

**RESEARCH BASED AND DESIGN BASED EDUCATION:
EXPERIENCES IN INDIA, UK, AND USA**

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ABSTRACT

The paper presents the recent trends and experiments being attempted in India, United Kingdom and the United States aimed at enhancing values from the approaches of Research based teaching-learning as well as Design based teaching-learning methodologies. Based on the authors' preliminary first hand experiences and investigations on the approaches reported by peers, the paper brings out the constraints, difficulties and challenges in implementation of relatively well established steps followed in the western system of higher education, in the eastern societies. The paper further deliberates upon possible hybridization by blending of approaches followed earlier with the intended changes in pedagogy.

Keywords: Research based education, Design based education, connected curriculum, project based learning, role of culture in pedagogy

1. INTRODUCTION AND BACKGROUND

The paper is based on the first author's experience in extending UCL's focus on "Research Based Teaching (RBT)" through a variant offered as "Design Based Teaching (DBT)" at the third author's laboratory (UCL Touch Lab), and subsequently collaborating with the second author to implement "Project Based Learning (PBL)" pedagogy at JKLU, inspired by approaches used at Olin College of Engineering. This cross-continental journey posed several interesting pedagogic research questions including the differences, similarities and relationships

between the three approaches keeping in view the socio-cultural aspects of teaching and learning.

As a part of promotion of RBT, UCL emphasized on so called "connected curriculum" [1,2,3] and introduced an Integrated Engineering Programme (IEP) at the start of the 2014-15 academic year for a new cohort of about 700 students in engineering. This was an outcome of a comprehensive multi-disciplinary curriculum review of engineering education intending to engage the students with the practical application of engineering and skills needed to undertake projects effectively, from the very beginning of their degree. UCL's 2014-15 batch graduated in 2018 with BEng/BSc degrees. During this period of 3 years, approximately 3000 students participated in a mixture of IEP and non-IEP curriculum till the 2017-18 academic year where all the students in undergraduate engineering were enrolled in IEP curriculum. This gave a unique opportunity to compare the two curriculums through focus groups and an online survey that has indicated: (a) IEP students were more likely to discuss with others outside their class, ideas from their self-reading or lectures by faculty resulting in increased enthusiasm about the studies in general; (b) IEP students were in higher agreement that the minors contribute towards skillset broadening enabling wider career options as UCL's education contributed to their ability to solve complex real-world problems [4].

In India, JKLU is one of the pioneer institutions to take the lead in introducing PBL as part of their mission of re-imagining education through experiential learning in both engineering and

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management schools. The first batch of PBL oriented curriculum was implemented in the 2018-19 academic year.

Traditional understanding of “research”, particularly in the eastern culture is to view it as a specialized and highly narrowed scope investigation, likely to be conducted in a doctoral level program only. This explains lack of research or its another but different form, namely, innovation driven activities leading to patent applications from the personnel trained at most of the undergraduate study institutions in India. There is a downward trend in patent application filing from the western education system trained personnel too, including from the USA [5] where at a more foundational level, lack of interest to embrace STEM curriculum is becoming a serious challenge. These and other factors are responsible for introduction of Design and Project based teaching and learning pedagogies that are reported to engage the students in a more interesting manner [6].

The relationship between design and learning is well known as there are several earlier reported research articles on the topic. Introduction of design activities for science learning probably originated from concerns about the declining diversity, quality and quantity of future engineers in the USA [6]. It has been recognized that design can serve to open doors to possible engineering or science careers [7] by acting as a vehicle by which real-world problem solving skills can be cultivated [8] right from K-12 level science classes. It has been reported that engineering design process can be effectively combined with scientific inquiry as an instructional approach [9; 10; 11a, 11b; 12] by means of a design-project in which students are required to use and extend their science or math knowledge to develop a technological solution to a practical problem using available resources. While this design-based learning (DBL) approach has been found to enhance engagement with students as they are able to relate science with its practical application, a so called design-science gap was identified [8] and an attempt to study the same was also reported [13]. Schunn Lab team has reported successful design based learning experiments for STEM [14]. As design based teaching relies heavily on past or active case studies of design activity, in our opinion, case-based reasoning is a relevant aspect to be aware of, e.g. Leake, [15]. While most of the DBL pedagogy appears to have evolved in a school education context, this has been analyzed and extended even in the context of higher education, e.g. by Gómez Puente [16]. As an experienced design engineer, while guiding students as interns as well as their academic projects, the first author has observed that minimal guidance as a popular pedagogy may have limitations as substantiated by reported investigations, e.g. Kirschner et. al, [17] as well as inferences from student feedback and focus group discussions at JKL U as reported in this paper, however, we believe that with enhanced capabilities of technology, it is now possible to develop student centered self-paced design based learning, e.g. Burnette [18].

The paper is organized as follows. Section 2 states the enquiry part of the work by listing out the formulated research

questions. Section 3 outlines the approach and methodology followed in order to answer the research questions. Section 4 presents the results and discusses the rationale towards deduced conclusions. Section 5 briefs the conclusions.

2. RESEARCH QUESTIONS

The paper attempts to partly and at a preliminary level seek answers to the following inquisitive aspects of teaching-learning approaches using ethnographic methods, student feedback and focus group discussions:

2.1 Effects of the teaching-learning approaches

This question targets understanding, interpretation and comparison of the functioning of the approaches including Research Based Teaching, Research Based Learning (RBL), Design Based Teaching (DBT), Design Based Learning, Project Based Teaching (PBT), and Project Based Learning processes. For the purpose of this paper, we limit the scope to these processes that directly came across in the primary theme of the study relevance at UCL and JKL U. Numerous other terms used in the reported literature, for example, Problem Based Learning (Savery, 1996 [19]) are not addressed.

2.2 Effects of other factors

This question targets to gain understanding of several other factors that may affect the teaching-learning process.

The influences of factors affecting working of a student in a solo learning mode in UCL as compared to working under a group dynamics environment at JKL U is of interest.

Another factor of interest is whether or not a particular teaching or learning method is more effective in a particular year of study. Is it more effective to introduce Design, Project or Research based learning when a student starts his or her studies at the very beginning of the engineering curriculum or is it desirable that preliminary years are grounded with conventional lectures based pedagogy and later transition happens to the new pedagogy?

We also intended to explore at a preliminary level whether or not there are any influences of location on the effectiveness of pedagogic approach, in this instance the countries being UK and India. Furthermore, the influences of socio-cultural upbringing of self or peers are factors that are likely to influence the effectiveness of an approach of teaching or learning.

3. APPROACH AND METHODOLOGY

A case study of a single final year (year 3 of engineering undergraduate program in the UK) was used for study of the DBT-DBL approach as an extension of UCL’s current focus on the RBT-RBL approach. A cohort of 56 first year (year 1 of a 4 year engineering undergraduate program in India) JKL U students (11 female, 45 male) in the 18-20 years age group belonging to several disciplines of engineering (computer science, electrical & electronics, mechanical) was used for focus

groups based study of the PBT-PBL approach. A typical group size was 5 students for each project, range being 4 to 6 students. The course titled “Design & Prototyping” was offered for the full duration of the first semester (August-December) of the 2018-19 academic year with 2 to 4 concurrent instructors in a studio style setup.

The UCL student was of similar ethnic and upbringing background as the JKLU students: Indian origin, predominantly from northern region. The UCL student as well as all the JKLU students had completed their high school education (11th and 12th grades) in India. Another similarity was in terms of performance in competitive examinations for entry into India’s much sought after publicly funded Indian Institutes of Technology and National Institutes of Technology. None of the students (UCL and JKLU) had performed well enough in the concerned entrance tests to be able to get entry to those institutions.

The identity of the individual students is protected for personal confidentiality.

4. RESULTS AND DISCUSSION

UCL Case Summary

Connected curriculum and research based teaching were at the predominant implementation stages at UCL since 2014. The case study student was from Computer Science background and had taken up the challenge of investigating possible new configurations of a robotic hand design applying a multi-disciplinary approach. Both hardware and software design considerations were initiated and investigated by the student with minimal guidance and supervision.

The student investigated different manual surgical instruments and proposed a switching mechanism for a robotic surgery hand where through the click of a button, gesture or even voice command, the hand could switch which kind of surgical tool it is holding and retract the unwanted or unutilized tool back into a sterilizing storage area within the hand or dispose-off the tool tip through a disposal chute embedded into a ‘disposal finger’.

The complexity of the problem demanded significant self-learning for the student as well as utilization of student teaching through peers of other departments. This was significant as in spite of not being a group project, the student reached out to others with complementary expertise to seek support. The student could also teach the supervisor areas from programming and core computer science at an adequate level necessary to understand the functioning of the overall system contributing to fair amount of teacher learning.

JKLU Case Summary

The Design and Prototyping course at JKLU was taken by all first-year, engineering students at JKLU in the 2018-2019 academic year. The course was intended to be a broad

introduction to design, and to train students on fabrication techniques that could be used in prototyping their designs. Instruction in the class was completely studio-style with students working in groups on different projects.

Student comfort-level in the class was mixed at the beginning of the semester due to number of factors such as being unfamiliar with the pedagogical approach, the utility of user-oriented design education in an engineering career, being uncomfortable working in groups, open-endedness of the projects, and student evaluations which were along several dimensions which students were not used to being evaluated on, including professionalism and teamwork. As the semester progressed, students became more comfortable with the pedagogical approaches taken, and started appreciating the utility of user-oriented design, in particular, after multiple interactions with the focus groups. Since the same cohort of students were also enrolled in an integrated, project-based, calculus and physics class at the same time, they received ample exposure to project-based learning as well as team-based assignments. As a result, their comfort level in working in teams in a studio-style classroom environment rapidly improved over the course of the semester.

At Olin College of Engineering whose curriculum and pedagogical approaches inspired many elements of the Design and Prototyping course, most of the enrolled students have had experience working on project teams in their high schools either through participation in club teams like the FIRST robotics competition or even in their classes. Furthermore, Olin College selects and opts for students who are interested in these approaches through its admissions process which includes an on-campus interview weekend. As such, Olin students have a higher comfort level with team-based learning environment and project-based education compared to incoming students at JKLU.

By the end of the semester however, JKLU students had an improved comfort level with the pedagogical approaches taken in the Design and Prototyping course. Additionally, a number of student teams worked on projects which they were interested in carrying forward in subsequent semesters. As such, for a first iteration of such a course in an engineering program, and with students who are unaccustomed to the subject material as well as pedagogical approach, this course can be considered a success. The keys to this success include a low student-faculty ratio of about 20:1 for this class, faculty members who had experience in design-based education, significant international experience, in particular from educational and professional work in North America and a subset of the faculty who were mentored by the faculty who underwent training at Olin.

Effects of the teaching-learning approaches

In order to understand the differences between the research, design and project based teaching-learning approaches, we first attempted to get a clarity about the interrelationships of the four

principal domains in the teaching-learning process: teacher's learning, teacher's teaching, student's learning and student's teaching. Based on observations of the information flow dynamics in research based, design based and project based approaches, Figure 1 was formulated.

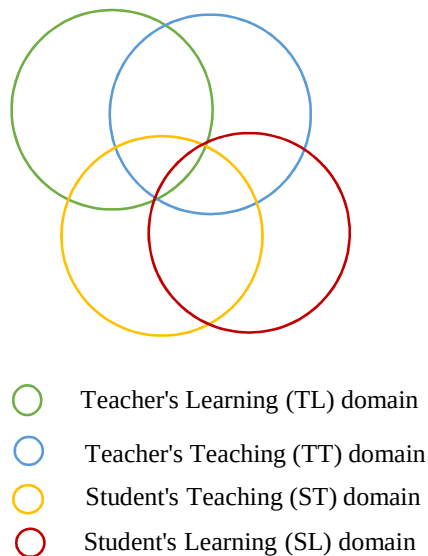


FIGURE 1: INTERRELATIONSHIPS BETWEEN THE LEARNING AND TEACHING DOMAINS OF A TEACHER AND HIS/HER STUDENT

The sizes of the domain circles and their extents of overlaps representing the strength of an interrelation are not to scale. They were found to be varying dependent on the approach based on the ethnographic inquiries of both students and instructors. It was observed that the extent of variation was dynamic and may change from class to class depending on various environmental circumstances and factors. The limited study conducted for this paper is not adequate to quantify the variations and project with adequate confidence any specific trends or patterns that may be considered indicative inferences, however, recognition of differences between research based teaching, research based learning, design based teaching, design based learning, project based teaching, and project based learning based on the interrelationship depicted in Figure 1 appears to be a good first step towards further investigations.

It can be said that in order to teach, a teacher first learns. The teacher's learning is a compilation of his/her learning from academic, industrial, career, life experiences, teaching experiences, feedback from students, what is learnt in a class from the student's successes and failures, peer teachers, etc.

While learning is by and large a receiving process, teaching is a delivery process- giving to the receiver either directly or indirectly. An important variant of delivering is facilitating that is more predominant in the relatively newer approaches,

compared to conventional lecture based delivery of content. While a teacher's teaching is largely derived from his/her learning as per above paragraph, it is also substantially influenced by both a student's teaching as well as learning.

A student's teaching was observed as taking several forms, for example, a higher extent of self-teaching in the case of the UCL student. While a student's teaching of the supervisor was also found to be of relatively higher level in the context of a multi-disciplinary domain design based approach (viz. the computer science student was motivated enough to appraise the non-core expertise areas of the design). On the contrary, the JKLU students provided general feedback, and performance as almost the only methods of teaching their teachers. Peer teaching is another important component of a student's teaching. This could not be assessed in the case of UCL due to lack of group dynamics in the Design based teaching-learning process in the particular case study, however, there was evidence of improvement in the JKLU focus groups as compared to conventional classrooms. The reason for improved peer teaching was observed as availability of more time during class hours for interactions with peers. In a conventional classroom, there is almost no opportunity for peer teaching; it is mostly achieved by personal friendships outside class hours. A significant outcome of this was a marginal to considerable improvement in the performance of the relatively weaker students in the focus groups.

Finally, a student's learning is the ultimate goal of the teaching-learning process. In an outcome based learning expectation followed at JKLU and most institutions of higher education across the globe, a student's learning is interconnected with the three other domains. It was observed that self-learning is an important part of success of the relatively newer pedagogic approaches, but the JKLU students were not fully prepared to embrace the same to begin with, requiring scaffolding through increased tutorial style interventions and extended support beyond the classroom. Some introduction of conventional style lectures is also contemplated that amounts to a hybrid approach between PBL and conventional class. Another approach adopted to encourage self-reading and understanding before a PBL session was to conduct short quizzes, or interactive question and answer sessions on expected prior-reading topics.

A summary of the indicative proportions of the strengths of SL-TT, SL-TL, and SL-ST interactions contributing to the student learning (SL) in the three approaches studied during the reported work, namely, Research Based Teaching and Learning (RBT-RBL), Design Based Teaching and Learning (DBT-DBL), and Project Based Teaching and Learning (PBT-PBL) is depicted in Figure 2. For providing a reference, the proportions estimated based on past experiences in a conventional classroom lecture based approach is also included. At this point, the findings are only ballpark indicators and need to be considered with caution in view of the small sample sizes, single geographic location in each country, and limitations of ethnographic

methods, student feedback and focus group discussions under these reported constraints.

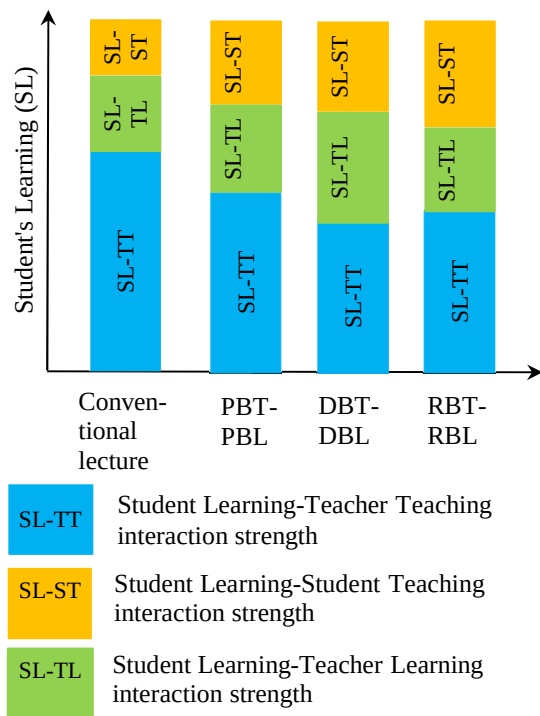


FIGURE 2: INDICATIVE PROPORTIONS OF THE STRENGTHS OF INTERACTIONS CONTRIBUTING TO STUDENT LEARNING IN PROJECT BASED, DESIGN BASED AND RESEARCH BASED APPROACHES

The differences observed in the indicative proportions of interaction strengths can be related to the subtle differences in the scopes of process specifications in the three approaches followed consciously or unconsciously by the teachers and students. In relative terms, the highest level of abstract reasoning exists in Research based Teaching-Learning approach, followed by design based, and project based approaches, in reducing order. Abstract reasoning can flourish more in interactive environments enhancing student teaching and teacher learning. There is very little need for abstract reasoning to be applied in a conventional lecture based approach in undergraduate engineering studies. While we tend to use the term “project” loosely and suffix the term with the other two terms, i.e. Research Project or Design Project; for the purpose of discussions in this paper, the three terms have different levels of connotations. A research based approach defines a problem in a way that needs a deeper critical thinking. A design based approach is more applied and relatively narrower in scope compared to research as it would focus more on the embodiments and their relative configurations and interactions. A project based approach can theoretically be either research oriented, or

design oriented, or a hybrid of the two depending on the strengths, constraints, and challenges of a group and its resources. That is the way PBL is implemented at Olin. However, to begin with, its adaptation at JKLU is intended to give students a flavor of applicability of theoretical teaching in practical real world situations to enable the students to be better equipped for actual workplace. As the PBL-PBT approach establishes and stabilizes, it can be progressively enhanced to demand increased elements of abstract reasoning skills.

Effects of other factors

Based on the observations during the study, it appears that a student working alone can seek external assistance through peer circles as evidenced from high level of interdisciplinary knowledge gained by the UCL student from peers. However, group working may help a relatively weaker student as the peer support is available more readily during the class hours itself, as was the case in JKLU.

The study reported in this paper is inadequate to come to an authentic conclusion as regards the desired year of introduction of a teaching-learning approach, although based on the limited UCL and JKLU cases it appears that with proper planning, it may be possible to introduce a change in pedagogy in either the beginning years or the later years. Factors that may be enabling this are, for example, maturity in student outlook, personality and need for placement in career path that may motivate higher level of capacity in an advanced year student to adapt to a new approach.

As regards influences of location on the effectiveness of pedagogic approach, as stated earlier that Olin College students were better prepared to embrace PBL due to their high school experiences; it appears that till there is major reform in the school education system in India which emphasizes heavily on memory based learning (ironically a legacy of the British era education system inherited and continued, although it has changed significantly in current U.K.), the western locations would remain relatively more conducive to teaching-learning approaches that demand a higher degree of abstract thinking. Nevertheless, the extent of success achieved at JKLU indicates that persistence and some degree of hybridization has the potential for a suitable model bespoke to Indian circumstances.

5. CONCLUSION

Based on the experiences gained through the implementation of design based teaching-learning as a variant of research based teaching-learning, and project based teaching-learning, preliminary findings indicate distinct characteristics of the three approaches in terms of different proportions of strengths of interactions contributing to student learning. This appears to be related to the levels of abstract reasoning required in different pedagogic approaches. Enhancement in peer learning can potentially assist weaker students in a group based studio setting. Some amount of hybridization with conventional approach appears to be necessary to begin with, until the school

education system better prepares the students in India to apply abstract reasoning during the learning process.

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