WIP: Modifying In-Class Activities to Engage Engineering Students and Activate Learning

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***Abstract*—Contribution: This work in progress innovative practice paper describes an approach to implement Peter Liljedahl's classroom practices in a college first-year engineering course. Background: This course meets twice each week in a studio-style classroom. Liljedahl defines a thinking classroom as "a space that is inhabited by thinking individuals as well as individuals thinking collectively, learning together and constructing knowledge and understanding through activity and discussion" [1]. Thinking classrooms and in-class activities are also supported by Vygotsky's [2] Zone of Proximal Development theory and Bruner's [3] scaffolding methods. Original applications of Liljedahl's research are in secondary school mathematics courses, including the uses of visibly random groups and vertical non-permanent surfaces. Visibly random groups are temporary groups of students where the students can clearly see the random group assignment process [4]. This paper proposes a new style of in-class activities in this first-year engineering course and explains a research design procedure to test if this style improves students' achievement of learning objectives. Intended outcomes: My proposed in-class activity format involves groups of four engineering students working together to solve a problem while standing up and writing on a vertical surface with a non-permanent writing tool. Additionally, this modified format in each class session seeks to provide students with incentive to complete in-class activities and feedback while completing them. Incentive can come from the "gamification" of in-class activities [5], leaderboards, team-oriented events, or adding more relevant background context. Feedback can be provided to students through implementing Learning Management System quizzes or MATLAB P-code in coding activities. Application design: This approach aims to improve student learning by providing students with a new, consistent format for in-class activities that is exciting, engaging, and team-oriented. Students in a control group or an experimental group will take pre- and post- tests before and after experiencing the traditional or modified in-class activities. Expected findings: I anticipate class sections that participate in the alternative in-class activity format will have significantly higher mastery levels than the traditional sections. The existing in-class activities are already aligned with course learning objectives, but encouraging students to complete them thoroughly with their group may help each student gain a better understanding of the content.**

Keywords—First-year engineering, in-class activities, Learning Management Systems, MATLAB.

I. Background

Most first-year engineering students at a large university in the United States take an entry level engineering design class during their first semester. During the second semester, passing students advance to the second level design class. Both classes have similar structures. This paper will focus on the second level class which teaches coding in MATLAB, teaming skills, engineering professional skills, and mathematical modeling.

Students meet twice each week in a studio-style classroom with face-to-face seating. The teaching team consists of an instructor, graduate teaching assistant, and four undergraduate teaching assistants. Additionally, two undergraduate graders assist the teaching team outside of class. Each class section has at most 120 students. In a typical semester, 16 sections of the class are led by 12 instructors. Instructors teach at most three sections each semester.

Attendance is required for students and absences negatively impact grades. A typical two-hour class session consists of a 20–60-minute interactive lecture followed by about one hour of "studio time" where students can work on assignments with the help of the teaching team. This class follows the Bauhaus studio model described by reference [6].

Most lectures have pauses for students to work on the day's in-class activity (ICA). The ICAs are aligned with the learning objectives for each class session and are sometimes simpler versions of the homework assignments. The ICAs break instruction into digestible chunks and gradually introduce the content for the day, allowing students to practice in a low-stakes environment with support from classmates and the teaching team. These assignments are not graded, but sometimes students are asked to submit them to the Learning Management System for attendance credit.

An example of an ICA is script debugging, where students are instructed to download a MATLAB code file from the Learning Management System and correct the code so it would run without errors. After the students have time to work on their own, the instructor may solve the ICA on the projector so students can check their work. Sometimes, the solutions are uploaded to the Learning Management System.

II. Literature Review

Liljedahl [7] recommends teachers have their students work in (1) visibly random groups while (2) standing up and (3) writing on a non-permanent (4) vertical surface. Liljedahl [7] found that student groups perform better while working within these guidelines.

One of my former colleagues shared a new practice he implemented in his high school history and psychology classes, based on Liljedahl's mathematics education research and suggested classroom practices. At the start of some class sessions, the teacher offered the students a warm up activity. He posted a problem or activity on the projector screen, and students were assigned to a new, random group to solve each day's task. Each student has a name card that is randomly distributed to each desk as the students arrive, creating visibly random groups. The teacher would move all the chairs to one side of the classroom so students who are able to stand are encouraged to stand up and engage more closely with their group until they solve the problem. Students must solve the problem (or make significant effort) to "earn their chair" for the rest of class.

The purposes of this practice are to give students a "warmup" exercise and to ease the transition between subjects in school. These activities at the start of class might help a student switch their brain into history mode in the short break after an hour of math class.

Liljedahl's [1] theories are consistent with Vygotsky's [2] Zone of Proximal Development theory: this framework supports team formation methods where groups have team members at slightly different skill levels that are still proximal to each other. Reference [6] argues that when team formation is systematic and intentional, each group should have support from a "ringer" to help struggling students succeed. Bruner defined scaffolding in the context of children's language development as "a process of setting up the situation to make the child's entry easy and successful and then gradually pulling back" [3], [8].

The "gamification" of in-class activities is explained in a recent study by reference [5]. From my experience, a benefit of gamified quizzes is the instant feedback provided to students; in their study, they found that gamification was a significant positive predictor of learning process performance. Additionally, I found that students who participated in gamified ICAs showed significantly higher intrinsic motivation than students in the control group.

III. Context

I have worked as a member of the first-year teaching team for two semesters. I have noticed that some students frequently and quickly become disengaged during the ICAs. Based on my personal experience, I hypothesize that the disengagement comes from (1) the lack of incentive to complete the ICAs and (2) the lack of instantaneous feedback in the ICAs.

In Spring 2024, I created a new ICA to evaluate students' teamwork, problem-solving, and MATLAB coding skills, refencing course concepts from the first two units of the second semester design class. This ICA was called "MATLAB Relay Race Escape Room". I instructed students to work with their groups to solve a "MATLAB Escape Room", under specific rules such as "You can help your teammates during their turn, but you cannot touch their computer" (see Appendix). Successful teams worked together, stood up, and moved around the table for each person's turn. Unsuccessful teams might let team members struggle with their task, give up early, or work on assignments for other classes during the activity. Some teams may give up early, preventing the teammates assigned the later tasks from starting if the first tasks are not completed.

To improve this activity before implementing it again in another class section, I provided a paper copy of the solution to each member of the teaching team and clearly discussed procedure, such as giving hints to the teams that were falling behind. I also created hint slides to display periodically and instructed each team to mark off their team's tasks on the whiteboard wall at each checkpoint. This gave a visual representation to the students of who was in the lead, similar to an actual relay race. Additionally, this clearly showed the teaching team which teams needed support to keep up.

Another instructor affiliated with the course observed overwhelmingly positive feedback on this ICA from online student reflection comments.

A. *Incentive*

Instead of working on ICAs during class, students sometimes immediately disengage and work on assignments for other classes, play computer games, or chat with their neighbors during the ICA work time. Attendance is recorded and graded in this engineering class, so students are motivated to be physically present, and sometimes nothing more. The ICAs sometimes are submitted to the Learning Management System, but they are never marked nor graded. In-class activities are written well; they are sometimes a simplified version of the next homework assignment, and/or target only one skill, unlike the homework which combines multiple skills into longer problems. This ICA and assignment structure is a type of soft scaffolding; completing the ICAs with the assistance of the teaching team should prepare the students to start homework assignments on their own.

Because ICAs and class participation are not graded, there is no extrinsic motivation for students to complete them. Students who are intrinsically motivated by wanting to learn, future assignment or exam grades, or a desire to follow instructions are more likely to choose to complete the activities instead of doing nothing during the work time. There is no instant reward for completing an ICA.

A proposal to solve this problem is to simply grade the ICAs, but I argue this does not solve the bigger problem of motivation type. Students should have the opportunity to learn on their own and discover which concepts they do not understand and need more help with by working on and struggling with these ICAs. Forcing students to complete these activities with the threat of losing points removes any student autonomy in a class session.

B. *Feedback*

Another issue with the ICAs is that students must wait to see if they are correct. If a student has 10 minutes to solve the ICA, and it takes them five minutes and they are incorrect, they have wasted five minutes where they could have been iterating and correcting their mistakes. Encouraging students to check their answer with a peer or a teaching assistant if they finish early allows students with incorrect answers to make corrections and learn from their mistakes. For example, one ICA asked students to write code for input validation, and a requirement was "validation will fail if the input has dimensions greater than one". If a student coded "x > 1" which checks the value of x rather than the dimensions of x, feedback would assist them in checking their mistake and using the correct function, "length(x)". Rather than thinking their work was correct and waiting for the solution, students could iterate with feedback from the teaching team and fixed their code before the solution is revealed.

Another practical implementation could be to use a Learning Management System or other online tool for feedback. The students could submit their answer to iClicker or a D2L Brightspace quiz to receive instant feedback if they are correct or not. A quiz with unlimited attempts might motivate students to solve the ICA and iterate until their solution is correct. In MATLAB, P-code files with test cases could be used to hide the answer and verify when code is correct.

Students are used to receiving instant feedback from online sources in other classes. Some college classes at this university use Cengage WebAssign or McGraw-Hill Connect for homework assignments. These tools randomize problems for students and allow multiple attempts for questions with numeric answers. If a student is incorrect, the tool will return feedback and allow another attempt. Students are required to purchase access to Cengage WebAssign and McGraw-Hill Connect for each class that uses it for homework, differing from tools that are open-source or offer a university license.

LON-CAPA is a free and open-source tool formerly supported by the university that advertises "immediate feedback and even adaptive feedback capabilities" [9]. LON-CAPA has built-in feedback for classes such as physics, anticipating common mistakes and responding appropriately. For example, if a student enters -450 J/s and the correct answer is +450 J/s, LON-CAPA will recognize that the magnitude is correct and the direction is incorrect, then prompt the student to check the direction of the heat transfer. MATLAB P-code and Learning Management System quizzes could be used to provide the same feedback for expected or common errors with some additional development for each course.

IV. Research Design

In an attempt to avoid significantly modifying the structure of the second level engineering design course, I propose the following intervention methodology:

I will define two types of sections in the course: a control group and an experimental group. Students in the control group will participate in the traditional set of ICAs, while students in the experimental group experience the modified ICAs. Different individuals will be used in each sample, and the samples may not be the same size. The live academic research setting prevents complete random assignment of participants to groups, creating a quasi-experiment [10].

The experimental group will participate in the modified ICAs described earlier: warmup activities, group work on vertical surfaces, gamified activities, and rapid feedback. All of the ICAs will align with each class session's learning objectives; only the delivery method will vary between groups.

To accurately assess the effect of ICA style between each group, I will administer pre- and post-assessments to the students. The assessments will align with the learning objectives targeted by the course's ICAs. To analyze effects on learning objective achievement more-closely, pre- and post-tests can be administered at the beginning and end of a unit instead of the entire semester.

After each class session, students have the option to freely submit anonymous feedback and questions about the day's content to an online student reflection tool.

I will calculate the difference in the pre- and post-test scores for each student and perform a t-test between the groups to analyze if there is a significant difference between groups. I plan to collect data from three class sections in the experimental group and at least three sections in the control group.

A. *Hypotheses*

Given Liljedahl's [7] findings of increased attention span, discussion quality, and participation, I anticipate that I will see similar results in a new setting: a college first-year engineering course. Based on this premise, this study brings two hypotheses:

Hypothesis 1: The difference between post- and pre-test scores for the intervention group will be significantly higher than that of the control group.

Hypothesis 2: Students in the intervention group will discuss positive satisfaction and engagement with the gamified ICAs in the unprompted, optional student reflections.

B. *Limitations*

Some limitations of this study design include sample size and bias. As mentioned earlier, a large limitation is attempting to not significantly alter the existing structure of the introductory engineering design courses. Because of this, it may be difficult to find multiple instructors willing to change their sections into an intervention group. This study is limited by the team of instructors teaching the many sections of the course. The modifications to the ICAs must be kept simple enough for instructors properly implement, without negatively impacting student learning. Some instructors may be unwilling to participate if this study requests significant extra effort from them.

Another limitation is the power of the instrument used to measure learning objective satisfaction. Rigorous development of a rubric is required to ensure the pre- and post-tests accurately measure learning objective satisfaction.

Finally, an important limitation is scalability. Liljedahl's research is intended for implementation in secondary mathematics classrooms which typically have 20-30 students, so scaling this model for large college classes is a logistical problem that must be considered. Instructors and curriculum developers need a strong plan for implementing this research design, such as how to have students move around to a new assigned seat on each day of class.

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APPENDIX

MATLAB Team "Relay Race" ICA Example

Rules:

Assign each person a letter A through D. If you have a three-person team, person A will also be person D. If you are missing 2 or 3 team members today, we'll assign you another team to work with today. You are allowed to stand up and move around your table. You can help your teammates during their turn, but you cannot touch their computer! You can use Google, the Learning Management System, Gradescope, ChatGPT, etc. You cannot message or communicate with anyone outside of your team. You can ask for help from a teaching assistant if you get stuck.

To get started: Download your assigned P-code file from the Learning Management System

Task Instructions:

Task A:

Create a vector named x with the whole numbers 1 through 21 (inclusive). Create a vector named y that has 50 numbers evenly spaced out, starting at 1 and ending at 100. Hint: use Google to find a MATLAB function that can do this in one line of code. Solve the following equation using matrix multiplication:

$$y * \sqrt{y} + \ln(y) - \bar{x}$$

Hint: x bar is the average of the x vector. Store your answer as a variable called taska_ans. Run ICA_checker_A(taska_ans) to check your work and to get the Task B instructions.

Task B:

Use a repetition structure to create a square matrix named A with the numbers 1 to 100. The numbers should increase as you move right across each row. Then, create a variable called B that contains the standard deviation of the linear indices of all the prime numbers in A

Task C:

Solve a word puzzle to continue. Given a matrix C, how many elements of C are perfectly divisible by 3?

Task D:

Translate the following pseudocode into MATLAB code:

If the element of z is greater than 5, double it. If it is less than or equal to 5, divide it by 2. If it is perfectly divisible by 4, triple it and don't perform the previously stated conditions.

Run your selection structure for the integers 1 to 35 and save your new vector as D_ans.

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