Evaluation of Transfer of Learning in a Pre-College Engineering Short Course (Evaluation)

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ABSTRACT

Engineering classrooms aim to prepare students to tackle multidisciplinary problems. It is impossible and impractical for instructors to cover every variant of a problem. Instead, instructors emphasize preparing students to address scenarios beyond those explicitly taught, bringing the concept of "transfer of learning" to the classroom. This education theory involves students applying previously acquired information, strategies, and skills to unfamiliar contexts. Since the turn of the century, extensive educational research and industry training-oriented efforts have worked on developing mechanisms to assess this transfer. However, many existing assessment methods are proprietary or very tailored to specific training applications. In this study, the authors adapt the Factors for the Evaluation of Transfer (FET) model [1] to evaluate the effectiveness of transfer of learning in a pre-college engineering short course. This model considers the transfer of learning through dimensions (trainee, training, and organization), achieved learning, and intent to transfer. The instructors implemented curricula emphasizing civil engineering applications related to buildings, water systems, infrastructure resilience, human comfort, and energy balance. For the course final project, students proposed solutions to build a lunar infrastructure habitat, requiring them to extrapolate from terrestrial designs discussed in the classroom to extraterrestrial contexts. Instructors enhanced the course material with transfer techniques such as analogy-driven learning, real-world problem-solving exercises, and facilitated discussions of lunar design challenges. The FET model was embedded in the pre-course, post-course, and feedback surveys. The authors found evidence of successful transfer from these artifacts, suggesting that the pedagogy and curricula implemented were effective at promoting transfer of learning. Furthermore, anecdotal instructor observations indicated that students effectively applied the acquired knowledge from the course to novel contexts. Future iterations of this course will focus on improving pedagogical approaches to teaching for a successful transfer, embedding the FET model in daily assignments to track transfer progress formally, and implicitly encouraging collaboration between groups.

Tags: pre-college engineering, transfer of learning, extraterrestrial habitats, transfer model

INTRODUCTION

Nelson Mandela once said, “Education is the most powerful weapon which you can use to change the world.” Although the authors agree with the sentiment, perhaps the quote should be adjusted to say that *effective* education is the most powerful. Effective teaching involves the understanding, techniques, methods, and actions that result in successful learning outcomes for students [2]. Among these aspects of course design and delivery, researchers have agreed that transfer is one of the most important. Transfer is a cognitive practice that measures learners' ability to apply their acquired knowledge in various ways under different circumstances than they learned it [3]. Teaching theories indicate that various instructional methods can assist students in achieving the intellectual development necessary to apply their knowledge [4]. In this study, the authors seek to determine if the instructional methods used in a recently completed course successfully fostered the transfer of learning.

The course consisted of a one-week, one-credit summer residential course. Students currently enrolled in a domestic high school were eligible to apply and be admitted by Purdue University’s summer programs office. Approximately 40 students participated in this unique civil engineering-focused program. The week revolved around engineering for the future, with students learning about various aspects of civil engineering and later given the task of considering how they would design a structure in an extraterrestrial habitat for future use. Student artifacts included pre-course, post-course, and evaluation surveys. These surveys were used to evaluate the effectiveness of the course and the impact of novel activities and assessments on student outcomes.

BACKGROUND

Transfer of Learning (ToL) is the application of skills, knowledge, or attitudes learned in one situation to another learning situation [5]. While the concept and practice of transferring learning have always been intrinsic to educational objectives, it was not until it was defined as an explicit goal of education plans that it was formally named. Fundamentally, ToL asks students to apply their learning to contexts different than where they originally learned them [3]. ToL is central in engineering education, given the complex nature of problems in engineering and the tailored, problem-specific solutions they demand. In engineering classrooms, learners must apply foundational concepts creatively and flexibly in varied contexts [6]. ToL can be promoted through strategies like inquiry, problem-based, or project-based learning, where students apply theoretical knowledge to real-world engineering problems, fostering deeper understanding and retention [7].

When successfully achieved, ToL ensures that learning extends beyond memorization and is effectively applied in real-world situations, enhancing problem-solving skills and adaptability [4]. However, assessing ToL is challenging due to the difficulty in measuring the application of knowledge to new and diverse contexts and many factors that are believed to affect transfer. For example, Haskell [8] showed that traditional assessments (standardized, end-of-chapter, or objective tests) focus on specific, discrete knowledge or skills rather than on the integrated and flexible application of knowledge that ToL requires. As a result, these traditional assessments may not be appropriate to assess transfer.

Various models have been developed in the past to assess ToL. For instance, in [9], the authors developed the Learning Transfer System Inventory (LTSI), which evaluates factors affecting knowledge transfer within organizations and companies. Specific tools and rubrics have been developed in engineering education to measure a student's ability to apply core principles across different contexts [10]. Some performance assessment tools (PAT), such as portfolios, simulations, and other authentic assessments, allow for more complex demonstrations of knowledge and skills, including assessing the ability to transfer learning to new situations [11]. Similarly, the Situational Judgment Tests (SJT) expose learners to realistic scenarios and ask them to choose the best response from several options. They can assess the ability to transfer knowledge and skills to new and complex situations [12]. Both PATs and SJTs seek to mirror real-world tasks and require the application, analysis, synthesis, and evaluation of knowledge and skills. Other techniques, including comparisons of the knowledge before and after the learning process, have proven helpful as educators can infer the extent of learning transfer. Concept mappings are a recurrent example of assessment methods that allow learners to visually represent their understanding and organization of knowledge [13].

Besides the educational field, transfer assessment strategies have been developed in the Transfer of Training (ToT) discipline. For example, the Four Levels of Training Evaluation (FLTE) developed in [14] provides a framework for assessing training programs' effectiveness, including transfer. Notably, the third level of their framework, 'Behavior,' assesses how participants apply what they learned during training when they return to the job. Similarly, the authors in [15] created the Transfer of Training Measure (TTM), a tool designed to assess the transfer of training quantitatively. It evaluates how individuals apply the skills and knowledge gained in training to their job.

In this work, the researchers will use a technique developed for the ToT assessment, the Factors for the Evaluation of Transfer (FET) model [1]. FET is a framework designed to evaluate ToL through the factors that impede or facilitate the transfer. In contrast with other methods that focus on *determining* the factors (see, for example, [9], [16], [17]), the FET model aims to *assess* them [1]. Furthermore, the FET's framework encompasses evaluating multiple dimensions influencing the ToL. Specifically, the FET model's categories include transfer dimensions, achieved learning, and intent to transfer. The transfer dimensions are:

1. **Trainee**, which includes factors related to the participants' reactions to a training program, such as motivation of transfer, self-efficacy, and locus of control;
2. **Training**, that evaluates the training itself and its design, and includes factors such as the instructions given to the trainees or the introduction of follow-up sessions; and
3. **Organization**, which contains factors related to the workplace, like manager's support to transfer or peers' support to transfer.

Moreover, the other two categories are:

1. **Achieved learning**, to measure the extent of learning achieved during training, and
2. **Intent to transfer**, used to measure the trainees' intention to apply the learned skills in their job.

A visual representation of the FET model is presented in Figure 1.

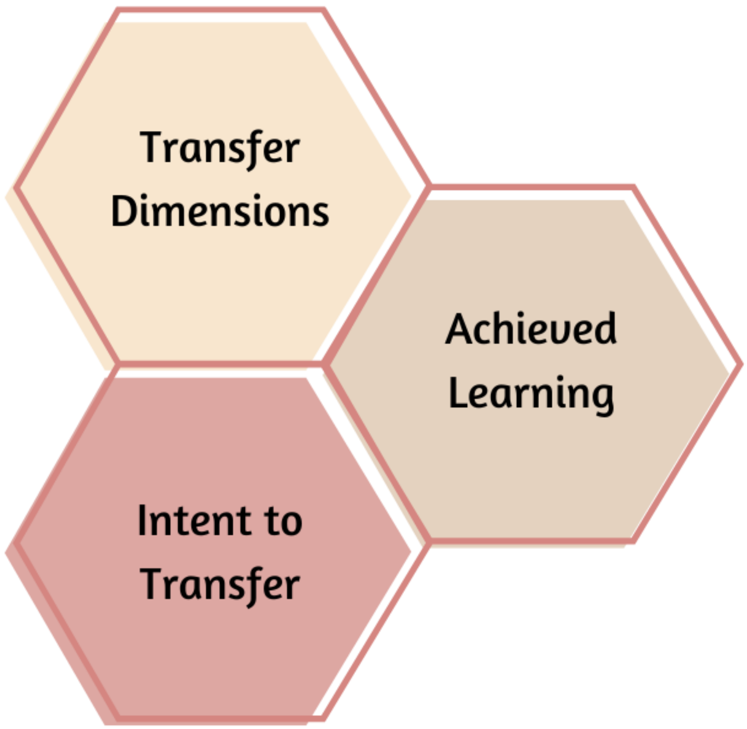

Figure 1. Visual representation of the FET model

The FET model is applied to evaluate the ToL in the engineering short course of this study due to its comprehensive approach that encompasses multiple dimensions and variables influencing transfer. Besides, its focus on intent and achieved learning aligns well with the objectives of engineering education because these two variables enable the assessment of the learners' and educators' attitudes toward the learning process.

COURSE DESCRIPTION AND CONTENT

The course consisted of a one-week university-level course for residential high school students. Participants were in class from 8 am to 5 pm and received one college credit for successful completion. The course focused on introducing students to civil engineering. The course was designed to challenge the students to consider how infrastructure should look in the future in light of the changing world and demands. The course was built around a project intended to involve students in the principles and practices of various areas within Civil Engineering, including structures, water resources, social science, systems of systems, and architectural engineering. Students worked in teams to complete this final design project. The broad course outcomes were to describe civil engineering applications, recognize the impact of civil engineering in improving society, and work effectively in a team. Instructional activities varied daily but included laboratory visits, several hands-on experiments, active learning activities, and traditional lectures. Active learning classrooms were used due to their collaborative learning arrangement so students and instructors could work effectively with others and walk around the classroom.

A secondary goal of this course was to empower graduate students with the pedagogical skills for university teaching and course development. The course instructors were doctoral students enrolled in different civil engineering disciplines. Instructors were selected through an application process during the fall semester, approximately 9 months before the course, and met regularly to develop course activities and coordinate logistics throughout the spring semester and early summer.

Course planning contained various steps ranging from recruiting and training instructors to recruiting high school students, developing course content (i.e., syllabus and assessments), incorporating active learning techniques, collecting feedback, and assessing the program's effectiveness. While developing the course, an emphasis was placed on the transfer of learning to help students apply theoretical concepts learned in the classroom to real-world engineering problems.

The development of the course used backward design as previous work showed it was effective in promoting transfer of learning [18]. First, instructors determined the course situational factors to examine specific contextual elements within the teaching and learning environment, such as student enrollment, prior knowledge of the subject, and the course delivery method. In the next development phase, the focus shifted towards establishing course goals. A Course Design Plan (CDP) spreadsheet was prepared to enhance clarity and facilitate comprehension among instructors. It incorporated learning outcomes (course-level goals), learning objectives (unit/lesson-level goals), methods of assessment, strategies of grading/feedback, and learning activities. The CDP served as a tool to articulate instructors' thoughts systematically, ensuring alignment with the intended learning outcomes. Individual assessment methods for the subdiscipline, as well as for the overall course, were developed by each instructor. Subsequently, a systematic grading method was developed to evaluate student performance in individual and team assignments.

Given the constraints of a one-week course duration, the instructors directed their efforts toward fostering in-depth knowledge relevant to a group project. The topics covered in each discipline included

- **Structures**: how structures carry loads and how they can be designed to withstand hazards.
- **Water resources:** how water is a fundamental building block of life and the role of purification systems.
- **Social science:** how infrastructure is designed to meet human needs, how humans interact with infrastructure, and how to encourage socially responsible construction.
- **System of systems:** how independent systems work together for a common goal and how to design systems that withstand human-made and natural hazards.
- **Architectural engineering:** how energy balance is incorporated in building design and how buildings can be designed for human comfort.

These lessons aimed to apply the concepts learned to a final building resilient lunar habitat project. The final project asked students to identify three (3) disciplines relevant to habitat design and three (3) hazards that could drive the design. The final deliverable required students to showcase their design in a team poster presentation to a general audience. This project required students to apply their knowledge from familiar terrestrial designs presented in the classroom to the unique challenges posed by extraterrestrial environments.

The instructors adapted the content to present to a pre-college audience while incorporating active learning, lab visits, and hands-on activities. The class activities included visiting a large-scale structural engineering facility and an architectural engineering laboratory. This firsthand exposure to experimental structures provided insight into the design considerations for an extraterrestrial lunar habitat and emphasized the importance of infrastructure resilience to multiple hazards. During the visits, students were encouraged to ask questions to complement their understanding of resilient habitat design.

Additional active learning activities included debates, group discussions, and engineering design challenges. Examples of these activities are presented below:

- **Debate and group discussion:** students were organized into two teams and tasked with selecting either promoting on-site renewable energy or off-site renewable energy. Students were allotted 10 minutes for team organization and 3 minutes for initial statements. After that, students could present 1-minute counterarguments and responses, with the restriction that only students who had not spoken yet were allowed to present. This approach encouraged participation and a debate enriched with multiple perspectives. At the end, a new representative from each team summarized their stance in a 2-minute final statement.
- **Engineering design challenge—MOLA kit:** students created an earthquake-resilient model structure using columns, beams, and frames. Students started with an unbraced frame and then added additional cross-braces to resist lateral loads. Students gained insight into earthquake-resilient design, different structures' responses to earthquakes, and the importance of bracing in structural design. This hands-on activity allowed students to apply theoretical knowledge and reinforce their understanding of earthquake-resistant structures.
- **Engineering design challenge—da Vinci Bridge:** students used small wooden pieces to construct a bridge based on the principles of interconnectedness of individual elements in building the whole structure, a concept introduced by Leonardo da Vinci. This activity highlighted the significance of a holistic approach to engineering design.
- **Engineering design challenge—M&Ms:** students explored the impact-absorbing characteristics of various materials in safeguarding M&M candies from external forces. The students wrapped the M&M candies in paper, foam, and impact gel. Subsequently, they subjected the candies to an impact force using their fist and assessed the influence of shock-absorbing materials in mitigating the impact on the candies. This hands-on activity helped students to understand the use of shock-absorbing materials in the design of a safe habitat.

METHODOLOGY

Study model

The FET model includes three main categories: transfer dimensions, achieved learning, and intent to transfer. The first category, <u>transfer dimensions</u>, covers the trainee, training, and organization. Each dimension encompasses factors found to affect the efficacy of transfer. The factors regarding the transfer dimensions are: satisfaction with training, motivation to transfer, self-efficacy, locus of control, orientation towards job's requirements, transfer design, lack of possibilities to transfer, accountability, manager's support to transfer, and peer's support to transfer. A visual representation of the transfer dimensions is presented in Figure 2. For this course assessment, three student artifacts (pre-course, post-course, and evaluation survey) were divided according to their corresponding FET category, as shown in Table 2. The description of these elements and the connection between the original model and the use here are described in the following text. For this analysis, only Likert questions were used.

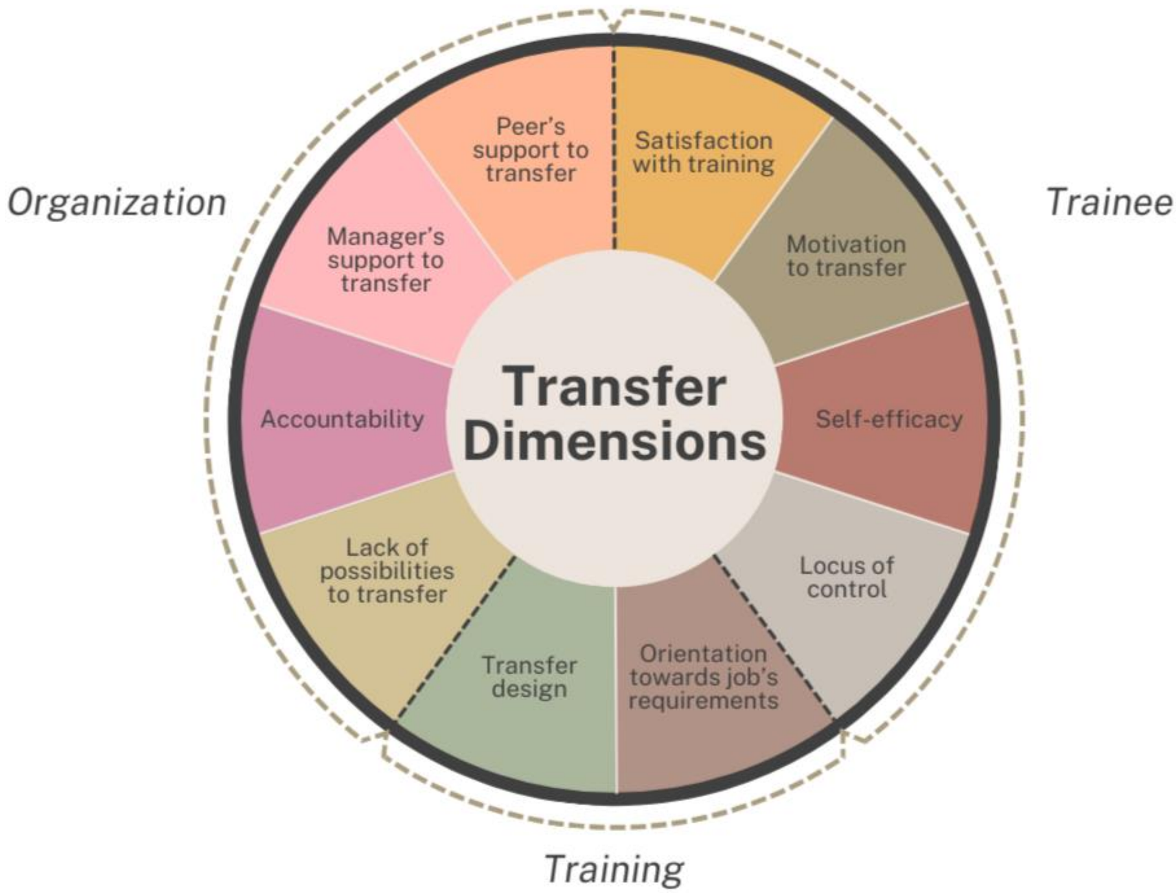

Figure 2. Transfer Dimensions in the FET model

The first four factors, satisfaction with training, motivation to transfer, self-efficacy, and locus of control, are in the *trainee dimension*. This dimension is focused on parts of ToL that the trainee has the most impact on:

- **Satisfaction with training:** associated with participants' response to the training. In the context of this work, this aspect is evaluated by students' self-reported satisfaction with the material they were learning.
- **Motivation to transfer:** captures participants' desire to learn and use the training. For this aspect, students were asked if they usually wanted to put what they learned into practice in the pre-course and post-course surveys.

- **Self-efficacy:** the belief that one can execute the task at hand. Self-efficacy is well understood to be positively correlated with transfer, as learners who believe they are personally capable of doing the task are more successful at completing it. In this study, learners were asked if they felt capable of putting what they were learning into practice. This question was posed in the pre-course and post-course surveys to assess any change over time.
- **Locus of control:** trainee's belief that they control the outcome rather than external forces. Individuals who believe they can affect a specific outcome are more likely to have achieved ToL. Students were asked about their level of agreement with the following statement: "Success in applying the course content to the final project depended on me."

The following two dimensions, orientation towards the job's requirements and transfer design, are in the *training dimension*. This dimension focuses on aspects of the training that are directly impacted by the content and delivery method of the training.

- **Orientation towards job requirements:** used to assess how connected the provided training is to the current needs of the trainee. For example, training a worker on how to use a hammer before hammering rather than training a worker how to use a screwdriver before hammering. In the context of this course, students were asked if the course activities and lessons were applicable and useful for the final project.
- **Transfer design:** encompasses the training method and strategies used. This dimension can include instructions provided and course design. This element was assessed by considering if students believed they were presented with relevant examples of transfer.

Finally, the *organization dimension* encompasses factors the organization controls, including the lack of possibilities to transfer, accountability, manager's support to transfer, and peer support to transfer.

- **Lack of possibilities to transfer:** opportunities trainees have to use the training. If trainees do not have clear opportunities to transfer the knowledge they have learned, they cannot effectively demonstrate transfer of learning. This aspect was assessed using the two prompts, "this course helped me understand how to apply concepts from one scenario to another" and "the course project allowed me to apply what I learned throughout the week".
- **Accountability**: to assess the external expectations related to using the training that the trainee receives. This aspect is assessed by asking learners if instructors provided clear expectations and fairly assessed student work.
- **Manager's support to transfer:** encompasses the support a trainee receives from their manager both through the training as well as the emotional support and providing additional resources to make learning easier. In the context of this assessment, the manager is the instructor. As such, the focus of assessing this dimension related to the students' perception of the support provided by the instructors when learning. This factor was assessed separately for each instructor but reported here as a composite score.
- **Peers' support to transfer:** support a trainee receives from peers to use the skills presented in the training. This aspect can also include peer feedback. For the course, this

dimension was assessed inside project groups, and students were asked to consider the degree to which their teammates contributed to their learning.

Outside of the transfer dimensions, two other categories are considered in the model: achieved learning and intent to transfer. These high-level dimensions play a role in the transfer of learning by assessing if any learning occurred and if the trainee had any intention to transfer the knowledge. Without a trainee having any knowledge or retention of the training, they cannot transfer this knowledge to another scenario. Similarly, if trainees are not going to try to transfer the knowledge, it will not be transferred.

- **Achieved learning:** assess if the trainee has any knowledge or retention of the training. For this purpose, an analytical rubric was designed for the final deliverable and academic poster to assess if learning occurred based on the course learning outcomes. This rubric is presented in Table 1. This dimension was also assessed by students self-reporting broadening of knowledge.
- **Intent to transfer:** evaluated based on a review of academic posters to determine if the students intended to apply concepts from class to the final project. If posters showed evidence of transfer, students must have had an intent to transfer. Students' self-reported attitudes towards transfer also assessed this factor.

The Likert scale responses to the questions presented in Table 2 have been converted to numerical values (Strongly Disagree = 0 to Strongly Agree = 4) for each factor to provide the mean and median scores. The scores were evaluated across the three dimensions to assess the student-reported strength of these dimensions. Higher scores indicate greater effectiveness of the factor. For questions asked before and after the course, as in the case of the pre- and post-course surveys, a comparison of scores is provided to assess changes in learning or attitudes. An increase in scores can indicate successful transfer of learning. In addition to considering the dimensions using Likert questions, open-ended questions were used to understand student responses better and understand any themes from the data.

Table 1. Poster rubric for evaluating transfer of learning

Criteria	No Evidence (0%)	Underachieved (50%)	Partially Achieved (80%)	Fully Achieved (100%)
Identify 3 areas of civil engineering that impact the design of a space habitat	Team does not identify any relevant areas of civil engineering.	Team identifies one area relevant and two areas irrelevant Team identifies two areas relevant	Team identifies two areas relevant and one area not relevant.	• Team identifies three areas of civil engineering relevant to the design of a space habitat.
Identify 3 hazards relevant to the moon	No hazards relevant to the moon are identified.	Team identifies one area relevant and two areas irrelevant. Team identifies two areas relevant	Team identifies two areas relevant and one area not relevant.	• Team identifies three hazards relevant to moon habitat.
Describe 3 resiliency features, one relevant to each hazard	No resiliency features described	Team describes two resiliency features relevant to two hazards Team describes one resiliency features relevant to three hazards	Team describes three resiliency features relevant to two hazards Team describes two resiliency features relevant to three hazards	• Team identifies three resiliency features. • Each hazard is addressed by at least one resiliency feature.
Effective poster	Team achieves 0 'Fully Achieved' goals	Team achieves 1 of 3 'Fully Achieved' goals	Team achieves 2 of 3 'Fully Achieved' goals	• Poster is visually appealing. • Poster covers all required material. • No distracting typos or grammar issues.

Table 2. Mapping of FET model elements to course artifacts

Factors for the Evaluation of Transfer (FET) model			
Transfer Dimensions	*Trainee*	**Satisfaction with training**	I am happy with the content learned throughout the course
		Motivation to transfer	I usually want to put what I have learned in class into practice
		Self-efficacy	When I follow what I have learned in class, I feel I am capable of putting it to use
		Locus of control	Success in applying the course content to the final project depended on me
	Training	**Orientation towards job's requirements**	The course taught the relevant content to produce a successful final project
		Transfer design	I was given examples of how to apply course content in the final project
	Organization	**Lack of possibilities to transfer**	This course helped me understand how to apply concepts from one scenario to another The course project allowed me to apply what I learned throughout the week
		Accountability	Instructors clearly defined expectations for learning Instructors fairly assessed student learning (e.g., through quizzes, homework, projects, and other graded work)
		Manager's support to transfer	The instructor encouraged me to use class content for the final project
		Peer's support to transfer	My teammates encouraged me to apply course content in the final project
Achieved learning			This course broadened my knowledge of the study and practice of civil engineering
Intent to transfer			I want to apply what I learned during the course in the future

RESULTS

Results from the model

Table 3 presents the results from the FET model for measuring the transfer of learning in the course. The model measures the responses from student artifacts such as the pre-course, post-course, evaluation surveys, and academic posters. Each value in Table 3 is followed by the standard deviation (σ). The sample size was 38 students, except for the pre-course survey (sample size = 42) and post-course survey (sample size = 41). From this analysis, it is apparent that students highly rated most aspects related to the transfer of learning and demonstrated via various methods to have achieved learning transfer.

Table 3. Transfer of Learning results provided by the FET model

Dimension	Level	Aspect	Post-Course Evaluation (out of 4)
Transfer Dimensions	Trainee	Satisfaction with training	3.50 [σ = 0.64]
		Motivation to transfer	3.59 [σ = 0.66] (3.45 [σ = 0.54] pre-course)
		Self-efficacy	3.37 [σ = 0.76] (3.00 [σ = 0.65] pre-course)
		Locus of control	3.11 [σ = 0.82]
	Training	Orientation towards job's requirements	3.39 [σ = 0.74]
		Transfer design	3.58 [σ = 0.59]
	Organization	Lack of possibilities to transfer	3.34 [σ = 0.66] 3.55 [σ = 0.59]
		Accountability	3.32 [σ = 0.69] 3.66 [σ = 0.53]
		Manager's support to transfer	3.65* [σ = 0.55]
		Peer's support to transfer	3.29 [σ = 0.76]
Achieved learning			3.66 [σ = 0.47] 3.69 [σ = 0.43] (academic poster)
Intent to transfer			3.39 [σ = 0.71] Achieved (academic poster)

*This item was captured for each instructor separately. Presented here is the average of instructor individual scores.

The results from the FET model provide insightful data about the transfer of learning within the trainee dimension, including satisfaction with training, motivation to transfer, self-efficacy, and locus of control. The course demonstrated success in the trainee dimension. Students showed high satisfaction with the training content (3.50/4) and an increased motivation to transfer learning from pre-course (3.45) to post-course (3.59). Self-efficacy also improved, indicating enhanced confidence in applying learned skills (from 3.00 pre-course to 3.37 post-course). The locus of control was moderately high (3.11), suggesting a good level of student belief in controlling their learning outcomes.

In further analysis, if the responses "strongly agree" in the pre-course survey and the post-course survey, the responses were removed from the sample. The "Motivation to transfer" average improved from 2.94 to 3.53, and "Self-efficacy" from 3.21 to 3.41. This analysis indicates that, among those who initially did not strongly agree with both statements in the pre and post-course survey, they saw a greater increase in their motivation to transfer than self-efficacy through the duration of the course.

Scores in the training dimension were strong. The relevance of course content to real-world scenarios (orientation towards job requirements) was rated at 3.39, while the effectiveness of the course's instructional design (transfer design) was scored at 3.58, indicating a well-received training methodology. The organization dimension also yielded positive results. The course provided ample opportunities for knowledge application (lack of possibilities to transfer: 3.34 and 3.55), clear expectations and fair assessments (accountability: 3.32 and 3.66), strong instructor support (3.65), and good peer support (3.29).

Achieved learning was rated highly at 3.66, showing effective knowledge conveyance. The intent to transfer, indicating students' readiness to apply skills in future contexts, was also strong at 3.39. The assessment of academic posters was reported as 3.69, demonstrating the students' ability to transfer their recently learned knowledge to a new challenge.

Students commonly identified hands-on activities as their favorite parts of the course, including smashing M&Ms (48%), the in-class debate (20%), building a da Vinci bridge (15%), and building with MOLA kits (18%). Similarly, over 30% of respondents stated that the one thing they would improve with the course was implementing even more hands-on activities. Finally, anecdotal evidence from instructors reviewing student artifacts indicated that students effectively applied the acquired knowledge from the course to novel contexts.

CONCLUSIONS

This study, grounded in the application of the Factors for the Evaluation of Transfer (FET) model, showcases the effectiveness of the engineering course in facilitating the transfer of learning among pre-college students. The final assessment of the student artifacts provides evidence of the success of the course in achieving its educational objectives.

Key strengths of the course were identified across various dimensions of the FET model. In the *trainee dimension*, there was an increase in students' motivation to transfer learning and a notable improvement in self-efficacy, suggesting that students not only desired to apply their learning but also felt confident in their ability to do so. For example, the trainee dimension grading increased from 3.00 in the pre-course survey to 3.37 in the post-course survey. This increment demonstrated an improvement in the students' motivation to transfer learning. The high level of satisfaction with training content points to the quality and relevance of the course material.

The *training dimension*, encompassing the orientation towards job requirements and transfer design, received high scores. This indicates that the course content was effectively aligned with practical applications and that the instructional strategies employed were successful in engaging students. This alignment is crucial in engineering education, where the application of theory to real-world scenarios is a fundamental learning outcome.

In the *organizational dimension*, the course demonstrated its strength in providing opportunities for knowledge application, setting clear expectations, and offering robust instructor support. The positive assessment in the area of peer support also reflects a collaborative learning environment conducive to the transfer of learning.

The high score in achieved learning, complemented by the favorable evaluation of academic posters, demonstrates that students not only grasped the course content but were also able to effectively apply their knowledge to a complex project. The intent to transfer, as reflected in students' attitudes and the quality of academic posters, further signifies the course's role in preparing students to apply their learning in future contexts.

Finally, the study affirms the effectiveness of the course in promoting transfer of learning in a short, intensive format. The positive outcomes across all dimensions of the FET model, along with the high-quality academic posters, indicate that the course successfully met its educational goals and achieved successful transfer. These results offer valuable insights for future course design and showcase the importance of aligning instructional methods with the objectives of transfer of learning in engineering education.

Future work will explore how to modify the FET model presented in this paper to assess the transfer of learning in the classroom, apply it to a focus group, assess its success, and provide guidance for future implementation. More statistical analysis and additional pre- and post-course survey questions will be explored and trialed. Future research could also explore the long-term impact of these instructional methods on students' ability to apply engineering principles in diverse real-world scenarios, further enhancing our understanding of effective teaching practices in engineering education.

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APPENDIX A – COURSE SURVEYS

<u>Pre-Course and Post-Course (PC) Survey</u>

<u>Likert Questions</u>

1. I can think through an engineering problem and propose solutions.
2. I usually want to put what I have learned in class into practice.*
3. When I follow what I have learned in class, I feel I am capable of putting it to use.*
4. I understand the relevance of civil engineering in real-life problems.
5. I am interested in studying civil engineering in college.

<u>Open Ended Questions</u>

6. How would you define civil engineering?
7. What do civil engineers do?
8. What should engineers think about when designing tomorrow's infrastructure?
9. Is it difficult to apply a topic you learned on one setting to another? Why or why not?
10. Where are you typically creative?

<u>Evaluation Survey</u>

<u>Course Materials (CM) Questions (Likert)</u>

1. The instructional materials (i.e., slides, readings, handouts, etc.) increased my knowledge and skills in the subject matter.
2. The course was organized in a manner that helped me understand underlying concepts.
3. The lectures, readings, and assignments complemented each other.
4. Assignments were reflective of the course content.
5. The course taught the relevant content to produce a successful final project.*
6. My teammates encouraged me to apply course content in the final project.*
7. I am happy with the content learned throughout the course.*

<u>Course Structure (CS) Questions (Likert)</u>

1. I understand the relevance of the material to real-world challenges.
2. I believe what I learned in this course is important.
3. Instructors clearly defined expectations for learning.*
4. Instructors fairly assessed student learning (e.g., through quizzes, homework, projects, and other graded work).*
5. The course project allowed me to apply what I learned throughout the week.*
6. I was given examples of how to apply course content in the final project.*
7. Success in applying the course content to the final project depended on me.*

<u>Course Learning (CL) Questions (Likert)</u>

1. This course helped me develop professional skills (e.g., written or oral communication, reading computer literacy, teamwork, etc.).*
2. This course broadened my knowledge of the study and practice of civil engineering.*
3. This course helped me understand how to apply concepts from one scenario to another.*
4. This course encouraged creative thinking.
5. This course encouraged me to consider a career in civil engineering.
6. I want to apply what I learned during the course in the future.*

<u>Course Instructors (CI) Questions (per instructor)</u>

1. The instructor was well-prepared for class.
2. The instructor used class time effectively.
3. The instructor's teaching methods aided my learning.
4. The instructor encouraged student participation in class.
5. The instructor encouraged me to use class content for the final project.*
6. I would recommend this instructor to others.

<u>Open Ended (OE) Questions</u>

7. What were one or two of your favorite course activities? Why were these memorable?
8. What do you think could be improved in this course?
9. Would you recommend this course to a friend? Why or why not?
10. Anything else you would like us to know?

*Applied to the FET model