The Development and Expansion of Undergraduate Learning

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Abstract

Undergraduate learning has mostly focused on preparing students to effectively deal with complex, future situations through use of mainly known, technical knowledge within a discipline which is a too narrow focus. Future situations, even in our knowledge-driven society, are mostly unknown in the present and require more than just known technical knowledge. Learning that is based on known, mainly technical knowledge is most likely to be inadequate in preparing students for the complex and integrated society whose future problems remain vague and generally unknown to us. Future problems require more than technical knowledge and includes practical and emancipatory aspects of knowledge. In an attempt to contribute a broadened meaning of learning that could make students better prepared for the future, I developed Learnshops in which students were given real problems to resolve guided by a TRIZ-based model. TRIZ is a heuristic problem-solving technique. The purpose was to develop their analytical, synthetic and practical abilities. A Design-based Research method was used to test the effectiveness of the Learnshops and glean out a broader meaning of learning drawn from findings.

1. Introduction

Undergraduate learning has mostly focused on transmitting knowledge that is produced through empirical-analytical means and which is instrumental in nature. This knowledge which is essentially technical involves causal logic of determining cause-effect relationships and has been instrumental in creating our modern societies but is generally insufficient in addressing all of societal challenges. According to Habermas, this mainly technical knowledge does not adequately address all of the many moral and social problems that societies face [8]. Bernstein suggests that this mainly technical knowledge encourages “socially-empty” trainability which eschews equally valid purposes of learning such as gain in practical and emancipatory knowledge [3]. Practical knowledge pays attention to understanding other people which subsumes making an effort to learn others’ social and cultural ways of knowing and doing so that meaningful conversations

that lead to shared ideas, consensus on vital issues and reaching common cause are developed and sustained. In learning, this practical knowledge calls for the harnessing of subjective meanings such that distorted self-knowledge, interpretations and perceptions are improved to leverage collective human wisdom to resolve complex societal problems. Emancipatory knowledge focuses on how people attempt to use knowledge, rational action and critical reflection to liberate themselves from coercion, self-imposed constraints and reification of social structures and institutions [8]. In order to achieve the purpose of liberating themselves, people ought to critique knowledge and entrenched ideologies including internalized social constraints. In other words, institutionalised learning has to address all the three aspects of knowledge – technical, practical and emancipatory – if it were to develop students that are capable of resolving complex societal problems that require science, raw materials, teamwork and active agency (which includes independence of thought and action) for effective resolution. Institutionalized learning thus carries with it the hope that what students encounter in classrooms as sample situations of the reality out there could be successfully carried to other especially future situations where all three aspects of knowledge are essential. In essence, students’ learning entails effectiveness in decisions and actions of the future as preceded by new or revised interpretations of an experience as drawn from the combination of technical, practical and emancipatory knowledge. In other words, students gain concepts and tools in formal learning that should help them deal with future situations more effectively which means that they become competent in developing new or revised interpretations that guide handling of future situations which mostly leverage all three aspects of knowledge. University classrooms provide less-authentic situations as compared to real ones out there in the world and thus justify their existence on the basis that students can use lessons

learned in these less-authentic samples of reality when called to do so in some future situations. This means that every learning situation implies, to an important degree, another real situation of application so that there is always potential to apply gained concepts and tools in real situations in ways that resolve the problem at hand. There is, however, a big difference between using sample situations where most if not all variables of the problem are well-known and solutions are readily available and authentic problems where problem variables are vague and solutions are unknown. Bowden and Marton argue that university learning has suffered, over time, from the paradox of using what is known and certain in the discipline at a particular point in time to prepare students for the uncertain, unknown future [4]. Törnkqvist, accentuating the point Bowden and Marton make, suggests that the hybridization of three educational approaches has been instrumental in the narrow focus on known, technical knowledge in undergraduate learning [4] [15]. First, undergraduate learning is generally based on established and settled knowledge which had been generated in such a way as to have universal appeal and applicability. It is this underpinning of undergraduate learning on clean, universal knowledge that has, according to Törnkqvist, entrenched pedagogies that transmit past knowledge to students [15]. This, in turn, compromises focus on real-life present and future scenarios which may require more than just the guidance of settled knowledge and thus include practical and emancipatory knowledge. Given the dualistic nature of this technical knowledge, there has been the tendency to prepare especially undergraduate students to answer pre-set questions with definite answers rather than orientating them to ask deep, complex questions with no ready-made solutions [7]. This point leads to the second issue that Törnkqvist raises which is that undergraduate learning is noted mostly for the drill and practice routines which can hardly assist students to resolve complex societal problems [15]. Chang and Hsiao succinctly capture this view of undergraduate learning as:

“Indoctrination of domain knowledge...most problems given to students in class are well defined with only one correct solution. Under current training, students are asked to solve these ‘textbook’ problems, which are simple, well formulated in particular forms, and have standardized approaches and answers” [6].

Törnkqvist further argues that undergraduate learning has been heavily reliant on abstract mental schemas as the basis of learning and making sense of experience at the expense of developing concrete context-based, situated schemas [15]. I believe both sets of mental schemas drawn from all three aspects of knowledge have a place in the fostering of students’ complex problem-solving. Ideas generation, hypothesizing and synthesizing are as equally valid as practically applying solutions to almost intractable real-life problems. Another critical factor that is considered relevant in the general marginalization of complex problem-solving especially at undergraduate level is the module-based semester system which drives the content-loaded undergraduate curricula. The implication of this approach to undergraduate learning is that it tends to pressure teachers into completing the prescribed syllabus. This approach thus allows very little space and time for formative approaches to teaching where reflective practice and iterative improvement of one’s practice are made possible. According to Runté, teachers operating under these industry images of division of labour, task management and strict timeline:

“Feel pressured to teach to the test, rather than to respond to student interests... teachers retreat into rote memorization of the basics, rather than encouraging critical thinking (and creative thinking), because they know that most standardized examinations are incapable of measuring such higher mental activity” [14].

It was particularly important for me to consider all these issues and find a breach between what takes place in a classroom and the reality out there and this was a boundary issue. In the next section, I elaborate on this issue as ways of sketching a theoretical framework for the study. Once the framing theory is adumbrated in the next section, I explain the research methodology and methods used in the study to test out the effectiveness of Learnshops designed to expose the strength and limits of students gained formal knowledge in real situations. I further share the results of the study and provide a broader meaning of learning that encapsulates students’ access to the means of critical understanding and the means to open new possibilities. I argue that this broad understanding of learning is a precondition for preparing students to handle future situations.

2. Learning as Boundary Experiencing

Bernstein defines student' enhancement as “a condition of experiencing boundaries, be they social, intellectual or personal, not as prisons, or stereotypes, but as tension points condensing the past and opening possible futures” [3]. The use of what is certain and known in preparing students for the future is often based on the condensed knowledge of the past and when that is used exclusively in learning then enhancement is restricted to past and present and, less on the future. Access to future effectiveness is thus axiomatically and profoundly curtailed. This could be understood as surface enhancement because deep enhancement of students entails access to the means of critical understanding of the past and present situations and the opening up of new, future possibilities. Enhancement occurs within disciplines so that disciplines decide on what means are made available to students which determines boundaries of participation and inclusion and, thus what students can legitimately claim access to and what is forbidden or ignored. Inclusion in learning involves the potential for students to construct, maintain, reconstruct and transform disciplinary boundaries. The challenge is on how students could effectively make some contribution in reconstructing and transforming disciplinary boundaries and thus enrich their interpretation of experience which could, in turn, improve decisions and actions geared towards solving real, future problems. In order to aid clarity, I make use of Bernstein's understanding of education as boundary experiencing with particular focus on its possible social outcomes, that is, on its promise that students will become effective in solving problems of the future [3]. There is thus a legitimate expectation that through the appropriation and remaking of knowledge in education tutelage that students' enhancement will occur. It is the regulation of knowledge appropriation that is of importance here particularly sites of knowledge appropriation.

Knowledge sites are key determinants of how disciplines set boundaries around two key forms of knowledge – knowledge that is context-independent and one that is context-dependent. Context-independent knowledge is considered clean, universal and often unproblematic because it has been produced through rigorous processes of science and peer review. This is the knowledge that underpins disciplinary knowledge and forms the basis of organizing classroom practices most of the time. It is often coherent in form, explicit, systematically structured, hierarchically organized and it gets selected and regulated within disciplines [3]. In many undergraduate studies, this is the only legitimate form

of knowledge and is appropriated within formal institutions as official knowledge sites. Context-dependent knowledge is local, authentic, tacit, segmental, multi-layered and is often contradictory across contexts [3]. It is generally marginalized and mostly ignored in formal sites of knowledge appropriation especially the undergraduate sites of knowledge delivery. Students experience learning in line with the degree to which it sets limits on both sites of knowledge appropriation (formal, informal). In cases where only disciplinary knowledge in the form of context-independent knowledge is accentuated, students' ways of seeing the world through less-authentic lenses of the discipline and ways of acting (handling future, authentic situations) become dialectically differentiated. The former seeks to provide surface enhancement because focus is on making available known concepts and tools that may aid handling of future situations and modeling their application through less-authentic situations.

There are fewer, in institutionalized learning, opportunities for students to experience the handling of authentic situations in real contexts where multiple variables and contradictions exist which often expose the limits of gained formal concepts and tools and create a need to develop other equally legitimate forms of knowledge. Handling authentic situations requires more than gained formal, technical knowledge. The misconception that textbooks or any other learning materials within a discipline necessarily contain reliable and adequate explanations, concepts and tools that aggregate handling of authentic situations is limiting and limits students' access to the means of critical understanding and opening of new, future possibilities which require additional gain in practical and emancipatory knowledge. Kalantzis and Cope argue that disciplinary knowledge packaged in textbook-driven curricula inform students of “things” of the outside world in a manner that is distant and distancing [9]. They further argue that these “things” in the textbook get organized in formal knowledge appropriation sites in the form of syllabi whether content or outcomes are emphasized. In the study that is reported here, I advance the view that students' enhancement, that is, access to the means of critical understanding and opening new, future possibilities involves developing students' capabilities of analysis, synthesis and practical application in real, authentic situations so that they could engage in effective action in situations of the future through gain in new or revised interpretation of an experience. Enhancement through less-authentic situations as expounded in textbooks or any other learning materials tend to orientate students into spaces of answering rather than asking questions which tend to

limit but not entirely take away the means to critical understanding and exploration of new possibilities [13]. Such enhancement tends to lead to rational and some critical understanding. Enhancement through real, authentic situations has the potential to make available to students the means of criticality and exploration which provide opportunities for reflective action and better ways of handling future, authentic situations.

3. Setting-up the Research Project

In order to test out students' enhancement through authentic situations, I set-up a research project designed to allow students opportunities to deal with multiple variables and contradictions that real situations contain. It was, however, significant that exposing students to such authentic situations would require some level of flexible tutelage so that the need to allow for active agency and autonomy of students in dealing with authentic situations was cushioned against possible paralysis. Students were trained on a TRIZ-based Creativity Model that I developed since 2008 and received positive reviews in subsequent years in international conferences and journals [11] [13]. The model is based on TRIZ as stated. TRIZ is a heuristic problem-solving technique which was developed by the Russian Genrich Saulovich Alshuller in 1946. The TRIZ principles that guided the model refer to its focus on both technical and non-technical aspects of a situation under consideration, its use of a systematic and scientific approach in consideration of a situation at hand, its problematising and critiquing of maximum constraints in a given situation in search of its even higher design or ideality and its use of relatively

fewer concepts in positing the theory. Based on these principles of TRIZ, I developed a model of creative thinking which sought to make available to students the means of both critical understanding of a given situation and the search for the situation's higher design by considering carefully factors that lead a situation not to perform at an optimal level. In the next section, I briefly describe this model of students' creative and complex problem-solving.

4. The Creativity Model

Other than the principles that undergird TRIZ as tersely described above, three other reasons motivated my choice of TRIZ as the basis of developing the creativity model that could foster students' abilities of analysis, synthesis and practical application of an idea. First, TRIZ makes use of a relatively small number of concepts, heuristics and effective knowledge databases to solve real, authentic problems of any kind of the classes of problems ranging from quality improvement through to preventing shortcomings in a situation [1]. Second, TRIZ has proved effective in problem formulation, system analysis, system failure analysis and patterns of system evolution [1] [13]. Third, TRIZ draws from McGregor's Theory Y [10]. McGregor's Theory Y is an important departure from McGregor's Theory X which tended to accentuate control and prediction of people's behavior in problem-solving. McGregor's Theory Y emphasizes human's active agency and, free but systematic generation of ideas to resolve real problems. What follows is the designed model of creativity and a brief description of its six stages.

Figure 1: The TRIZ-Based Creativity Model and its Six Stages

Step 1 of the model is based on the idea that a situation (system, technology, circumstance, product) under consideration can better be tackled and improved if it is thoroughly understood. In this step, students are expected to critically interrogate the conceptualization of a situation at hand including its logic, application and interpretations given by various players in the situation so that its current maximum constraint can be thoroughly understood. Without this base knowledge, students could not be expected to move to the next steps of the model. You cannot improve what you do not understand. For most undergraduate students, this step tests the limits of the formal concepts and tools they have acquired (rational and critical thinking skills) as well as some research skills.

Students were expected to figure out the design, operations and the science behind a particular situation before seeking its higher and optimal levels. Step 2 is a rhetorical question because its focus is on whether a situation has reached its maximum, formal form (highest ideal). We all know that no situation can reach its ultimate maximum constraint so that we can only perpetually move towards perfection. We can safely thus assume that each situation is never working near perfect (ultimate ideality) so that its limits/boundary can be sensed and re-interpreted so as to lead to new possibilities. Step 3 draws from the reality that an ultimate form of a situation represents a new opportunity to sense limits and attempt expansion of boundaries. In this step, students are expected to identify factors/variables or triggers that

compromise a situation such that it is unable to operate near-perfect. This step is about the investigation of a set of causation or constraints as well as aggravators of a situation. In this model, I identified only six classes of inventive problem-solving and would expect students to add to the list so that these classes serve as unexhaustive variables rather than as prisons to block exploration and systematic inquiry. Step 5 is based on the idea that problem variables have been successfully identified in step 4 so that step 5 marks the beginning of the solution space. In this step, students begin to think about how a situation will proceed from its less-ideal stage towards a more, higher level of design and operation. A good example is when phones were moved from a centralized point to individual access (mobile phones), that is, from integration to segmentation. The last step involves identifying and estimating resources required to improve a situation.

5. Research Design and Method

The Design-Based Research (DBR) methodology was used to test out the designed learning enacted as Learnshops. DBR methodology is a relatively new, interdisciplinary research framework designed to help educational researchers to engage in theoretically-informed research in authentic classroom settings [2] [5] [12]. DBR draws from multiple research practices within a variety of disciplines and research methodologies and 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. The most important feature of DBR methodology is its attempt to impact classroom practice. Its DBR method has some features of traditional experimental or quasi-experimental designs but differ in terms of research location, complexity of variables, focus of research, unfolding procedures, degree of social interaction, characterizing findings and role of participants as described in Table 1. DBR scholars have identified seven major differences between traditional experimentation design and DBR method as outlined in Table 1. The key aspect of DBR method that is relevant here is in the location of research which occurs “*in the real-life settings*” that are authentic and complex [5] [14]. The study, through Learnshops, developed alternative learning conditions that incorporated all three aspects of knowledge – technical (science), practical (teamwork) and emancipatory (active agency) – to foster undergraduates’ complex problem-solving and, at the same time, raise awareness around the need for environmental sustainability. Students’ learning in Learnshops thus went to understanding and attempting to unravel the messiness of real societal problems. At the core of Learnshops is the use of flexible design revision, multiple dependent variables that comprise the transferability and application of gained knowledge that transcends disciplinary boundaries and the limits of a traditional undergraduate learning context such that research participants are not treated as subjects that can be assigned to a treatment rather are considered as co-researchers in both design and analysis of collected data [2]. At the heart of the Learnshops is thus the desire to impact local practices in such a way as to provide real solutions to real problems. Ten Learnshops were organized. In the first Learnshop, participants were pre-tested on their creative abilities using Torrance’s Tests of Creative Thinking (TTCT)

which were to be compared with post-test results to determine success of the intervention. TTCT measures a number of ideas each student generate per given task and time (fluency), a variety of the generated ideas (flexibility) and the uniqueness of generated ideas (originality). TTCT are standardized tests that have proven to be cultural neutral.

In the second Learnshop, participants were exposed to textual and statistical data on dwindling natural resources, the unsustainability of unfettered use of these natural resources by the capitalist commercial activity and the need for constraint and use of alternative renewable energies. The purpose of this Learnshop was to create a learning anxiety through presentation of disconfirmation data and ignite a change process.

In Learnshop three, participants were explicitly trained on a TRIZ-based Creativity model. In the fourth Learnshop, participants were divided into three teams of six members. Each of the teams was given a mini project on water, energy and paper production technologies. It was expected that each team could attempt to search, through use of the TRIZ-based Creativity model, the higher designs of these technologies by challenging their existing constraints. Resources were also made available to teams to visit industries or companies that dealt with these technologies for purposes of understanding their current conditions, internal efforts on improving each one of them and then generating ideas that could contribute in the higher designs of these technologies. Participants were not expected to design and develop prototypes due to time constraints only share their experiences and ideas. In Learnshops five, six and seven, teams reported on progress made starting with their research and visits to industries. Learnshops eight and nine, teams presented their probable solutions which were interrogated by others. Learnshop ten was dedicated to debriefing of participants, the taking of the TTCT and another round of interviews on creativity and its valuing.

Table 1: Comparison of Traditional and DBR Method [2]

Category	Traditional Methods	Experimental	DBR Method
Research Location	Laboratory settings		Authentic classroom settings
Complexity of variables	Mostly single or couple of dependent variables		Involves multiple dependent variables including learning context variables (learning of content, transfer) and system variables such as dissemination, sustainability
Research Focus	Identifying few variables and holding others constant		Characterizing a situation in all its complexity
Procedures	Fixed		Flexible design revision
Social interaction	Isolates students to control interaction		Involves complex social interactions where participants share ideas and solve problems
Findings	Test hypotheses		Looks at multiple aspects of the design and developing a profile that characterize the design in practice.
Participants' Role	Treated as subjects		Involved in design and analysis

The study was designed this way because it had to meet some level of validity as outlined with the DBR paradigm. In terms of DBR, the claims of any study that uses DBR methodology and its methods can only be considered as legitimate, meaningful and appropriate when those claims are based on accumulated empirical data and logical arguments. DBR approaches are premised on consequentiality of the study, that is, on the ability of the study or planned investigation to impact practice in a specific context rather than on claims of truth as is the case in positivist traditions. Threats to traditional validity in DBR often include the deliberate exclusion of a control group for comparison with a group that received treatment, non-isolation of variables to determine cause-effect of independent and dependent variables and lack of opportunities to retest and verify results as in laboratory settings. As already stated, the significance of a particular study its consequentiality or usefulness in impacting a local practice and contribution in advancing a theory that will be of use to others.

The most important aspect in determining significance in DBR studies is the extent to which evidence gathered can account for change in local practice what Brown refers to as 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 situation [5]. These changes or

consequences can be considered as evidence in support of validity within the limitations and parameters of collected data. DBR is thus premised on two key claims of validity. First, its claim has to be based on adduced evidence that demonstrate that local practice has been positively impacted through showing a number of outcomes that have been achieved by the study. Second, DBR has to draw connections between theoretical assertions and claims that transcend the local context. The goal of DBR is, therefore, not to attempt replicability but rather to share the designed artifacts and how it can be extrapolated in other contexts. DBR was implemented in this study in the form of Learnshops with pre- and post-test measures using TTCT to increase even further its validity.

6. Results

The TTCT scores were subjected to a t-test to determine significance. The t-test results in Table 2 indicate that two of the three metric variables that measured students' creativity show significant improvement on students' generation of a variety of ideas ($p=0,003$) and the unusualness of the generated ideas ($p=0,001$). The mean scores of all three metric variables of the TTCT increased when the pre- and posttest scores of students are compared which indicates the general improvement of students'

creativity performance post-intervention. The t-test also shows statistical significance between the TTCT metric variables which indicates that students' scores on fluency, flexibility and originality increased post-

intervention although with varying degrees. The standard deviation increased post-intervention as the result of two students making no progress at all during the intervention.

Table 2: Mean, Standard Deviation, T-test and P-value 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

During students' presentations of the problem each team identified, the water team was able to discover an anomaly in students' residences. The team discovered that when students are present in the residences, the water bills goes down and when students were mostly in university recess and thus not at the residences, the water bill increased substantially. The team then investigated the anomaly further which compelled it to visit the local municipality and make inquiries on the lifespan of pipes, material used and the water purification system and chemicals used. For the water purification, the team was referred to Rand Water Board which is responsible for it. Once the team had analyzed the data, it came to the conclusion that the main water pipes have been installed for more than forty years and their actual lifespan is twenty-five years and that the bitumen which lines the pipes to prevent corrosion had depleted which affected the quality of the pipes and insufficiently protected the pipes. This reduced the lifespan of pipes even further and thus resulted in leaks in the main pipes so that during high use of water, pressure was removed from the main pipes and thus fewer leakages and during low use then the pressure was on main pipes which increased leakages hence high costs.

7. The Expanded Undergraduate Learning

The main purpose of the research project was to develop and expand undergraduate learning at the

level of knowledge appropriation, agency, study level and skill base. At the knowledge level, there was a need to incorporate all three aspects of knowledge into undergraduate learning and expand the sites of knowledge appropriation beyond formal institutions. The students' projects compelled them to visit various social sites such as municipalities and industries and thus transcended their traditional site of knowledge appropriation and sought knowledge and information in search of solutions beyond disciplinary boundaries. Students' active agency meant that they made decisions and acted on knowledge and information they themselves selected, in a sequence they chose, in their own pace and worked on the one they evaluated as relevant in quest of solutions. The broadened learning seems to work better in intermediate and advanced undergraduate level. During search for solutions, students analyzed and evaluated a lot of information including which ideas and direction to take leading to deeper development of their analytical abilities. They further made connections on available information which helped them to develop their synthetic abilities. Towards the end of the research project, students were already designing water leak detectors for commercial and domestic use which helped them develop their application abilities.

8. References

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