

Innovating final year (capstone) projects in engineering education

Dr. PradeepWaychal

SVKM's NMIMS (Deemed-to-be-University), Shirpur
Pradeep.waychal@gmail.com

Abstract : The final year (capstone) projects are the largest - and in many cases the only - projects that engineering students execute. The projects require sufficient attention both at the selection and execution phases. We designed and delivered a workshop to the final (senior) year students, at the start of the year. It helped them to choose projects aligned with their passions and that can solve real life problems. Twenty nine out of thirty seven students - who attended the workshop - opined that they changed the direction or the project. We require iterating the experiment with more number of students for validation of the concept and refining the workshop to accrue benefits to more students.

1. Introduction

The Project and Team-Based Learning instructional strategy has proven its efficacy. The challenges of the engineering education, such as the emphasis on outcome based education and the challenging 21st century problems, can be easily met with the strategy. We believe that it is not possible to meet requirements articulated by leading educators and mandated by various accreditation agencies without using the strategy.

Sibley and Spiridoff have noted that the TBL results in course goals shifting from knowing to applying, the teacher changing his role from “sage on stage” to “guide at side” as voiced by Murray Gell-Mann and students becoming more active and taking responsibility for learning. Michaelsen based on his medical education study has argued that team learning allows efficient use of instructional resources without sacrificing the ability to develop students' higher level cognitive skills, providing social support for students, promoting the development of interpersonal and group skills, and building and maintaining the enthusiasm of faculty members.

Perrenet, et al. point out benefits of PBL in early years as helping in motivating and cognitive aspects better than the conventional teaching approach and, and in later years as taking on more open and complicated problems. Mills and Treagust, reviewed evaluations of project-based learning programs in engineering to conclude that the students participating

Dr. PradeepWaychal

SVKM's NMIMS (Deemed-to-be-University), Shirpur
Pradeep.waychal@gmail.com

in the program demonstrate better motivation, communication and teamwork skills, and better understanding of issues of professional practice resulting in satisfying industry requirements. They have warned the downside of the strategy as weaker engineering fundamentals and extra effort required by projects and possible interpersonal conflicts. Prince and Felder have found many benefits of the strategy such as adoption of deeper approach to learning, challenging dualistic type of thinking, and acquiring critical thinking and self-directed learning skills resulting in broad range of learning outcomes. Bell has explained that Project-Based Learning (PBL) helps students develop 21st century skills. Dym, et al. have proven that the first year (freshman) – corner stone – projects' result in increasing retention and quality of the engineers. A host of universities around the world - Aalborg, Roskilde Denmark, Bremen, TU Berlin, Dortmund and Oldenburg in Germany, Delft and Wageningen in the Netherlands, Monash and Central Queensland in Australia, and Olin in the US - have reported benefits of TBL-PBL.

Dyer has rightly cautioned difficulties in administering the strategy. He asserts that the TBL PBL is just not forming teams and allocating projects but involves helping students function as good teams. Otherwise, the end result may be just a few students taking over and completing the task. This may result in many students harboring negative feeling about team activities before they start their professional career.

Thus the benefits of TBL-PBL are articulated well by policy makers and proven emphatically by researchers – albeit more in qualitative than quantitative way.

Students can work on projects right from their first (freshman) year. Some institutions have introduced such corner stone projects. Many leverage the PBL TBL strategy in the second (sophomore) and third (junior) years through standalone courses or a part of design courses. All such projects tend to be smaller and simpler. It is only in the final (senior) year that students get to work on larger and complex projects. Such senior or capstone project courses have existed at engineering schools for many years. They provide student engineers the opportunity to solve real-world engineering and perhaps open ended problems, and have been highly regarded as important learning activities. When asked how beneficial their capstone program was to their students; faculty members overwhelmingly felt that their programs were very

beneficial to their students, with a rating of 8.6 on a 10 point scale.

Over four thousand Indian engineering institutions admit around 1.6 million students every year and almost all of them graduate. They work on capstone projects with a team of 3-4 people working for around 4-6 full time months resulting in more than 40,000 projects with 80,000 person year efforts. If these efforts are properly guided, we may be able to provide innovative solutions to many critical real life problems and groom students to be great engineers with pronounced innovation competency.

The innovation competency is highly desirable as the engineering field is becoming increasingly complex across all its branches. The complexity has increased even more due to a growing interdependence among disciplines and the emergence of a wide range of new technologies. It has been observed that recent engineering graduates lack this competency. The traditional and still dominant engineering curriculum at most universities, especially in third-world countries, makes little provision for developing it.

2. Workshop on 'Innovating Success through B. Tech. Projects'

There are no two views about criticality of innovation competencies in engineering profession. Engineering education, therefore, must take appropriate steps to develop it. The capstone projects are indeed a great opportunity to develop or refine the competency. Recognizing this, we designed and delivered a workshop with the following elements.

The workshop used the definition of innovation as "fresh thinking that delivers value to customers". It was designed on the principles that "Creativity can be taught," "Student Centered Learning is a good instructional strategy for developing creativity," and "Challenges and Diversity are good accelerators for developing creativity."

The workshop started with convincing cognitive, affective and executional requirements for successfully executing a mundane to exotic project or activity. We refer to this as requirements of head, heart and hand working in coordination and label it as a 3H model. Then we clarified that innovation is born to a challenge (about which you have passion). We defined the passion as undying enthusiasm despite

conductive or non-conductive environment. We then presented the fourteen grand challenges, and major Indian challenges and Indian National Academy of Engineering (INAE) initiatives. We also asked each engineering department head and school head (we have pharmacy and textile schools on our campus) to present the problems that would require engineering solutions. Based on this, we asked each student to choose challenge about which they feel passionate and formed teams. We then explained innovation process and administered a team exercise of building a water container with the help of newspaper and some stationary. That helped them to both understand the process and their team mates. We also equipped them with knowledge of the seven habits. We presented some of the real life innovation examples as well as creativity techniques. The techniques were illustrated by asking them to generate ideas in the challenge that they have chosen. We then discussed various possibilities around their challenges, ideas and potential projects.

3. Result

The workshop was very well-received and earned a rating of 4.4/5 from the participants and excellent qualitative feedback such as it was highly interactive, inspiring and motivating. They did feel that the workshop was longer. We also asked them the project that they had planned before coming for the workshop and at the end of the workshop. Some of the sample responses to that are provided in table 1 below.

Project Before the workshop	Project after the workshop
Was not decided	Work in the field of nonconventional energy
Machine to test shape of belt	Electricity generation using biomass
Not decided	Not finalized but now have a direction of thought
My project was sticking to just my department	Now I am going to work with other departments
Any analysis project	Education application - it is in the field of my passion
Nothing	A material to be made to reduce air pollution
Was very vague and I didn't have any clear idea	Is much more streamlined and to the point
Collaboration tool	Low cost water cleaner

Analysis of refrigerating system	Solving difficulties of pharmacy laboratories
Simply for myself and my grades	Innovating and deployable for other's use
Mobile app development	Give it a second thought
Designing of some instrument	Designing solar water cooler

Table 1: Projects before and after the workshop
We analyzed all the responses and have presented them in figure 1 below.

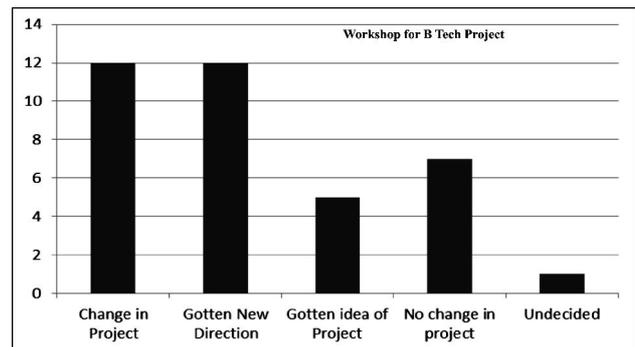


Figure. 1: Response of students with respect to their pre-workshop and post-workshop projects

4. Conclusion

Project and Team based learning instruction strategy is emerging as a panacea for the current and future challenges of engineering education. The strategy can be used right from the first year with projects of increasing complexity in the subsequent years. Of course, there are enough institutions where students work on their first project in the final year. In any case, the final year (capstone or B Tech Projects (BTP)) project becomes the most important part of the engineering education and can provide maximal returns to the students, institution and perhaps industry, government and social organizations. The project can be executed with innovative elements in it and can include solving some real life problem that can help either industry or other organizations.

We did so by conducting a day long workshop on 'Innovating Success through B Tech Projects'. The workshop introduced students to 'what, why and how' of Innovation - especially in Indian context. The 'how part' emphasized the need of identifying the challenge about which they feel most passionate. Each of them was counseled to choose a project in close alignment with the challenge and that has right scope and size. Out of the 37 students who attended the workshop, all but seven students did not change the project and one

remained undecided. The remaining students either changed or zeroed on their project or changed the complete direction.

We require tracking the complete project life cycle and propel students towards innovative elements in it at every stage. We also have to run the workshop at different colleges in different geographies and validate the impact. We require industry organizations using the projects choice and project execution as one of the important tools in their selection process.

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