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IUSE 2315777: Teaching Engineering Students to be Better Learners through A Course-integrated Approach: Student Engagement and Impacts on Learning Skills and Performance

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Project motivation and background

Learning is a lifelong process exercised within and beyond the classroom and is a vital professional skill. Engineers, in particular, must adjust to rapidly evolving technologies and practices that require continuous learning and adaptation long after their initial formal training and transition into their professional careers.Education research emphasizes the need for engineering students to hone these lifelong learning skills. Effective learning requires them to adopt self-regulated learning strategies to synthesize and apply knowledge, and evaluate problems using engineering principles effectively (Zimmerman, 2000). However, students often default to ineffective learning strategies such as rereading, highlighting, repetition, and rote memorization (Blasiman et al., 2017; Dattathreya, & Shillingford, 2017), and do not exercise the higher-order thinking required to solve difficult engineering problems and reach conceptual mastery. As a result, students often struggle in their courses, which may negatively affect their curricular progress and ability to adjust to university life.

However, despite the critical role of effective learning skills in their academic and professional success, engineering students receive minimal guidance on how to become effective learners. The engineering curriculum has traditionally emphasized teaching the content while assuming that students are equipped to manage their own learning. Although recently more efforts were made in delivering evidence-based learning strategies to engineering students (Blasiman et al., 2017; Santangelo et al., 2021), most of the training was delivered in extracurricular format. This includes stand-alone learn-how-to-learn classes or workshops delivered by student success centers, or one-time learning-strategies lectures delivered in a course context (McGuire, 2015). However, these interventions were not found to result in the desired transfer of skills. While they did raise their awareness of effective learning, students still found it difficult to transfer these learning strategies to their own learning context within their engineering courses. To address such a challenge, interventions on effective learning strategies could be integrated in the discipline context itself (Wingate, 2007). This project examines how to successfully design and implement a scaffolded and course-integrated intervention on learning strategies. We investigate how the intervention impacts students' knowledge, belief, commitment, planning, and attitude of using effective learning strategies and their course performance.

Project details

The aim of this project (NSF IUSE #2315777) is to develop, implement, and evaluate course-integrated learning interventions and their impact on student learning in engineering classrooms. The project has two primary objectives. The first objective is to develop discipline-specific training modules that are grounded in the framework of self-regulated learning (the process of goal setting, planning, self-monitoring, and reflection) (Santangelo et al., 2022). These modules focus on evidence-based learning strategies such as active recall, concept mapping, summarizing, self-explaining, and self-testing. A key innovation of this project is the alignment of course content with the application of learning strategies to ensure there is a direct connection between student learning practices and the technical material being taught. This project includes close collaboration among faculty, our campus teaching and learning center, and a student success unit to ensure that modules are adaptable to a range of engineering disciplines and include practices that are transferable to both current and subsequent courses. The second objective involves the implementation of these training modules across both lower-division and upper-division courses in the Mechanical and Aerospace Engineering and

Electrical and Computer Engineering departments. Once implemented, students' short-term and long-term academic performance, attitudes toward our interventions, learning habits, and self-efficacy are measured to evaluate the effectiveness, transferability, and impact of the training interventions. By embedding the developed training practices into the curriculum, our approach ensures that learning strategies are perceived not as supplemental activities, but as a core part of engineering education. This paper presents our first two year results on this project and our plans for future studies and improvements.

Methodology

Our course-integrated intervention project on self-regulated learning strategies is built on three pillars: (1) supporting students' cognitive development by teaching effective learning strategies, (2) fostering students' affective development by encouraging a growth mindset, and (3) promoting students' metacognitive development by providing structured feedback and reflection opportunities. This approach to encouraging the adoption of effective learning strategies is informed by the knowledge, belief, commitment, and planning (KBCP) framework for learning strategy training (McDaniel & Einstein, 2020), integrated with principles of self-regulated learning (Zimmerman, 2000). In each target course, students' adoption of effective learning strategies will be supported by interventions aiming to enhance students': (1) knowledge about these strategies, through explicit instruction on target learning strategies with engineering-specific examples, (2) belief in the effectiveness of the strategies, through in-class demonstrations and guided practice, allowing students to experience the benefits firsthand, (3) commitment to using the strategies, through the integration of utility-value interventions, and (4) implementation planning, through structured assignments and activities that direct students on when and how to apply specific strategies to their engineering studies.

The components are being implemented across multiple mechanical and electrical engineering courses and involve training materials, new and redesigned assignments, adjusted assessments promoting deep learning, and specialized TA training. To evaluate the effectiveness of this intervention, we are using pre- and post-course surveys, quasi-experimental designs comparing intervention and non-intervention course sections, and longitudinal tracking of strategy transfer to subsequent courses. Data collection methods include surveys, interviews, focus groups, tracking course performance metrics, and analysis of student work.

Results

Overview In the first two years of the project, the research team implemented a pilot intervention four times in five unique Mechanical and Aerospace Engineering (MAE), and Electrical and Computer Engineering (ECE) courses: MAE 30A - Statics and Introduction to Dynamics, MAE 131A - Solid Mechanics, MAE 8 - MATLAB Programming, ECE 100-Linear Electronic Systems, and ECE 35 - Introduction to Analog Design. All the courses are lower division foundational courses, and students have historically reported the class to be difficult, which made the classes ideal candidates for the learning strategies intervention. The implementations use the same intervention design KBCP framework while maintaining some flexibility in terms of the specific targeted learning strategies, format of the learning strategies, introduction lecture, method for feedback, format, and incentives for student participation, etc. All the pilot interventions were implemented in a research university, in a 10-week-long quarter. The key characteristics of the intervention for each course have been summarized in Table 1.

Table 1. Overview of the class context of the courses in which the learning strategies intervention was implemented

	MAE 30A **Statics and Dynamics**	**MAE 131A** **Solid Mechanics I**	**MAE 8** **Matlab programming**	**ECE 100** **Linear Electronic Systems**	**ECE 35** **Introduction to Analog Design**

Class Level	Sophomore		Sophomore		Sophomore	Junior		Sophomore
Main topics	Engineering Mechanics - Statics and Introduction to Dynamics		Stress and strain analysis		Computer programming	Active and passive electrical circuits, such as filters, integrators, differentiators, and oscillator circuits		Basics of electronics
Implementation quarter	Winter 2025	Winter 2025	Spring 2024	Spring 2025	Fall 2025	Spring 2024	Fall 2024	Fall 2024
Class Size	107	101	n=129	143	n=173	n=118	n=123	n=267
The overall estimated intervention participation rate	90%	90% for the intro lecture 35% for most assignments	About 33% for most assignments	35% for most of the assignments	Class attendance	31%	30%	10%
Targeted enhanced learning strategies	Elaboration, retrieval practice, spaced learning, interleaved practice, self-care for overall health				Group project management, self-regulation, reflection report, in-class metacognitive activities	Mind map		Elaboration, concept maps, Feynman technique, retrieval practice, spaced practice, interleaved practice, environmental strategies, behavioral strategies
Introduction lecture, timing, and duration	Week 2 (80 minutes)		Week 4 (80 minutes)	None, Recorded video provided	None	Week 4 (20 minutes)	Week 2 (20 minutes)	Weeks 1, 2, and 3 (50 minutes each)
Metacognition	Yes				In-class metacognitive activities	Yes, as integrated into the activity		Yes
Growth Mindset	Yes				no	No		Yes
Assignments and activities	None	Video modules: metacognition modules, growth mindset modules. Weekly assignments: Post-lecture active recall, concept mapping, schedule planning, and learning reflection.			In-class metacognitive activities, reflection report	Weekly mind map submissions starting at the end of the introduction week		Group discussions during the lecture sessions (ungraded, voluntary)
Feedback format	None	The first 3 assignments, graded with comments			N/A	Yes		N/A

In the following section, we briefly describe the preliminary results for each class.

1. **MAE 30A and MAE 131A in Spring 2024, Winter 2025 and Spring 2025**

In Spring 2024, Winter 2025, and Spring 2025, self-regulated learning (SRL) interventions were implemented four times across MAE 30A and MAE 131A, including two sections of MAE 30A in Winter 2025. Across all offerings, approximately 85–90% of students attended the introductory lecture, “How to Learn More Effectively.” Submission rates for learning-strategy assignments (e.g., active recall, concept mapping) were consistently around 35–40%. Students who participated were commonly motivated by a desire for self-improvement, specifically, becoming more effective learners, as well as by the availability of extra credit. Several students who were initially skeptical of the learning strategies reported that, after participating for extra credit, they found the strategies genuinely beneficial. Among students who did not submit learning-strategy assignments, the most frequently cited barrier was lack of time, attributed to heavy course loads or personal obligations. Some students also indicated that their primary goal was simply to pass the course and that their existing study strategies were sufficient for that purpose.

The majority of students reported that the learning strategies improved their learning, with some describing active recall as a “game changer.” Differences emerged between courses: students in MAE 131A reported greater appreciation for concept mapping than those in MAE 30A. We hypothesize that this difference is related to the broader range of topics in MAE 131A, for which concept mapping may be particularly effective. Perceived utility of the learning strategies was strongly and positively correlated with the quality of students’ submissions. For example, students who produced higher-quality concept maps with meaningful connections among topics were more likely to perceive concept mapping as highly beneficial. Across all course settings and exam types, effective use of learning strategies was positively correlated with exam performance.

2. **ECE 100 in Spring and Fall 2024**

In the Spring and Fall 2024 offerings of ECE 100, Linear Electronics Systems, the instructor introduced an optional extra credit mind mapping activity to promote effective learning strategies. Early lectures emphasized mind maps as a tool for strengthening conceptual understanding. Students who chose to participate created weekly mind maps, submitted them through a Google Form, and reflected on their time investment and perceived value. A dedicated Discord server fostered collaboration, where the instructor and tutor provided feedback and helped correct misunderstandings.

Participation remained consistent across quarters, with 37 students engaging in each term. The activity began in week 4 during Spring, but started earlier in week 2 in Fall. Pre- and post-quarter surveys captured student perspectives on the activity. Spring 2024 results showed performance-related differences in engagement: high-performing students participated more actively and used advanced learning strategies, while lower-performing students engaged less. In Fall 2024, participants of the mind map activity achieved higher final exam scores than those who did not participate and reported stronger self-regulated learning behaviors; this result was statistically significant. Overall, these results show that mind mapping is an effective learning strategy, particularly when introduced early and supported with feedback.

3. **ECE 35 In Fall 2024 and Winter 2025**

ECE 35 is a lower-division core electrical engineering course. The learning skills intervention consisted of ten optional 50-minute weekly workshops, integrated into one of the two weekly discussion sections. In Fall 2024, a pilot version of the intervention was implemented to develop and refine the workshop materials, and the full study was then conducted in Winter 2025. Grounded in cognitive psychology and engineering pedagogy, the workshops addressed growth mindset, self-regulated learning, time management, and evidence-based study strategies through interactive, course-contextualized activities. Of the 179 students enrolled in the course, 47 engaged in the workshops (defined as attending at least four sessions), which were optional and only minimally incentivized.

A pre-survey and an end-of-quarter survey were used to gauge student sentiment and feedback. Students who engaged in the workshops reported statistically significant gains in self-rated knowledge of effective learning strategies and confidence in applying these strategies, while other students showed no significant change. In addition, participating students rated all strategies as useful overall, with time management, growth mindset, and metacognitive reflection receiving the highest ratings.

4. **MAE 8 in Fall 2024**

In this programming course, the intervention integrated instruction on AI-assisted programming, metacognition, and effective learning strategies with opportunities for collaboration, self-regulation, and reflection. In the final three weeks, students worked on a group project, involving modular design, simulation, visualization, user-interface development, and project management—requiring knowledge beyond what was taught in class and necessitating self-directed learning. Following project completion, students were asked to write a reflection report and participate in an interactive conference, reinforcing awareness of learning strategies, teamwork, and project management.

Analysis of reflection reports and performance data (173 participants) suggests that the integrated approach positively influenced students' learning behaviors, metacognitive awareness, and skill development. Students frequently reported gains in ability to define and decompose problems, debug and validate code, iteratively refine solutions, and manage collaborative workflows. Many described using AI tools to assist them in brainstorming, debugging, and refinement, while still acknowledging the importance of human judgment, conceptual understanding, and careful evaluation of AI feedback. Reflections also highlighted the role of teamwork, communication, and shared responsibility in shaping project efficiency and learning experiences. Student performance on the project and final exam was strong (average score above 90%), suggesting that students were able to effectively apply learning strategies and metacognitive awareness when working on complex programming tasks requiring new learning and critical evaluation of AI feedback.

Next steps

The first two years of implementing the learning strategies intervention have yielded highly positive outcomes. We observed meaningful improvements in students' learning behaviors and attitudes, as well as a positive association with learning performance among students who actively participated in the intervention. Because participation in the learning strategies activities was optional, student engagement varied across courses. Compared to Year 1, engagement increased in several courses during Year 2; however, overall participation remained lower than desired. Insufficient engagement continues to be the primary challenge in ensuring that the intervention benefits all students who could potentially gain from it. Data collected in Year 2 enabled us to identify several key motivators and obstacles that either supported or hindered student engagement. These insights are directly informing planned design refinements for Year 3, with the goal of increasing participation and sustained engagement.

Another challenge that emerged was that a subset of students participated in the learning strategies activities throughout the quarter but did not perceive them as helpful. Further analysis revealed that some of these students did not engage with the learning strategies effectively and did not engage in meaningful reflection to evaluate and adjust their approaches. This finding suggests that while the intervention emphasized the introduction and use of learning strategies, it placed insufficient emphasis on reflection and metacognitive regulation, both of which are critical components of successful self-regulated learning. To address this limitation, the Year 3 intervention will place greater emphasis on metacognitive reflection, particularly on helping students evaluate the effectiveness of the strategies they use and make informed adjustments. This will be implemented primarily through more frequent and structured reflective activities integrated throughout the quarter.

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Reference

Dattathreya, P., & Shillingford, S. (2017). Identifying the ineffective study strategies of first year medical school students. *Medical Science Educator*, *27*, 295-307.

Blasiman, R. N., Dunlosky, J., & Rawson, K. A. (2017). The what, how much, and when of study strategies: Comparing intended versus actual study behaviour. *Memory*, *25*(6), 784-792.

McDaniel, M. A., & Einstein, G. O. (2020). Training learning strategies to promote self-regulation and transfer: The knowledge, belief, commitment, and planning framework. *Perspectives on Psychological Science*, *15*(6), 1363-1381.

McGuire, S.Y. (2015). Teach Students How to Learn: Strategies You Can Incorporate Into Any Course to Improve Student Metacognition, Study Skills, and Motivation (1st ed.). Routledge. https://doi.org/10.4324/9781003447313

Santangelo, J., Cadieux, M., & Zapata, S. (2021). Developing student metacognitive skills using active learning with embedded metacognition instruction. *Journal of STEM Education: Innovations and Research*, *22*(2).

Sauvé, L., Fortin, A., Viger, C., & Landry, F. (2018). Ineffective learning strategies: a significant barrier to post-secondary perseverance. *Journal of Further and Higher Education*, *42*(2), 205-222.

Wingate, U. (2007). A framework for transition: Supporting ‘learning to learn’ in higher education. *Higher Education Quarterly*, *61*(3), 391-405

Zimmerman, B. J. (2000). A*ttaining self-regulation: A social cognitive perspective*. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), Handbook of self-regulation (pp. 13–41). Academic Press.