GIFTS: Learning Theory Workshop Led to First-Year Classroom Innovations

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Introduction and Background

This GIFTS paper presents an internal workshop that first-year engineering faculty at The Ohio State University attended on Learning Theories and the resulting classroom innovations that arose from that workshop. In Spring 2022, first-year engineering faculty at Ohio State attended an internal department-lead workshop about learning theories. All faculty who had taught first-year engineering that year were asked to attend. The workshop focused on how students learn and included many practices useful for developing student learning; these included retrieval practices, increasing sense of belonging & decreasing stereotype threat, metacognition & self-regulated learning, and transparency in teaching and learning. The workshop presented research on these topics and provided time for faculty to brainstorm class changes based on these ideas. The goal of this workshop was to communicate to all faculty teaching practices based on learning theories while also giving faculty time to reflect on their current practices and propose course modifications.

The course modifications focused on the first of a two-semester first-year engineering sequence for honors designated students at The Ohio State University. The class centers around problem solving and programming in MATLAB and C/C++. In Autumn 2022, there were 8 sections of the course taught by 6 instructors, for which the content and format were the same for all sections. The topics supported by learning theories and resulting course modifications, implemented in Autumn 2022, are discussed below along with their pedagogical rational.

Methods - Workshop Content and Classroom Innovations

The workshop took place over five days and was led by department experts in the topics being covered. Morning sessions consisted of learning theory review and instruction. In the afternoon, programmatic areas (e.g., first-year, capstone) broke out to discuss how the theories of the day were already featured in relevant courses and how to further incorporate the theories as practice in the classroom. The following morning, prior to instruction, the faculty shared out their plans and identified opportunities for collaboration. This learn-plan-share-collaborate cycle repeated throughout the workshop.

Spaced Retrieval

Spaced retrieval requires a learner to apply previously learned knowledge after some time has passed. This has obvious value as students must frequently pull from prior knowledge during exams, subsequent courses, and internships. This teaching practice within a course creates opportunities for practicing this skill. This has been shown in multiple contexts to improve retention of material [1]–[4]. Based on this, it was decided that the course should include more spaced retrieval.

Spaced retrieval fits nicely within a programming class as the topics tend to build on each other and are used together frequently. The course has always had weekly quizzes to review content and traditionally covered the previous week's topics. To add in an opportunity for spaced

retrieval, the quiz timeline was shifted to occur two weeks after the content was covered. This allowed students to get additional feedback on their assignments turned in on that content, but also allowed them to see additional material in between which could help strengthen their mental model of how the quiz content fits into the larger structure of the course.

Interleaved Retrieval

In interleaved retrieval, topics are regularly mixed to allow learners the opportunity to compare and contrast approaches and learn when to use each. This type of retrieval has been shown to improve test performance and learning in a variety of contexts [5]–[11]. Focusing on interleaved retrieval, one assigned problem each week was redesigned, requiring students to solve it using multiple techniques (often, one of these techniques was from a prior week which also reinforced spaced retrieval). Additionally, multiple synthesis days were added into the curriculum to focus on combining topics together and thinking through all the content learned to best solve the problem.

Sense of Belonging and Reducing Stereotype Threat

Stereotype threat in the classroom occurs when the pressure, stress, and distractions of stereotypes impact learning [12]. By increasing sense of belonging and reducing stereotype threat, students can focus more on their learning. Value affirmation activities have proven their effectiveness in these goals as they reassure students that they are valued even amid discrimination and stereotyping [12]. Value affirmation activities have also been found to reduce achievement gaps between genders, as well as, between minoritized and white students [13], [14] by reinforcing that the students are valued and their values are important [12].

In this course, students were asked to complete an anonymous reflection, value affirmation activity by reflecting on their values and the times that these values were important to them in their life. After their submissions, undergraduate teaching assistants reported back to the class about the various values in the course and were instructed to ensure their presentation was affirming those values. This full-circle opportunity gives students a chance to see their values shared and celebrated by the teaching team in a formal, in-class presentation.

Metacognition & Self-Regulated Learning

Metacognition is the ability to think about one's own thought processes and performance and is important to self-regulated learning[15]–[17]. To promote metacognition, exam wrappers were used to ask students before their midterm how they were preparing and what their goals were for the exam and then after the exam having them reflect on their performance. Before the exam students responded to an anonymous reflection prompt that asked them the following 2 questions:

- *Midterm exams are a significant part of your grade in most college courses. How have you been preparing for your midterm exams? What resources have you been using? Have your strategies been different for different courses? If so, why?*

- *What are your goals for studying over the next week? What are your goals for your exam performance?*

After the exam students were asked to review their work and identify the elements of the course where they performed well in addition to correcting any errors on the exam. For those students who performed well on the exam (>90%) they were asked instead to come up with an exam problem. Exam wrappers have been shown to increase student learning through reflection [18], [19].

Transparency in Learning and Teaching (TILT) framework

At the workshop the concepts of calibration and self-regulated learning were introduced as being important for students to be able to properly assess their own work [20]. These strategies are also related to creating equitable learning experiences. One way to encourage calibration and self-regulated learning is to use the Transparency in Learning and Teaching (TILT) framework [21]. The TILT framework aims to increase accessibility and equitable learning experiences [22] for all students by:

1. Stating the purpose and learning objectives for each assignment.
2. Defining clear tasks for each assignment.
3. Providing detailed rubrics which describe all criteria for success.

These three key elements to a transparent assignment [23] were added to all graded course material.

In the past, rubrics in this course had always been provided, but were lacking any detail. Previous concerns that students could use the rubrics to reverse engineer the solution yielded significant student stress and trained students to ask if their answers were correct instead of practicing techniques to evaluate and verify their own work. Following the TILT framework, rubrics with details for every point were provided for every assignment. In addition to increased equity of the learning experience, faculty workload was reduced due to fewer emails (ex. Why did I not receive points for X?) and increased grading consistency.

Lessons Learned and Ideas for the Future

The following lessons learned are from the instructors teaching the courses and include ideas for future class enhancements. These lessons were gathered based on informal discussions and observations from the instructors.

Students were resistant to spaced retrieval, but instructors found value

There were some students who were resistant to the spaced retrieval quiz schedule and did not like having new material introduced before being quizzed on the previous material. However, instructors thought this was a useful addition to the course. By allowing students the opportunity to process feedback and have this spaced retrieval opportunity it anecdotally seemed to aid with retention of the material. This could be taken one step further by adding a question to each quiz from content assessed in a previous quiz.

The value affirmation activity was viewed as a positive addition, but more is needed

The value affirmation reflection activity was a low time commitment activity for students to feel valued and to connect their personal values with their academic and professional engineering goals. This encouraged deep thought about how their values connect to why they want to be an engineer and what kind of engineer they want to be. However, there is more that can be done to increase a sense of belonging and reduce stereotype threat. One way is to expand the reflection assignment to also include an in-class component. For years, some faculty have incorporated a value sorting activity into the second semester first-year engineering course. In this activity students have reflected on their personal values and completed an activity to identify their top value. They then worked together with their assigned design project teams to discuss their value and why it is important to them. Teams have been encouraged to use those identified values as they think about how their team will operate and in writing a team working agreement. Recently this idea has organically taken hold in most classes, but moving forward we plan to formally incorporate this activity in all sections. Additionally, we are planning to incorporate more explicit diversity, equity, and inclusion content as it relates to teamwork. We plan to have explicit instruction on the importance of diverse and inclusive teams, strategies for inclusive teamwork, and implicit bias. Conveying the value of diversity and inclusion is a way to reduce stereotype threat and improve a sense of belonging, particularly those from minoritized groups.

Functions First! Using best teaching practices from foreign language in programming classes

Research in foreign language education shows that students learn best when elements of tense, sentence structure and vocabulary are interleaved[24], [25]. This promotes metacognition and retrieval over rote memorization. There are obvious parallels to teaching coding and we already implement some of these. Parson's problems[26] are one activity which give students completed lines of code and task them with arranging the lines into a working program. We have already increased the frequency of these activities to weekly[27], [28], but we are also brainstorming structural changes which would implement this idea on a more fundamental level. Functions are traditionally a more advanced topic presented later in the semester, but they also contain analogies to sentence structure. By providing students with completed functions at the beginning we can teach them how to build "sentences" (code that does something complex with function building blocks) and then slowly have them fill in the "vocabulary" (the specific working of each function. i.e., loops, conditionals, arrays). This would also allow us to interleave material more regularly throughout the semester.

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