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The Role of Project-based learning in first year engineering

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Abstract

The integration of professional competencies into the curriculum, which complement the technical expertise of engineers, is a prevailing worldwide trend in education. Consequently, every engineering program makes it a primary objective to provide engineering students with opportunities and learning settings that nurture the growth of professional skills right from the first year of engineering. Engineering educators presents a remarkable challenge, mainly due to the extensive requirements of modern engineering programs, which encompass instruction in mathematics, science, communications, project management, and design. Moreover, there is a range of additional skills essential for engineering professionals, including teamwork and effective communication, fostering creativity and design capabilities, as well as the ability to adapt and thrive in dynamic working environments that undergo constant change. The primary goal of the chosen instructional approach was to enhance student engagement and retention among freshmen by providing them with a hands-on engineering design experience. It is now widely acknowledged that improving the retention rates of engineering students can be achieved by incorporating introductory engineering courses alongside the traditional math and science classes within the first-year engineering curriculum. Faculty members who are dedicated to educational reform have recognized that passive lecture-based instruction should be replaced with active, integrative, project-based learning. Design plays a pivotal role in engineering education as it bridges both engineering and design disciplines, encouraging collaboration in multidisciplinary teams. Project-based learning stands out as one of the most effective approaches for cultivating these skills. This teaching method enhances student engagement and enables them to apply their freshly acquired skills to real engineering challenges. This review article aims to delve into the impact of project-based learning in the first year of engineering education, highlighting its role in transforming traditional teaching methods and equipping students with the practical skills and problem-solving abilities crucial for success in the engineering field.

Introduction

This review article explores the impact of design-based projects, commonly known as "design challenges," on enhancing student engagement and their retention in engineering programs. This study also targets to understand engineering students' preferences concerning design-based projects compared to traditional classroom and laboratory experiences.

The emerging global trend in education involves integrating professional competencies into the curriculum, complementing the technical aspects of engineering. Engineering education should be complete with technical knowledge in addition to the development of professional skills. Starting this process from freshmen engineering ensures students are well-prepared for future roles and contribute positively to the engineering profession. The introductory engineering course plays a critical role in establishing the foundational framework within which engineers operate. It serves the dual purpose of encouraging students' interest in the field of engineering and stimulating their motivation. Typically, students choose engineering programs because they

aspire to create and construct. This design-based project acts as a catalyst, by providing the initial guidance to set their engineering aspirations [1, 2, 3, 4]. There was a growing sense that incorporating discipline-specific design-related coursework into the curriculum at an earlier stage could potentially surge retention rates [5]. Engineering faculty members who are dedicated to advancing educational reform have recognized the inadequacies of passive lecture-based instruction. They understand that it should be replaced by active, integrated, and project-based learning methods [6].

According to Jonassen, Strobel and Lee (2006) [7, 10] Problem-based learning transform the classroom into an example of a professional engineering environment, providing students with the experience and skills they need to excel in their future careers. Frank and Brazilai 2002 [8, 10] McAlpine, Reidsema and Allen (2006) [9, 10] Project and problem-based learning methods inspire active learning and development of interdisciplinary knowledge [10].

Engineering educators believe that students should possess the capability to comprehend how to create design specifications and to progress from these specifications to the realization of a final product. Developing clear objectives and criteria, the generation of multiple design alternatives, the process of synthesizing, analysis, the physical construction of prototypes, testing, and evaluation. ABET, mandates that every engineering student's academic journey must encompass a significant engineering design experience. This experience should culminate their foundational learning, mathematics, basic sciences, humanities, social sciences, engineering principles, and practical communication skills [11, 12, 13]. Incorporating design content into the first year of engineering education is not a recent innovation. In fact, during the 1990s, universities across the United States introduced "Freshman Design" courses were introduced, however these the design projects were deliberately simple. The National Science Foundation's Gateway Engineering Education Coalition played a leading role in supporting this approach, with a specific focus on introducing design principles early in the engineering curriculum to enhance student retention rates [5].

Hyman, “a proposed solution to a problem,” identifies the engineer’s constraint that “the design itself is a value-added proposition, meaning there is a business value in the solution, or else why bother designing it?”. As summarized by Jerry Jenkins, CEO of Texas Instruments; “Most engineering jobs involve design and practice, not theory and research.” [10]. While there are undisputable benefits to integrating design problems into the curriculum during the freshman year of engineering education, it's important to acknowledge that such integration often demands a substantial commitment of faculty time and resources [15].

Project Based Learning

Project-based learning is an educational approach that promotes students to acquire a diverse set of skills and knowledge by creation of their own projects. This approach not only expands their understanding but also develops problem solving abilities and critical thinking.

This review article targets to explore the effectiveness of project-based learning in the freshman year of engineering education. In response to this educational trend, many institutions have crafted and introduced their introduction level engineering design courses, emphasizing hands-on

experience, and learning through project. Recognizing that each educational program is distinctive, and learning outcomes can vary significantly, it's essential to emphasize the need for monitoring and data collection. In this context, the author has few illustrative cases to demonstrate how the introduction of freshman year engineering design courses can influence student learning.

The current consensus in the academic community acknowledges that improving the retention rates of engineering students can be achieved by incorporating introductory engineering courses into the first-year engineering curriculum together with traditional math and science classes. Furthermore, integrating engineering design projects into the first-year curriculum, offers students valuable exposure to the distinctions between engineering and science. These projects enhance students' motivation for engineering and deepen their understanding of the field. [15].

The Rowan University introduced project-based learning in their first year Mechanical Engineering program, and the previous first year curriculum closely resembled many engineering programs, with mathematics and fundamental science courses. Discipline-specific design courses were introduced later in the program. This approach raised two significant concerns; firstly, students were introduced to hands-on design challenges only during the junior and senior years of their engineering education. As a result, the first two years were often perceived as lacking real-world context, with students primarily focusing on mathematics, basic sciences, and engineering theory without experiencing practical applications. Secondly, the Mechanical Engineering department faculty expressed concerns regarding student retention, particularly after the freshman year. Introducing discipline-specific design content earlier in the curriculum could help address this issue and potentially improve retention rates.

One notable feature of the new curriculum is the incorporation of two large-scale design projects, which are designed to engage students more intensely in practical engineering challenges.

Project 1- The Compressor Project: The objective of the compressor project was for students to undertake the design, construction, and testing of a compact air compressor, aiming to achieve the highest possible pressure and/or flow rate. Students were organized into teams of three or four, where they collaborated to determine the appropriate dimensions for the compressor's components. It's worth highlighting that virtually all the students who are engaged on this project with no prior experience in design or fabrication. At the project's outset, it was announced that two awards would be conferred: one for achieving the highest-pressure output and another for attaining the maximum flow rate.

Project-2- The walker Project: In contrast to the complexity of the first project, the second project was considerably more straightforward. Here, students were tasked with designing and constructing a simple walking "toy" employing a small, battery-powered motor.

In terms of student learning and satisfaction, the course proved to be a resounding success. Each team managed to successfully design and fabricate a functioning air compressor, and nearly every team successfully created a walking toy. In summary, the decision to shift Mechanical Design to the first semester of the first year seems to be a well-founded one.

Regarding the design projects, an overwhelming majority of the students, exceeding 90%, believed that both the projects were well-suited for first-year students. The feedback from students deeply illustrates their enthusiasm for hands-on design projects and the substantial educational value they gain from such experiences and similar % age of students expressed their intention to continue their studies in mechanical engineering. [5].

Louisiana Tech University developed a new concept based on project-based learning called Living with the Lab. It was introduced to their first-year engineering course along with regular math and science courses. The program also compares traditional laboratory and shop settings and the Living with the Lab curriculum.

In traditional laboratory and shop settings, it falls upon faculty members or technical staff to ensure that the necessary equipment is readily available and that supplies are well-stocked, allowing for the construction of prototypes or data collection. Managing these requirements over an extended period, especially with a large student cohort, can prove challenging and sometimes unmaintainable.

An innovative approach involves assigning robotics kits to individual students or student groups, effectively enabling the "laboratory" or "design platform" to accompany them wherever they go, be it their dorm rooms, or anywhere else. Besides, they have become expert at resolving most issues independently or with minimal guidance.

By entrusting students with the control of their own kits, we open the door to significantly enhancing experiential learning. This approach enables students to essentially live with the lab, resulting in increased hands-on engagement without placing an excessive burden on faculty time and resources.

The primary goal of the Living with the Lab curriculum is to cultivate innovative students who possess a can-do attitude. This is achieved through a project-based educational approach where students continually apply their technical knowledge and fundamental skills to tackle real-world problems. At its core, the curriculum firmly believes that when students take ownership of their laboratories, it not only encourages their learning but also expands the range of projects and design challenges they can undertake.

A Student’s t-test was conducted to assess the performance means of common course outcomes between the traditional and the Living with the Lab curricula. The results showed that the performance means for the Living with the Lab curriculum considerably surpassed those of the traditional curriculum.

We firmly believe that the newly employed project-based Living with the Lab curriculum is highly effective with abundant openings to develop the skill sets associated with hands-on learning. Our enthusiasm for this approach is tangible, and we are eager to extend this project-based experiences to courses across various engineering disciplines [6].

Virginia Military Institute introduced design-based projects, commonly known as "design challenges," to measure the impacts on learning and the possible increase of retention rates in the Mechanical Engineering program. Additionally, to explore engineering students' preferences

concerning design-based projects compared to traditional laboratory experiences. The LEGO clock project from the earlier lab-based course and the hovercraft project as part of the newly introduced project-based learning were introduced to the first-year engineering students.

Upon completing these projects, a survey was administered to investigate whether students intended to continue pursuing Mechanical Engineering or plan to change their major. Four years of survey were compared for analysis; in these four years, an approximate average of 87% of students in mechanical engineering decided to stay in the program. However, the retention rate didn't meet the high expectations compared to previous years before the implementation of project-based learning. The remaining 13% chose to change their majors or leave the institute by the end of their first semester. The reasons for their departure varied: some encountered difficulties in the calculus and chemistry courses. Some students felt that Mechanical Engineering did not align with their initial expectations. Therefore, it is conceivable, though not yet confirmed, that we might observe an uptick in retention rates after the freshman year, subsequently leading to higher graduation rates among students who opt to continue in mechanical engineering. The Virginia Military Institute intends to track these retention and graduation rates in the following years to gather more insights and plan to integrate more of these projects into the Mechanical Engineering course. This approach aims to enhance motivation among students and encourage more of them to persist in the mechanical engineering program beyond their freshman year [15].

"At the Universidad del Valle de Guatemala in Guatemala, a study has been conducted to explore students' viewpoints regarding a practical learning experience. This study introduces didactic models aimed at enhancing student engagement and compares them to the conventional engineering educational approach. The goal is to evaluate the impact of these innovative methods on students' overall educational experience." As they constructed each didactic model, students discovered that each one demanded a distinct strategy and planning approach. This variability surfaced from factors such as size, shape, tool requirements, and the level of effort needed for tasks like cleaning, lubrication, painting, and cutting.

Additionally, the project necessitated several technical lessons and the ability to make informed technical decisions. Throughout the project, students expressed that they gained valuable insights into mechanisms and mechanical components as they disassembled and reassembled them. Many of these mechanisms were new, prompting extensive research into their functionality and integral parts.

Students realized that project planning and effectively managing a team of volunteers presented challenges beyond their initial expectations. Engaging in this project proved to be a valuable opportunity for students to gain essential skills, including leadership, time management, organization, project planning, and teamwork. These experiences enriched their personal and professional growth, highlighting their education's practical and hands-on aspects. When asked about their preferences for learning methods, a significant 81% of students expressed a preference for utilizing the models. The remaining 19% of students were divided in their choices, with some favoring learning through projects, videos, and traditional classes. A substantial 90.5% of students believe that the models have significantly contributed to their learning

experience. These findings highlight the effectiveness of the learning experiences for most students [16].

Conclusion

The current global trend in education is marked by integrating professional competencies into curricula, complementing the technical aspects of engineering. The introductory engineering course is pivotal in laying the foundational framework within which engineers operate. There has been a growing realization that including discipline-specific design-focused coursework at an earlier stage could significantly increase retention rates. Engineering educators contend that students could not only grasp how to formulate design specifications and actualization of a final product. Multiple reviews show that student engagement with multitasking in project-based learning has been notably higher compared to traditional classroom settings. While it is evident that project-based learning enhances student learning in various aspects, such as project management, decision-making, project execution, and research. It's essential to acknowledge that the impact on retention rates requires more comprehensive data analysis since, it’s relatively variable each year, and influenced by diverse student populations and regional factors. Nonetheless, many universities and higher educational institutions are implementing a unified or shared first-year engineering course featuring numerous projects. This approach aids students in exploring their desires and making informed decisions about their specific engineering majors or even considering alternative paths outside of engineering.

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