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Need for Strengthening the Transferability Skills in Undergraduate Civil Engineering Students

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Abstract

The conventional domains of engineering knowledge, like civil engineering, are undergoing a tremendous transformation with the emergence of newer technological solutions. The majority of these solutions require operational convergence, placing a heavy demand on the academic learning process to ensure that graduates possess the skill transferability required at the workplace. This study examines the transferability of design skills in undergraduate civil engineering students through a longitudinal study conducted at the Kerala Technological University. In particular, the study analyzes the impact of freshmen *Design and Engineering* course on the transferability skills demonstrated by the same group of students in a senior-year *Group Project* course in the civil engineering program. The findings show that although most students displayed commendable skill acquisition in the freshmen course, the application of these acquired skills in the senior year course was suboptimal. This suggests a misalignment between skills learned and their translation into learning adaptability. The proficiency of students in identifying and applying the learned skills to a different setting and situation, as well as the ability to converge different learned skill sets and apply them in a new situation, was limited. This study highlights the challenges faced and the need for implementing a structured approach to include and evaluate students' transferability of learned skills throughout the program so that students can be prepared to leverage emerging opportunities in a knowledge-based economy.

1. Introduction

The advent of technology has brought a tremendous transformation of the teaching-learning process in engineering education regarding its content and delivery. As technologically assisted pedagogic approaches become increasingly common and data-driven decision support systems gain prominence in the professional domain, there is an urgent need to equip students to thrive in a knowledge-based economy [1]. Technological innovations in analytics, optimization, information sourcing, and prediction using tools like artificial intelligence help students overcome the barrier of resource access in the learning process [2,3]. The aforementioned tools are found to be effective in assisting the industry in rapid production and automated decision-making. As a result, traditional undergraduate engineering programs, like Civil Engineering, require a structured approach to ensure the transfer of learned skill sets and competencies to meet the demands of a knowledge-based economy [4].

The current job market demands more added responsibilities from a job seeker in terms of abilities in reskilling and upskilling themselves based on the developments in the domains of science, technology, engineering, and mathematics. The changes in the workplace due to the incorporation of artificial intelligence-based solutions strengthen the need for the learner to acquire competencies in skill delivery rather than learned knowledge. Universities have started focusing on specific skill incorporation in the taught programs, which could be adapted to various working environments. Thus, the need for assessment of taught skills and the ability of the learner to translate them becomes an inevitable component of teaching-learning assessments [5].

Various studies have highlighted the increasing importance of transferable skills in civil engineering education and their impact on the success of graduates in meeting industry demands [4,6,7]. Some of the widely recognized transferable skills are communication, teamwork, problem-solving, critical thinking, leadership skills, ethics, and adaptability [4,8]. The curriculum models used for the development of transferable skills are embedding, bolting-on, and integrating. In the “embedding” strategy, the transferable skills are incorporated directly into existing courses. Whereas “bolting-on” focuses on the explicit development of transferable skills as separate modules along with the core curriculum. The “integration” approach weaves transferable skill development throughout the entire curriculum in a systematic manner [9,10]. Pedagogical approaches like project-based learning, experiential learning, active learning, and interdisciplinary collaboration have been used for transferable skill development [11]. Additionally, many engineering courses rely on engineering design problems to develop skill transferability in students [12,13]. Assessment methods employed to evaluate skill transferability are surveys and reflections [14], standardized tests [15], and peer and expert/instructor evaluations. There are a limited number of studies [15] that track the skill transferability of a cohort of civil engineering students over a period of time. The data collected at multiple points in time can provide valuable insights into the long-term effectiveness of educational interventions in promoting skill transferability, inform curriculum design and pedagogical practices, and help in bridging the gap between academic preparation and industry expectations.

For the present study, we tracked the performance of the same cohort of students enrolled at Kerala Technological University across two different required courses within a civil engineering curriculum – *Design and Engineering* in freshmen year and *Group Project* in senior year. The first course, *Design and Engineering* in freshmen year was introduced as part of a new curriculum at the Kerala Technological University with specific learning outcomes targeting the attainment of skills in the cognitive, affective, and psychomotor domains. Mechanisms were in place to ensure high attainment levels for these learning outcomes during the course delivery in freshmen year. Though most students displayed commendable skill acquisition during their learning journey of the freshmen course, the application of these acquired skills in a senior year course *Group Project*, was suboptimal. The objective of the study is to assess the ability of students to transfer skills learned in freshmen year to a senior year group project. Specifically, the proficiency of students to identify and apply learned skills to a different setting and situation, and the ability of students to converge different learned skill sets and apply in a new situation are evaluated.

2. Background

A new undergraduate civil engineering curriculum was implemented at the Kerala Technological University prior to this study. This section provides an overview of the underlying vision guiding the introduction of *Design and Engineering* and *Group Project* courses within the new curriculum. Figure 1 illustrates the stages of competence expected in the students undergoing the four-year undergraduate civil engineering degree course as per the new curriculum. The knowledge component integrated into the course envelopes all the major subject domain knowledge levels with the outcomes designed following those listed by the ABET framework for engineering education [16]. The emergence of newer tools and techniques, which mostly consist of cross-disciplinary knowledge, demands an ability to improve the existing skill competency level and re-learning capability among the students. This aspect becomes clearer to students only when the students encounter a scenario that challenges the need to acquire an improved skill than that is already acquired by them. As displayed in Figure 1, the ability to transfer the learned skill is the culmination of all learning undergone by the students across the entire program.

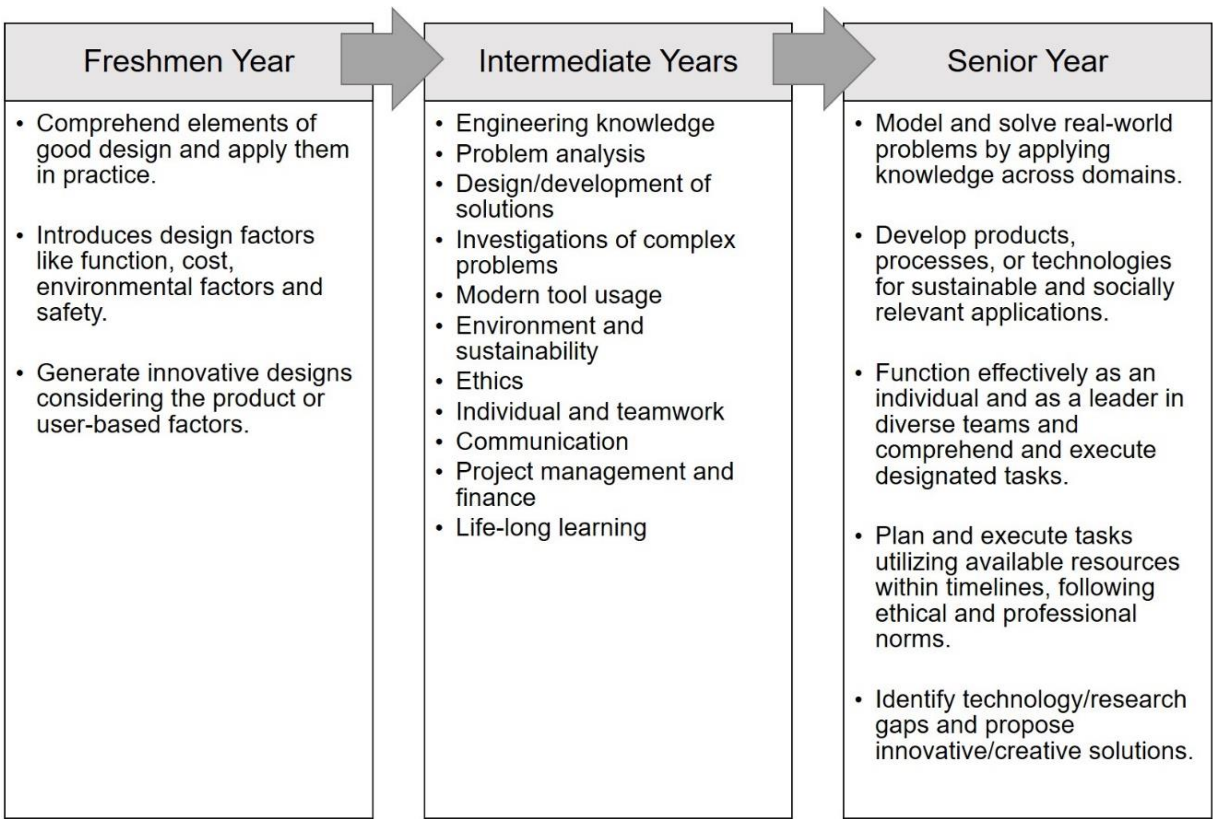

Figure 1. Learning outcomes designed to ensure design skill transferability component in engineering learning

The learning modules designed across the program create a well-structured layered knowledge system. The fundamental courses provide a proper learning background for the broad domain of study. They take the learner through the various diversified knowledge modules, which address a wide level of civil engineering knowledge spanning from simple components of the built environment to large infrastructural systems. The learning levels are designed for the sequential delivery of knowledge modules like system planning requirements, design for both the geometry and material, operation and maintenance, and end-of-life cycle and disposal. The curriculum expects the student to use the acquired knowledge in an appropriate combination based on the situation encountered by an engineer during professional practice. Often, the learning undergone by the student is unable to provide a vision regarding the manner of utilization of acquired knowledge for a given situation. This culminates in the student ending up as a re-learner of all the processes needed in the professional domain. The *Group Project* course was intended to be an opportunity for the students to undertake an introspection on the transferability ability acquired by them.

The *Design and Engineering* course was delivered as an early course to enable students to comprehend the entire cycle of the thought process of product design. As envisaged, the student would move through specific steps of action as illustrated in Figure 2. The general process for which a student is trained through this course would culminate in an understanding of several steps leading to a final product or an implemented solution. This provided an opportunity for collaborative actions and operational interlinkages not limited to a specific body of knowledge. As the *Design and Engineering* course was placed prior to the delivery of the major core subjects in the civil engineering curriculum, every subject that would follow in the subsequent semesters was expected to adopt the design thinking as done in the *Design and Engineering* course. The acquisition of the transferability skill among the students is assessed from the overall performance on the *Group Project*.

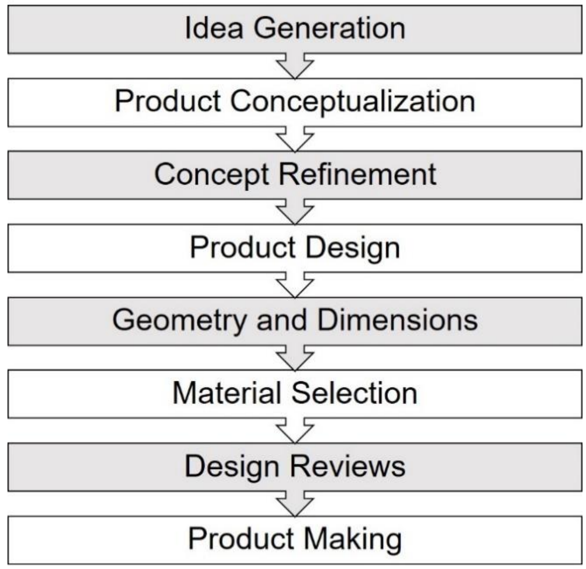

Figure 2. Skill acquisition process in the freshmen course on *Design and Engineering*

3. Methodology

The transferability of skills learned in the freshmen *Design and Engineering* course, to a senior year *Group Project* course was evaluated for a cohort of students. The study period was from 2018 to 2022 and tracked a group consisting of four-year undergraduate civil engineering students. Sixty-two freshmen enrolled during 2018-19. The same cohort in senior year 2021-22 consisted of 72 students. The difference in the student numbers is due to the lateral transfer facilities provided to the students from different institutions. To have a consistent data sample, 60 students consisting of 36 males and 24 females, who were able to progress together from the freshmen to the senior year in four years (2018-2022) were selected as the study group.

The freshmen *Design and Engineering* course was a three-credit course aimed to introduce the students to fundamental principles of design engineering, steps in the design process, and basic tools used in design. The *Group Project* course was a six-credit course in senior year intended to impart the ability to transfer design skills to diverse scenarios. *Group Project* required the simultaneous application of diverse skill elements already learned by students and the design thought process acquired through the course *Design and Engineering*. The modified skills that might be required by the students to address specific engineering challenges are chosen by them in the group project exercise. This action would stand as the testimony of their ability to understand the need for skill transfer required for a particular situation. The assessment structure for the freshmen course on *Design and Engineering* comprised 40% credit for a written test on design aptitude and creative thinking and 60% for design product submission. The *Group Project* was evaluated (100% credits) by a product/report submission and presentation at the end of the semester.

Skill sets acquired by the study group in the freshmen course on *Design and Engineering* and their influence in conceptualizing various design problems in the senior year *Group Project* were evaluated in this study. The design product submission/presentation for both *Design and Engineering* and *Group Project* are assessed by the instructors based on the following four evaluation criteria: i) ability to evolve solution sets; ii) ability to choose appropriate approach to arrive at the solution; iii) ability to identify the need for new skills/methods to arrive at the solution; iv) generation of the best possible solution. Numerical data from student grades in the two courses were used for quantitative analysis of skill development and transferability. Specifically, the scores obtained by students in the *Design and Engineering* course across the four evaluation criteria mentioned above were compared with their corresponding scores in the senior-level course on *Group Project*, as a measure of the transferability skills attained by the study group.

4. Results and Discussion

The performance of students in the courses *Design and Engineering* and *Group Project* are presented in Table 1. The students were monitored for the attainment of four abilities as described in the methodology. Additionally, the influence of abilities attained in the *Design and Engineering* course on the *Group Project* work undertaken by the same group of students in their senior year was examined. Comparing the overall scores, it is seen that 33% of the students excelled (scoring 85% or higher) in *Design and Engineering*, and only 5% of the same students achieved excellence in *Group Project*. This difference indicates a gap in the ability to transfer skills learned in freshmen year to senior year. Similarly, 35% of the students in *Design and Engineering* demonstrated excellent scores in their ability to identify skills needed in a new situation, and only 5% did the same in the *Group Project*. Furthermore, the evaluation of the ability to converge the different skill sets as measured by the ability to generate the best possible solution, showed results consistent with overall scores. This indicates a misalignment between skills learned and the ability of students to translate or adapt their earlier learning in the possible applicable domains. A gap exists in the teaching-learning process to ensure the transferability of skills among the students.

It is observed that the introduction of the freshmen course on *Design and Engineering* was intended to provide engineering design thinking in all the higher courses of learning. It can be said that the curriculum in this study used a combined embedded and bolted-on approach [9] by adding the two courses *Design and Engineering* and *Group Project*. However, the courses that were delivered during the intermediate years followed an instructional pattern not specifically adapted toward engineering design thinking. This could be one of the reasons why the abilities attained in the freshmen *Design and Engineering* course demonstrated a limited influence on the senior year *Group Project* course.

Table 1. Evaluation of skill transferability for a group of 60 students in *Design and Engineering* (DaE) and *Group Project* (GP)

Parameters of Evaluation	Excellent (Grade score 85 % and above)		Good (Grade score -60 % and above but less than 85 %)		Fair (Grade score -45 % and above but less than 60%)		Poor (Grade score - less than 45%)	
	DaE	GP	DaE	GP	DaE	GP	DaE	GP
Ability to evolve solution sets	22	3	32	27	6	26	Nil	4
Ability to choose appropriate approach to arrive at the solution	21	3	33	25	6	28	Nil	4
Ability to identify the need for new skills/methods to arrive at the solution	21	3	33	24	6	29	Nil	4
Generating the best possible solution	18	2	36	21	6	33	Nil	4
Overall Grades obtained	20	3	34	24	6	29	Nil	4

Furthermore, the curriculum specified in this study was a common curriculum that was adopted across many institutions under the Kerala Technological University, India. The general framework adopted is common to all institutions, however, the delivery mechanism adopted at each institute has wide variations as the normalization of approaches across affiliated institutions is not explicitly stated in the curriculum. This aspect raises the requirement of specific instructional steps comprising of classroom delivery and assessment patterns to ensure the desired learning outcomes for the students. As technology-enabled newer pedagogical instruments are being introduced such instructions are needed to confirm the changes in the teaching-learning process adopted in the affiliated mode of institutions, unlike in the schools or departments managed directly by the university where the academic policies development and implementation collaborate very closely.

One of the limitations of the study is the subjectivity of the instructor-assigned grades in *Group Project* assessments. Other types of assessments like surveys, reflections, or standardized tests [15] could be incorporated to diversify the data sources and give insight into student perspectives. Data on the transferability skills of students under the previous curriculum is missing; therefore, this study cannot provide insights into the curriculum improvement. Besides, since this curriculum is intended for adoption by multiple institutions a larger sample of students from different institutions could give a more comprehensive understanding of variation in teaching-learning practices across institutions. Future work could involve studies on refining the assessment methods, conducting qualitative evaluations of student experiences over a longer period of time, and analyzing larger datasets from different institutions that follow the same curriculum.

The following are some specific areas to focus on to improve the transfer of knowledge and skills from freshmen to upper-level courses.

- Assessment methods can include evaluation of the thought process of students in developing a solution alongside the assessment of final outcomes. However, this means that diverse assessment processes may be necessary given that each learning group might have a unique thought process, intermediate steps, and approaches in problem-solving. Assessments methods developed for interdisciplinary learning [17], systems thinking [18] and case studies [19] could be adapted with the help of instructional designers and used by the instructors.
- Instructors require training and support to prioritize the transferability of skills using metacognitive strategies. These strategies can guide students on how to reflect on the learning process, make connections, and apply to new situations [20, 21].
- Project-based learning (PBL) experiences need to be spread across the curriculum, starting from freshmen courses and extending into upper-level coursework. Despite the effectiveness of PBL instructors often face challenges in administering them, hence training and support to faculty may be necessary for its effective implementation [22].

5. Conclusion

The potential of a new civil engineering curriculum with a freshmen *Design and Engineering* course and a senior year *Group Project* course to improve the transferability of learned skills was examined in this study. The skill sets acquired by a cohort of sixty students during freshmen *Design and Engineering* did not manifest well in the project exercises undertaken independently by them in the senior year *Group Project*, though they had excelled in the training provided for the transferability aspect through the course *Design and Engineering*. The study results have indicated a misalignment between the cognitive, affective, and psychomotor learning outcomes attained and the ability of students to translate or adapt their earlier learning to the diverse domains chosen by them for their independent contribution. The ability to forecast the skill demand for different situations for better professional delivery is less appreciated at the end of the program. The results presented in the study have emphasized the need to integrate the skill transferability component at different academic learning levels. Consequently, there is a need for more investigations to explore approaches to incorporate and measure the transferability of learned skills in students, as well as to establish specific benchmarks to assess achievement in this aspect.

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