create learning anxiety and start a change process</td>
<td>Observational notes</td>
</tr>
<tr>
<td></td>
<td>Four: Explicit training on creativity model and Case Studies</td>
<td>Introducing a problem-solving process with non-routine problems</td>
<td>Observational notes</td>
</tr>
<tr>
<td></td>
<td>Five-Seven: students' discussions on chosen case study (energy, water, paper) – problem-identification, goal-setting, strategy grafting, implementation plan guided by creativity model</td>
<td>Students on the driving seat of the problem-solving process</td>
<td>Observational notes</td>
</tr>
<tr>
<td>2</td>
<td>Eight: off-campus investigation of chosen technology</td>
<td>The continuation of the problem-solving process outside classroom</td>
<td>Observation of fieldtrip planning and execution by students, feedback discussions observational notes</td>
</tr>
<tr>
<td></td>
<td>Nine: Presentation of suggested solutions to Case Studies problems</td>
<td>Observation of team defence of proposed solution</td>
<td>Observational notes</td>
</tr>
<tr>
<td></td>
<td>Ten: Post-testing on fluency, flexibility and originality of generated ideas. Post-test reflection on learnshops (students\lecturer)</td>
<td>Determination of whether intervention worked at creativity level, classroom impact and learning theory development</td>
<td>TTCT data, interviews data</td>
</tr>
</tbody>
</table>
Data Analysis Procedures

The first level of analysis of students' interview data was provided by the study conducted by Jackson and Shaw (2006) who identified features of creativity such as being imaginative, being original and being spontaneous, among others, as central to understanding creativity meaning-making (Table, 5.3.) which are used to analyze students views on the meaning of creativity. The second-level analysis related to possible categories that could emerge from qualitatively analyzing students’ interviews responses.

*Table 5.3.: Categorization of Students’ Creativity Meaning Interviews text*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Descriptions</th>
<th>Creativity type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Being Imaginative</td>
<td>Generating new ideas, thinking out of the box, looking beyond the obvious, seeing the world in different ways for exploration and better understanding</td>
<td>Emergenative (new creation, opens new paradigm, discovery, explosion of new ideas, inventive, innovative)</td>
</tr>
<tr>
<td>Being original</td>
<td>Quality of newness, producing new things or doing things that no one has ever done before</td>
<td>Emergenative</td>
</tr>
<tr>
<td>Being curious/growth-driven</td>
<td>Willingness to explore, experiment, take risks, dealing with uncertainty</td>
<td>Innovative (capacity to improve or reinvent existing system by using conceptualization skills)</td>
</tr>
<tr>
<td>Being Resourceful</td>
<td>Search and use knowledge to solve non-routine problems or improve existing technologies or systems, secure resources to overcome challenges or problems, sense opportunities, discern useful ideas and make good decisions, appreciate feedback, use feedback to constructively improve ideas</td>
<td>Inventive (problem-solving creativity or creation to improve existing systems or technologies)</td>
</tr>
<tr>
<td>Being spontaneous</td>
<td>Manifest in play, drawings, arts</td>
<td>Productive (noted in arts)</td>
</tr>
</tbody>
</table>
Given that the students’ interview schedules were completed in a written form, it was relatively easy to transcribe their responses and analyze them in terms of the descriptions in table 5.3., decide which category a response fell into and axiomatically decide which creativity type it represented.

There were only 24 research participants in this study so that the analysis was not necessarily time-intensive. Once the responses were categorized, tallies were used to count the number of responses in each category and draw generalizations based on the creativity type. In our qualitative analysis of students’ responses on the meaning of creativity, we searched for emerging themes and followed them up with Focus Group Interviews and where necessary added those categories in our somewhat pre-set categories.

For analyzing the value of creativity in respect of students’ future effectiveness in the workplace, life and classroom practice; we used the work of Jackson (2008) to establish the categories and followed the same process as above (Table 5.4).

Table 5.4.: Categorization of students’ Views on the Value of Creativity on future effectiveness and classroom practice

<table>
<thead>
<tr>
<th>Category</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic benefit</td>
<td>Knowledge economy needs creativity and innovation, work designs based on creativity and innovation, employment based on creativity and innovation, flexible, ephemeral jobs call for creative, innovative and entrepreneurial people, ideas generation, work in creative teams, opportunity sensing, mobilizing people and networking vital for self-preservation</td>
</tr>
<tr>
<td>Societal Benefit</td>
<td>Deepened participation, enhanced democracy, critical citizenry, provision of long-lasting solutions to problems, more productive and positive citizenry</td>
</tr>
<tr>
<td>Individual Benefit</td>
<td>Daily encounters and experiences become more vivid, enjoyable and rewarding, self-aggrandizement, enriches</td>
</tr>
<tr>
<td>Classroom practice benefits</td>
<td>Unusual, non-routine problems make learning challenging and more rewarding, banishes boredom of routines</td>
</tr>
</tbody>
</table>
In order to analyze students’ views on classroom activities that were likely to encourage creativity development and the potential of creativity to improve classroom practices and future effectiveness in the workplace, I referred to the work of Boshier and Huang (2008) which indicate that learning that involves young people in higher education should draw from students’ experiences, respect their self-directedness and smooth-out power relations in classroom encounters (Table 5.5). This kind of learning is associated with students’ active participation and agency, collaborative inquiry and strong democratic ethos which, in turn, develop into an educated state which is borne out of a complete “tapestry woven out of broad students’ experiences, grueling commitments and substantial risk-taking” (Boshier and Huang, 2008: 649).

**Table 5.5.: Categorization of Students’ Views on Classroom practices and Creativity Potential**

<table>
<thead>
<tr>
<th>Classroom Practices</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teamwork (Group Discussions)</td>
<td>Working with others to solve a problem (routine, non-routine), sociability, sensitivity, distributed tentativeness, genuine dialogic reconstruction, aligned intent, easiness</td>
</tr>
<tr>
<td>Research (Practicals)</td>
<td>Adaptability to newness, opportunity sensing, translating ideas into actions, developing critical and creative thinking skills, question formulation, information search skills, fieldworks, data interpretation, statistical and graph analysis</td>
</tr>
<tr>
<td>Technology-driven</td>
<td>Use ICT to learn, plan and search for information</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>Solve both routine and non-routine problems, use techniques or models of heuristic problem-solving, show independence and initiative in problem-solving, test assumptions, respect context</td>
</tr>
<tr>
<td>Communication</td>
<td>Share ideas clearly and convincingly, listen and understand, speak clearly and directly, read and interpret data, use numeracy and graphs, be sensitive, meet audience needs, persuade effectively</td>
</tr>
</tbody>
</table>
The TTCT data is analyzed in terms of the TTCT manual and follows the strict protocols of the standardized tests. The TTCT manual provides clear guidelines as to how to score and analyze the tests. It has also been established that any educator or researcher can administer and score the TTCT as long as the strict guidelines of the manual are followed. Studies on finding out the reliability of scoring the TTCT tests by educators or researchers show a reliability score of 0.96 meaning that with prudence, any educator or researcher can score the TTCT (Torrance, 1990; TTCT, 2008). TTCT scores were also subjected to t-tests to determine whether students’ scores on fluency, flexibility and originality increased post-learnshops.

**Ethical Issues**

I distinguish between ethical issues that relate to the study and its treatment of the research participants and the ethical issues embedded in the case studies. The study had no visible and immediate threats to the lives of the research participants except that DBR encourages participants to respond uniquely and creatively to the perturbations of institutional culture and, faculty and classroom sub-culture if transformation is to occur. In order to ensure that those participants who feel uncomfortable about the DBR approach are free to withdraw their participation anytime, we argued self-persuasion as the key driving force for participation in the learnshops so that participants were free to leave the learnshop as and when they so desired. Students provided an informed consent prior to participation in the study and the University of the Witwatersrand Ethics Committee, after satisfying itself of the ethicality of the study, provided the study with the ethical clearance.

The case studies address ethical issues on a specific engineering process. They deal mainly with the extent to which a human benefit that accrues out of an engineering process can be achieved at a reasonable cost to human and natural life. It is about balancing benefits with costs of producing such benefits in the engineering process as areas of difficulty.
The research participants were expected to calculate accruable benefits against the level of destruction that such an accruable benefit make on the natural resources and the human life what is termed ‘formative gain’ (Pitso, 2008). The ethical clearance was obtained from the University of the Witwatersrand Ethical Committee to proceed with the study in 2009.

Validity

The study’s claims to be legitimate, meaningful and appropriate can be viewed as validated when those claims are based on accumulated empirical data and logical arguments. DBR approaches are premised not on claims of truth as in the case of traditional positivist science but on consequentiality of the study (the ability of the planned intervention to do work in a specific context). Threats to traditional validity in DBR would then include the deliberate exclusion of a control group for comparison with the group that received treatment for facilitating comparisons, non-isolation of variables for measuring ‘cause-effect’ of independent and dependent variables and lack of opportunities to go back in the laboratory for further retesting and verification.

The significance of a particular study, under DBR, is its consequentiality or usefulness in impacting local practice and contribution in advancing a theory that will be of use to others. The essential criterion for determining the significance of a particular DBR study is the degree to which evidence gathered can account for change in local practice and learning theory what Messick (1992) calls ‘the evidence of consequential validity’ which asserts that the validity of a claim under DBR is based on the changes it produces in a given system. These changes or consequences can be considered as evidence in support of validity within the limitations and parameters of collected data. DBR allows for two key claims. Firstly, it has to make a claim and adduce evidence that local practice has been impacted through demonstrating a number of outcomes that have been achieved by the study. Secondly, DBR has to draw connections to theoretical assertions and claims that transcend the local context (Messick, 1992; Brualdi, 1999).
DB researchers are also expected not only to share the designed artifacts but also provide rich descriptions of context, guiding and emerging theory, design features of the intervention and the impact of these features on participation and learning.

The goal of DBR is, therefore, not to attempt replicability but rather to lay open and problematize the completed design and resultant implementation in a way that provides insight into the local dynamics and contribution to the building of theory (Messick, 1992). This is the only way of advancing credible assertions in DBR. DBR was implemented, in this study, in the form of learnshops.

The TTCT validity studies have been conducted over many years (Torrance and Wu, 1981; Millar, 2002; Yamada and Tam, 1996; Plucker, 1999). Plucker’s reanalysis of Torrance’s data (Plucker, 1999) confirms that the creative index is the best predictor for adult creative achievement across cultures.

**Summary**

This chapter provided a broad overview and purview of Design-Based Research, also known as design experimentation, as it is a relatively new research approach in educational research that is steeped in Deweyian pragmatism. DBR was also presented as a research approach that studies phenomena within naturalistic settings with a clear goal of impacting local practice and advancing a particular learning theory. A classroom intervention grounded in the principles of DBR was organized in terms of learnshops and was presented with a clear goal of facilitating the growth and development of creativity as measured in terms of the number of ideas students generated, the variety of those ideas and their novelty. The views of the students were also elicited through structured interview schedules and one focus group. Ethical concerns related to students’ degree of comfort in participating in the study with self-persuasion considered as the basis of participation. Furthermore, ethical considerations also involved problem-solving solutions that were framed within a postanthropocentric view of the environment where unfettered use of natural resources is frowned on. Lastly, validity was considered as consequential and framed within the utility discourse.