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Challenges and Successes of the Transition to Online Format of a Lower Division Aerospace Engineering Class during COVID-19

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Abstract

During the Spring 2020 semester, after the transition to online modality due to the COVID-19 pandemic, student engagement and participation level dropped significantly and student performance suffered in "Computer Programing for Aerospace Engineers" (AE 30), a lower division computer programming course in Aerospace Engineering. Cognitive empathy, metacognition, and zyBooks (specific brand of interactive online course material) are known to improve student engagement, participation, and performance. Thus, a cognitive empathy ice-breaker activity, a metacognition exam reflection exercise, and interactive zyBook exercises were incorporated and implemented in AE 30 to help mitigate the effects of the pandemic in the new online environment. The current investigation presents the assessment of the activities and exercises as effective means of improving student engagement, participation, and performance in an online modality amid a pandemic during the Spring 2020 semester. Instructor observations revealed that the cognitive empathy ice-breaker was a powerful way to allow students to share difficult emotions but created a distracting and intimidating atmosphere. However, after the cognitive empathy ice-breaker, students were more engaged and participative than on other days. The metacognition exam reflection and interactive zyBook exercises were found to be moderately correlated to improved student performance.

Introduction

After the transition to an online class format during mid-Spring 2020, student engagement, participation and performance dropped in "Computer Programming for Aerospace Engineers" (AE 30), a lower division computer programming course in Aerospace Engineering. This work presents the challenges that arose after the transition to the online modality and the assessment of interventions implemented in AE 30 during the Spring 2020 semester as effective tools to engage students, increase participation, and improve student performance amid a pandemic.

The shift to online class format changed how students attended AE 30 and the dynamics during class. Prior to the pandemic, AE 30 was taught face-to-face. Students would attend a 1-hour lecture and a 3-hour lab on a weekly basis. Lecture was held in a classroom, while lab was held in a computer lab. Students would complete Pre-Lecture Activities (PLAs) before coming to lecture, where PLAs were a combination of watching short videos and completing readings from the textbook. Lecture would start with a quiz on the material covered by the PLA, some time was

spent on reviewing the quiz answers, reviewing lesson concepts briefly, and doing a short In-Class Activity (ICA) in groups. During lab, students would write programs to solve aerospace engineering problems and the instructor would walk around the lab answering individual/group questions as needed. Throughout the course of the semester, students would complete a project (in teams) and three examinations. Mid-March 2020, however, COVID-19 forced AE 30 to move to an online modality. A synchronous online class format was adopted for AE 30 for the remainder of the Spring 2020 semester. In the online class format, students joined a synchronous class meeting for lecture and another one for lab through the videoconferencing software Zoom. Office hours also became an online Zoom meeting. Instead of walking around lab to answer questions, the instructor and the few students that attended lab would talk through questions as a group via Zoom. In the online environment, students were able to share their computer screen to show their code and the instructor was able to remote control the student's computer to demonstrate concepts. The planned course activities remained the same with the exception of the modifications and interventions implemented in response to challenges that arose.

The first challenge surfaced with Exam 1. The first exam of the term was to be an in-person exam to be taken during lab. However, after the online transition, the exam was modified to a take-home exam. The exam would be introduced during the first lab Zoom meeting, students would be able to ask questions, and finish the exam outside of lab. However, the first online lab, was only attended by 20% of the students, that is, 80% of students did not attend lab to ask questions about the exam. When the exam was due, many submissions were missing. Thus, the instructor reached out to each student individually to seek understanding of each person's situation.

The first intervention consisted of one-on-one conversations with each and every student that could be reached to understand individual needs going forward. During the one-on-one conversations students were asked the following questions:

1. What is an email address to reach you at?
2. Are you getting my class emails?
3. How are you attending lecture/lab/office hours?
4. How are you accessing the class software to get work done?
5. Do you prefer to take quizzes during lecture (synchronously) or before lecture in your own time (asynchronously)?
6. Will you be able to submit Lab 06 and Exam 01 next week?
7. Will you be able to prepare and present your Project presentations next week?

A majority of the students, 32 of 44 (72.72 %), were reached during the one-on-one conversations. The students that did not make an appointment during the first week, received an email requesting them to connect with the instructor. During the one-on-one conversations, the instructor was able to corroborate that she had the correct contact for most students and that students were indeed receiving the class communications. Most students were using their computer to connect to online meetings, except 2 students who were also using their phones. Most students had found a way to access class software, except 2 people who were still experiencing significant difficulties. No student preference was found for synchronous vs.

asynchronous quizzes. Most students were on track to submit the lab and take-home exam due the following week, except 1 person. Regarding the project, 7 students reported to be experiencing issues connecting with their team members. Some of the students that did not connect with the instructor were also not connecting with their project team members. In addition to the planned questions, the instructor also found out that 2 of the 12 students that did not connect with the instructor via Zoom, informed the instructor via email that they were struggling financially and academically and would have to stop participating in the class. Most students had relocated back to their family's home, nationally and internationally. Students also described concern that the class would see or hear family members in the background.

Exam 1 was the first indicator of low student performance. Although, the Exam 1 submission deadline was extended by 2 weeks and everyone eventually submitted the exam, the mean score was 68.77%. The last time the class was taught by the same instructor, during the Fall 2018 semester, the average score in Exam 1 was 76.42%. Compared to Fall 2018, the Spring 2020 Exam 1 mean score was low. Meanwhile, during synchronous online class meetings, student faces were not visible, student voices were rarely heard, and limited student feedback was received via the Zoom chat. Students were not participating nor performing at the expected level. Thus, a second intervention was implemented.

The second intervention was an ice-breaker activity that took place at the beginning of one of the subsequent online lecture classes. The activity was designed to build empathy, that is, create a space where the class (students and instructor) could empathize with one another's situation and emotions, feel accepted and understood, and make available the brain space necessary for learning.

Given the continued low lab attendance, in a third intervention, a free zyBook (specific brand of interactive online course material) was adopted to provide students with additional resources and help improve student performance despite the low interaction with the instructor. The zyBook was especially designed with content for AE 30 and provided a source of additional readings and exercises with the added benefit that the exercises in zyBooks are interactive, that is, students could try to master a topic by answering questions, receive instant feedback, and keep trying until the concept was mastered.[1][2][3] ZyBook activities were incorporated as part of PLAs and replaced quizzes. The mean score for Exam 2, however, did not show signs of improved student performance.

The continued low student performance demonstrated in Exam 2 prompted two additional interventions. The Exam 2 mean score during Spring 2020 semester was a 64.59 %, that is, a low average compared to a mean score of 76.42 % in the Fall 2018 semester. Therefore, after Exam 2 was graded and returned to students, two extra-credit assignments were made available to the students: (1) an exam reflection and (2) a zyBook problem set focused on a topic that students demonstrated difficulty with during Exam 2. Making the assignments worth extra-credit points allowed each student to choose if they wanted to complete the activity or not. After the exam reflection was completed, class feedback was provided during lecture.

In addition to the activities and interventions mentioned above, there were ICAs and polls that also took place during synchronous online class meetings in AE 30. Polls were used to measure participation. A time line showing key activities and interventions implemented in AE 30 during

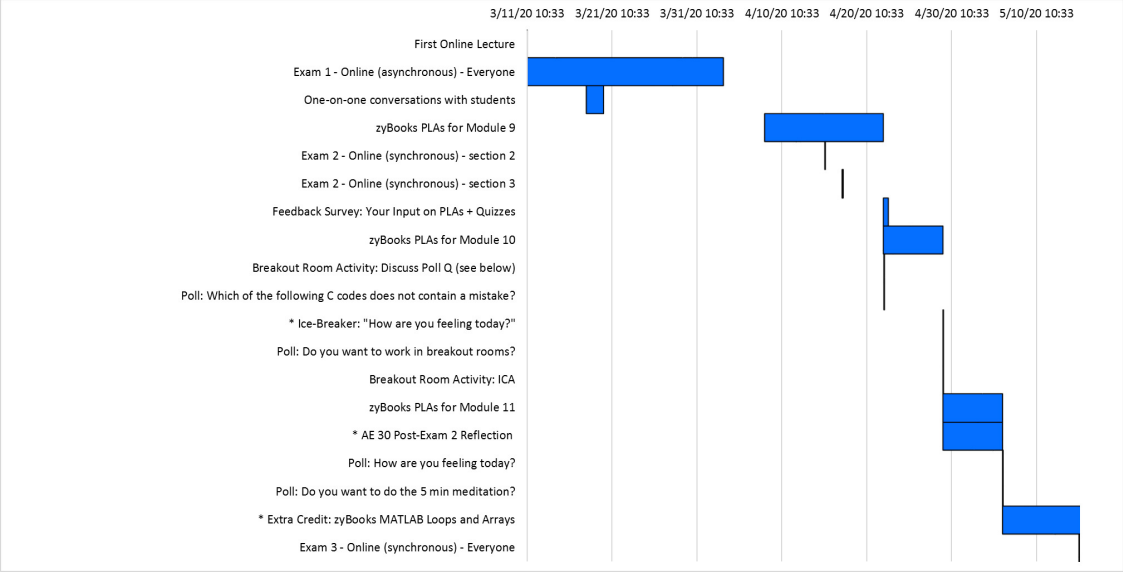


Figure 1: Time line of assignments and activities in AE 30 during Spring 2020 after the onset of the pandemic

Spring 2020 is provided in figure 1. Each activity is identified by name and listed on the vertical axis. The horizontal axis indicates time starting with the first online lecture of Spring 2020 and evolves forward in time through the end of the semester. A blue bar indicates at what point in the semester an activity was ongoing. The current investigation is focused on the assessment of the three activities that are indicated by an asterisk in figure 1.

The goal of the work presented here is to assess three of the interventions and activities implemented in AE 30 during the Spring 2020 semester as effective tools to improve student engagement, participation, and performance. The ‘cognitive empathy’ activity labeled “Ice-Breaker: How are you feeling today? ”, the ‘metacognition’ assignment titled “AE 30 Post-Exam 2 Reflection”, and the interactive textbook exercise assigned in preparation for Exam 3 named “Extra Credit: zyBooks MATLAB Loops and Arrays” are assessed. However, before the assessment of the activities can be presented, the terms ‘cognitive empathy’ and ‘metacognition’ must be defined, and more detail must be provided about zyBooks.

Cognitive empathy

The COVID-19 pandemic created a situation of high-stress for everyone world wide. Medina explains that stressed individuals do not learn, transfer, nor apply learned skills very well to new situations. Furthermore, stress hurts executive function, the type of thinking required for problem-solving.[4] However, empathy can diffuse emotions.[5]

Barrett-Lennard describes a cyclical process of how empathy unfolds or builds between two individuals, “A” and “B”, that consists of 5 steps and 3 phases.[6] Barret-Lennard’s empathy cycle is summarized in table 1. In the first step, A is actively attending to B’s expression of experience (and hoping/trusting A will be receptive). B’s experience becomes known to A in a second step.

Step	Description	Phase
1	A attends to B's expression of experience	Conditions for empathic process
2	A reads or resonates to B such that B's experience is known to A	Phase 1: empathic resonation (and personal understanding)
3	A expresses felt awareness of B's experiencing	Phase 2: expressed empathy (expressed empathic understanding)
4	B is attending to A's response to perceive the extent of A's understanding	Phase 3: received empathy
5	B resumes self-expression with feedback	Conditions for empathic process

Table 1: Barrett-Lennard's empathy cycle

Then, in a third step, A expresses in some way a felt awareness of B's experience. In the fourth step, B attends to A's response and perceives A's understanding. After the fourth step, the empathy cycle repeats starting from step 1, that is, the fifth step is a repetition of step 1. When the cycle repeats, B resumes self-expression but with elements of feedback. B's feedback could be confirming or corrective of A's understanding or informative of perceiving a relationship of personal understanding. The five steps can be divided into three phases. Before the cycle starts, the conditions for the empathic process described by step 1 (and step 5) must be present. Step 2 occurs in phase 1: empathic resonation. Phase 2: expressed empathy, consists of step 3. Step 4 happens in phase 3: received empathy. Step 5 closes the cycle, returning to the conditions for the empathic process.

According to Feshbach et al., in the context of teaching and learning, the therapist and client relationship is analogous to the teacher and student connection, respectively.[7][8][9] The hypothesis about cognitive empathy in education is that if the teacher can achieve and communicate empathy to the student, the latter will feel understood and accepted. In turn, the feelings of understanding and acceptance experienced by the student will then generate positive self-esteem and positive feelings towards the process of schooling. Rogers says:

> Empathy is clearly related to positive outcome. From schizophrenic patients to pupils in ordinary classrooms; from clients of a counselling centre to teachers in training; from neurotics in Germany to neurotics in the United States, the evidence is the same, and it indicates that the more the therapist or teacher is sensitively understanding, the more likely is constructive learning and change.[7]

Chang et al. found a positive relationship between teacher empathy and college student achievement indexes.[10] Wong (Lau) et al. define cognitive empathy as a person's ability to identify and understand another person's experience and, thus, understand why the other person may think and feel a certain way.[11] Wong (Lau) explains that cognitive empathy allows students to come from a range of experiences, feel safe to make mistakes, and frees up cognitive and affective brain space needed for learning. Faculty can empathize with students by representing the range of experiences while allowing students to remain silent. [12].

In AE 30, an ice-breaker style activity was implemented to build cognitive empathy between the students and the instructor. The activity began with the instructor representing the range of experiences the students might be living through, thus, allowing students to feel the instructor's empathy without forcing students to expose their feelings. Then, students were asked to share how they were feeling by anonymously and collaboratively annotating a slide online. The activity closed with the instructor's expressed empathy and offering coping resources allowing students to receive the instructor's empathy. The activity appears as "*Ice-Breaker: 'How are you feeling today?' " in figure 1.

Metacognition

Metacognition helps students learn about their own learning process and ultimately improve their performance.[12] The term metacognition was first used by John H. Flavell. In Flavell's words:

> Metacognition refers to ones knowledge concerning one's own cognitive processes and products or anything related to them, e.g., the learning-relevant properties of information or data. [13]

However, most commonly, the definition is given as "thinking about your own thinking". [14][15] Gregory Schraw describes metacognition as having two components: (1) knowledge of cognition and (2) regulation of cognition. Furthermore, the regulation of cognition is decomposed into planning, monitoring, and evaluating.[16] Similarly, McGuire describes metacognition as a process that can be decomposed into the following actions:

- thinking about one's own thinking
- conscious awareness of oneself as a problem solver
- monitoring, planning, and controlling one's mental processing
- accurately judging one's level of learning

McGuire says that when students use metacognition, they are able to reflect on their own learning process, keep what is working for them and eliminate what is not helping them learn. Furthermore, using metacognition can also help students judge how deeply they have learned about a subject.[14] There are multiple ways to incorporate metacognitive skill developing activities to a course. Dr. Marsha Lovett developed what she calls 'Exam Wrappers' that are structured reflection activities that prompt students to practice key metacognitive skills after getting back a graded exam. In particular, exam wrappers ask students questions regarding three aspects: (a) exam preparation, (b) errors made on the exam, and (c) changes/modifications for the next exam.[17] In AE 30, an activity similar to exam wrappers was implemented in the form of a survey that students took after receiving their graded Exam 2 and before taking Exam 3. The activity appears as "*AE 30 Post-Exam 2 Reflection" in figure 1.

ZyBooks

"ZyBooks" is a specific brand of interactive online course material that has been researched and found to increase student engagement with the course material and improve student performance.[1][2][3] A zyBook consists of an online collection of material selected by the instructor and made available to students in a specific class. Students and instructors access zyBooks online via the zyBooks website. ZyBooks contain written text material similar to what one might find in the hard-copy of a textbook, but zyBooks also include interactive experiences. In particular, zyBooks contain interactive exercises addressing different levels of Bloom's Taxonomy. For example, for a programming class like AE 30, the exercises might range from recalling facts and definitions to writing computer programs.[18] A zyBook interactive exercise is not marked complete until the student has answered the question correctly. Every time the student answers a question incorrectly, the zyBook provides feedback and allows the student to try again as many times as needed to get the correct answer. The instructor can set up groups of exercises as an assignment and track each student's progress. ZyBook assignments can also be integrated with some web-based Learning Management Systems (LMS), e.g., Canvas. Usually, zyBooks must be purchased by each student to access the interactive content for the semester. The cost aspect of zyBooks make them inaccessible to the low-income student population served by AE 30. However, after the onset of the pandemic, zyBooks were made available for free to students and educators for the remainder of the Spring 2020 semester. Lacking the interaction facilitated by labs because of low attendance and given the poor student performance in Exam 1 and Exam 2 motivated the adoption of a zyBook for AE 30 during the Spring 2020 semester. Interactive zyBook exercises were assigned as part of PLAs on a weekly basis and an extra credit set of exercises were assigned to help students master a concept that they struggled with in Exam 2 in preparation for Exam 3. In figure 1 the zyBook activities appear as "zyBooks PLAs for Module 9", "zyBooks PLAs for Module 10", "zyBooks PLAs for Module 11", and "*Extra Credit: zyBooks MATLAB Loops and Arrays".

Methods

The methods used to carry out the analysis in this investigation are both, quantitative and qualitative. The effectiveness of certain assignments/activities as means to improve student engagement/participation/performance was assessed using linear correlation, while other activities were evaluated by means of observations. The linear correlation coefficient, r, can be used to test if two quantities, x and y, are correlated.[19] A correlation coefficient $r > 0.7$ indicates a strong correlation between x and y, if $0.3 \leq r \leq 0.7$ the correlation between the quantities being tested is moderate, and if $r < 0.3$ the correlation between x and y is weak. The correlation coefficient was used to test for correlation between the degree of completion of the extra credit assignment, "Extra Credit: zyBooks MATLAB Loops and Arrays" and an improvement in Exam 3 performance in comparison to Exam 2 in a specific problem. The higher the correlation coefficient, the more effective the assignment was as a means to improve student performance. Similarly, the correlation coefficient was also used to test for correlation between the completion of the metacognition activity "AE 30 Post-Exam 2 Reflection" and an overall improvement in exam grade measured between Exam 2 and Exam 3. The effectiveness of the cognitive empathy activity "Ice-Breaker: How are you feeling today?" as a means to increase

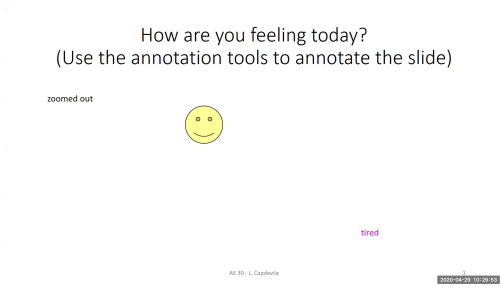
student engagement and participation was assessed using instructor observations.

Cognitive empathy ice-breaker, student participation, and engagement

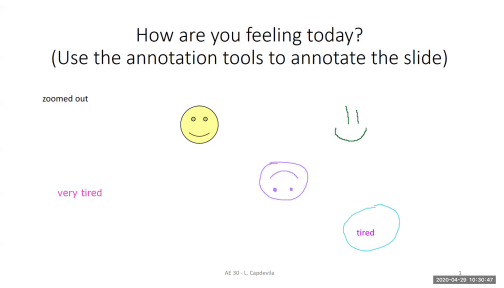
Based on the concept of cognitive empathy, an ice-breaker activity was designed to create a space where students could share how they feel, empathize with each other, and be more able to focus on learning. The activity was highly engaging for students and proved to draw out some of the difficult emotions that students were feeling at the time. Although it was difficult for the instructor to regain command of the class after the ice-breaker, the students were more participative and engaged in discussion than on other days.

As the ice-breaker activity unfolded, the student contributions demonstrated challenging emotions. The activity began with the instructor saying a few words aimed at representing the range of experiences people may be going through, e.g., experiencing the loss of a loved one, not having a personal space where to connect to class, being fatigued from attending online class/meetings, etc, and sharing her own personal feelings and situation in relation to the pandemic. Then, students were asked to collaboratively and anonymously annotate a slide titled "How are you feeling today?". Select screen captures extracted from the recorded lecture appear in figures 2(a)-2(f) showing the progression of student contributions. First, the word "HELP", a hanged stick figure, and the word "Dead" appeared on the screen. Then, the background was turned from white to black. Next, the text "can i take you out before the virus does??????" and the annotation "fprintf(" I'm dead ")" appear. To conclude the activity, the instructor voiced her own feelings and that while she is not aware of the specifics of each person's situation, she imagines everyone is tired of the situation the pandemic has put them in and that she is, however, very glad to be online because connecting with her students is the highlight of her week. Once, the ice-breaker was declared concluded, the instructor had difficulty in regaining control of the presentation in the online environment. The sixth screen capture in figure 2(f), shows the instructor attempting to start with the lecture content but she is overridden by a student that turns the screen black again and the text "I still have power" appears on the screen. The instructor had to re-set the presentation more than once. During the first few lecture slides, students kept doodling over the notes while the instructor tried to go over the material. The anonymous nature of the activity allowed the students to release an overwhelming amount of difficult emotions while becoming disconnected from the class material. The activity made the instructor feel overwhelmed by the emotions students displayed, powerless to carry on class, and unable to help individuals that may have felt adverse emotions as a result of the activity. The following class, the instructor issued an open invitation to talk to her if she could be of any help and provided links to campus resources for different kinds of support.

The building of empathy between the instructor and the students that occurred through the ice-breaker can be understood using Barrett-Lennard's empathy cycle.[6] Table 2 summarizes the events that took place as part of the ice-breaker and maps each event to the corresponding phase and step in the model. As can be seen from table 2, representing the range of experiences, items a-b, involved one cycle of Barrett-Lennard's empathy cycle, where the students did not need to express their experience (Phase 1). The collaborative activity, items c-g, goes through a second iteration of the empathy cycle. The level of empathy received by the students was not measured directly. Instead, the effect of felt empathy was observed on student engagement and participation



(a) First



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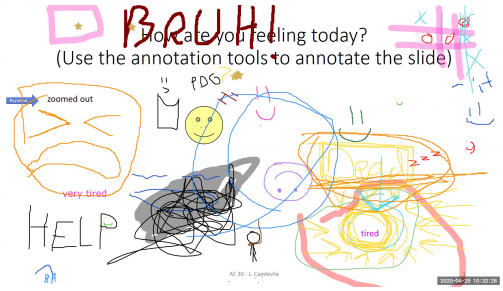
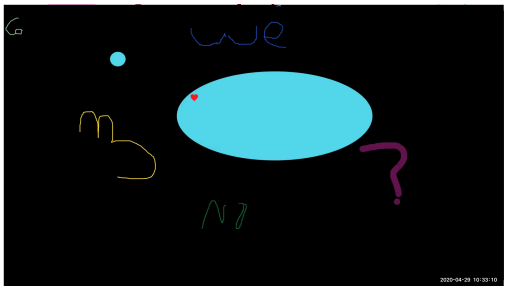
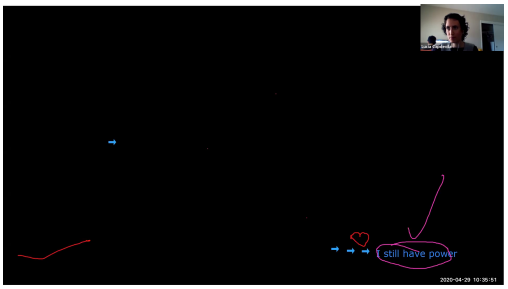


(c) Third



(d) Fourth

(e) Fifth



(f) Sixth

Figure 2: Ice-breaker screen captures

Ice-Breaker Event	Empathy Cycle Phase (Step)
a) Instructor represents the range of experiences	Phase 2 (step 3)
b) Students receive instructor's empathy	Phase 3 (step 4)
c) Instructor's pre-populated slide with expressions of her experience appear on screen d) Students add expressions of their experiences to the slide	Conditions for empathic process (step 1)
e) Instructor and students are attending to one another	Phase 1 (step 2)
f) Instructor responds to student's expression	Phase 2 (step 3)
g) Students receive instructor's empathy	Phase 3 (step 4)

Table 2: Map of ice-breaker events to Barrett-Lennard's empathy cycle

Date	Poll #	Respondents	Present	Participation %
$4/22/2020$	1	24	32	75.00
*$4/29/2020$	1	30	32	93.75
$5/6/2020$	1	29	31	93.55
$5/6/2020$	2	28	31	90.32

Table 3: Poll participation in AE 30 during Spring 2020

levels.

While the ice-breaker activity did create a distracting and intimidating atmosphere at the beginning of class, student poll participation and engagement level after the cognitive empathy ice-breaker was found to be higher than on other days. Table 3 provides AE 30 poll participation by day. Please note that there were two different polls on $5/6/2020$. Poll participation by percent of respondents on $4/29/2020$ (the day of the ice-breaker) was higher than on previous days ($4/22/2021$). However, poll participation on $4/29/2021$ was not noticeably higher than participation on either of the polls administered on $5/6/2021$. After the cognitive empathy activity, students were given an ICA (refer to "Introduction" section for acronym definition). During the ICA, 4 different student groups were observed and 3 out of 4 groups were very engaged and using the online system tools to work collaboratively. During the class discussion of the ICA, there were multiple questions to the instructor. In comparison to previous ICAs, the day of the ice-breaker students were much more engaged and talkative in their discussion groups and as a class.

Metacognition and student performance

Given the low student performance in AE 30 Exam 1 and Exam 2 during Spring 2020 (in comparison to the Fall 2018 semester), after Exam 2 was graded and returned, a metacognition

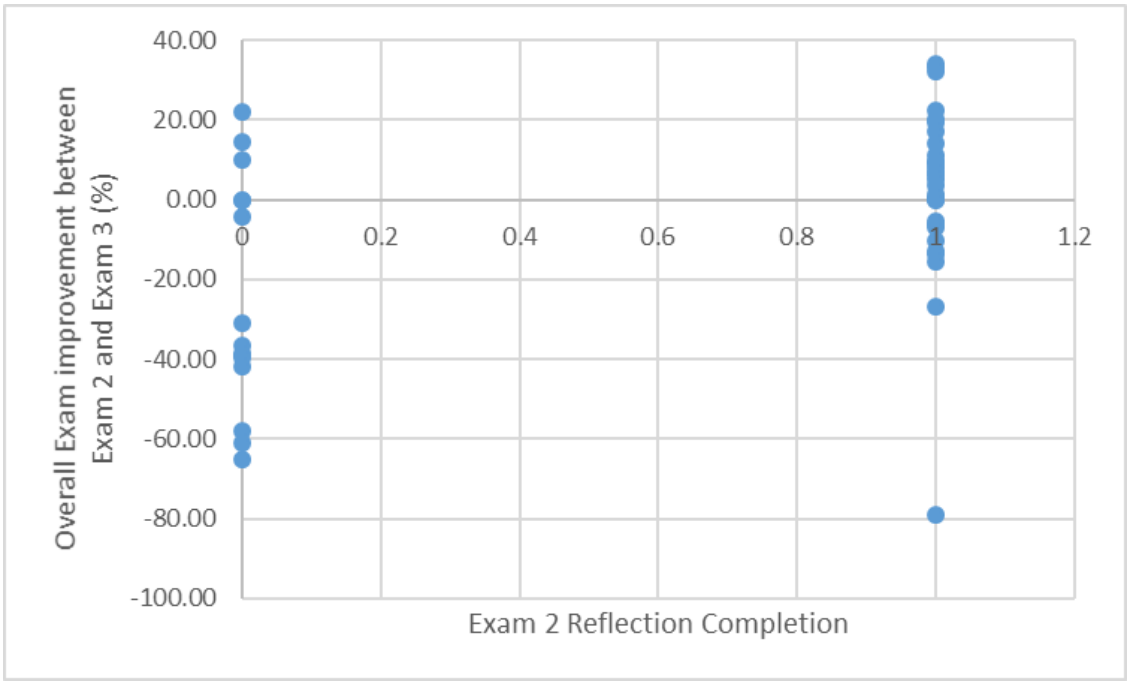


Figure 3: Overall exam score improvement between Exam 2 and Exam 3 as a function of the completion of the metacognitive Exam 2 reflection, where a 1 indicates completion.

activity titled "AE 30 Post-Exam 2 Reflection" was made available to help students improve their learning skills and their performance in the class. The metacognition activity is similar in nature to Dr. Lovett's 'exam wrappers' previously described.[17] The activity consisted of a guided reflection about student's preparation for Exam 2, an auto-evaluation of how their preparation worked based on their grade, and what might the student do differently in preparation for the next exam. The reflection was provided in the form of a survey with multiple choice questions and free-form answer options. A copy of the actual survey is included in the appendix to this paper. After the activity was complete, the instructor reviewed the student responses, provided class feedback, and invited students to visit her during office hours to make a detailed plan to improve their current performance. While not many students visited the instructor to discuss how to improve their performance, the hypothesis was that having completed the exam reflection alone would have an impact on the student's performance on Exam 3.

Correlation analysis was used to test the possible relationship between the completion of the metacognitive exercise and improvement in student performance. For each student, the improvement between second and third exams was calculated as the grade % in Exam 2 subtracted from the grade % in Exam 3. If a student completed the metacognition activity, a value of 1 was recorded. A zero was recorded if the student chose not to complete the reflection. Performance improvement data appears as a function of reflection completion data in figure 3. Then, the performance improvement measure was tested for correlation with the completion of the metacognitive activity by calculating the value of the correlation coefficient between the two quantities. The resulting value of $r = 0.4776$ corresponds to a moderate correlation between the completion of the metacognitive assignment and an improvement in exam grade. Therefore, the

metacognitive “AE 30 Post-Exam 2 Reflection” was moderately effective in improving student performance.

ZyBook activities, student opinion, and student performance

Shortly after the transition to online modality due to the pandemic, a zyBook (specific brand of interactive online course materials described in earlier section “ZyBooks”) was adopted in AE 30 to help mitigate the low lab attendance, diminished student/instructor interactions, and low exam performance (as compared to previous semesters). Students found zyBook activities helpful to learn new concepts and the correlation between the completion of zyBook activities and improved exam performance was found to be moderate.

Student opinion of zyBook activities was positive. Interactive zyBook activities were incorporated on a weekly basis as part of the PLAs while the quizzes about the PLAs were discontinued. After the first set of zyBook exercises, students were given a survey asking them “Do you find zyBooks activities helpful to learn new concepts?”. Only 25/44 students, that is, 56.8% of the class replied to the survey, but 96 % of respondents indicated that zyBook activites were helpful in learning new concepts. Student opinion is, however, subjective to each individual’s perception of their own learning process.

A specific assignment and exam problem were designed to obtain an objective measure of the effectiveness of zyBook activities as a means to improve student performance. In Exam 2, students demonstrated special difficulty with a problem that combined the concepts of loops and arrays in programming. Therefore, a set of interactive textbook activities covering the topics were assigned for extra credit, “Extra Credit: zyBooks MATLAB Loops and Arrays”, in preparation for Exam 3 and students were told there might be a question that combined loops and arrays in the following exam. Each zyBook question must be answered correctly for the activity to be marked complete. Unlike traditional exercises, students get feedback every time a question is answered incorrectly and are allowed to try as many times as needed to get a correct answer. However, the question may vary slightly between trials. Making the activity worth extra credit meant that students could choose to complete the activity or not. In Exam 3, the students were presented once again with a problem that combined loops and arrays. The score on the loop and array problem was recorded for each student in Exam 2 and Exam 3 and the percent score increase in the loop and array problem was calculated. The percent completion of the extra credit assignment was also recorded. The performance improvement data appears as a function of zyBooks activity completion data in figure 4. Then, the linear correlation coefficient was calculated to test the correlation between the exam problem percent score increase and extra credit percent completion. The resulting correlation coefficient was $r = 0.4027$, indicating a moderate correlation between the two variables. That is, there is a moderate correlation between completing the interactive textbook activities prior to Exam 3 and exhibiting an improved performance in the loops and array problem in Exam 3 in comparison to Exam 2. Therefore, zyBook exercises were moderatively effective in improving student performance in the topic of loops and arrays.

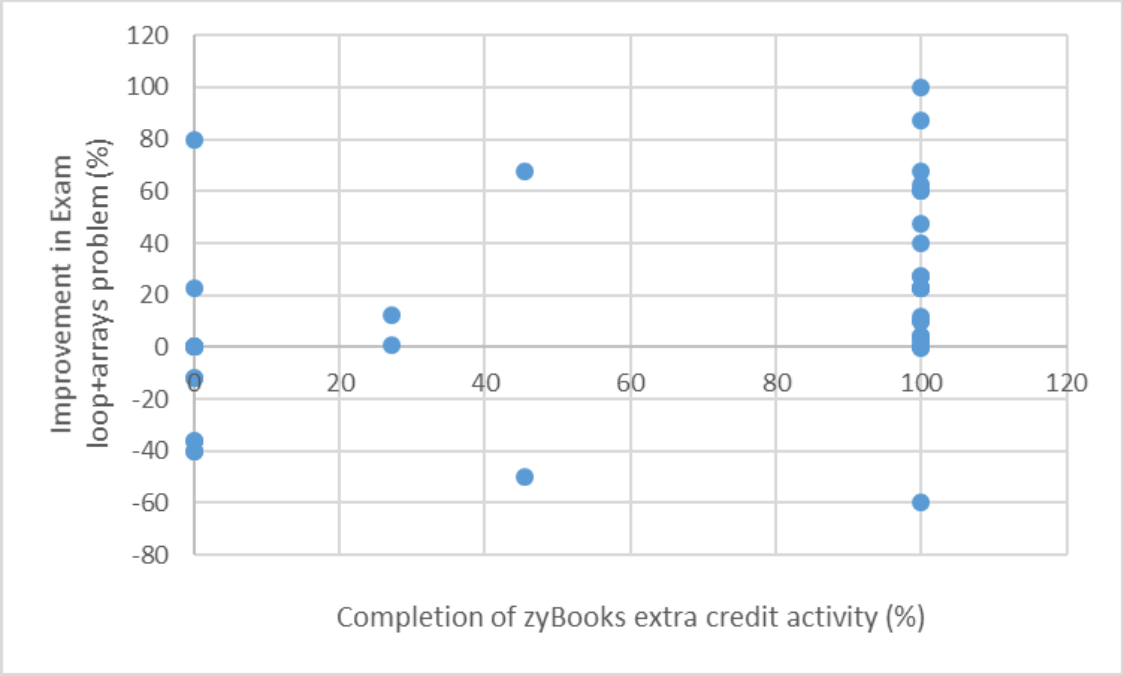


Figure 4: Score improvement between Exam 2 and Exam 3 in loops and arrays problem as a function of the degree of completion of zyBooks activity

Summary and future work

The activities implemented in AE 30 during Spring 2020 aimed at mitigating decreased student engagement, participation, and performance were moderately effective, but the successes were also accompanied by challenges. The cognitive empathy ice-breaker allowed students to share their feelings about their situation without being exposed and receive the instructor's empathy upon the conclusion of the activity. However, the difficult emotional release also created a distracting and intimidating atmosphere and the anonymity of the ice-breaker left the instructor unable to help students individually. Nonetheless, student engagement and participation on the day of the ice-breaker were higher than on other days. The metacognitive Exam 2 reflection and zyBooks activities were both moderately correlated to improved student performance. In the future, it is of interest to modify and re-implement some of the activities from Spring 2020 in AE 30.

While it may not be possible to re-adopt zyBooks in AE 30, metacognition and cognitive empathy activities will be improved and re-implemented. ZyBooks proved to be a moderately effective means to improve student performance and are very suitable for a flipped-learning environments, such as AE 30, for online or in-person classes. However, the cost of zyBooks, while much cheaper than other textbooks, cannot compete with texts freely available to AE 30 students through the university library given that the student population is generally low income. Thus, it will not be possible to re-adopt a zyBook for AE 30 in the future. The cognitive empathy ice-breaker activity proved to be a very powerful exercise. In the future, it is of interest to modify the activity to direct the power of the exercise towards connecting students to the course content.

Next time, the ice-breaker will be followed by a second stage where students are asked to collaboratively annotate a slide with their answer to the question "what might help you feel better?". As part of this last stage, the instructor will provide the formal institutional resources that she provided during Spring 2020. The additional stage will allow students process the difficult emotions that surface during the first stage and to brainstorm ways to help themselves together with their peers and the instructor. Identifying ways to cope with the difficult emotions might help students better focus on class once the activity is concluded. It is also of interest to identify the appropriate scale and tool to measure the level of empathy felt by the students through the ice-breaker. The metacognitive Exam 2 reflection is an easily implementable activity that can be incorporated to AE 30 every semester. In the future, it is of interest to adapt the current format of the exam reflection to align more closely with Lovett's 'exam wrappers'. As Dr. Lovett and her colleagues demonstrated, exam wrappers are highly adaptable to classes across a wide variety of subjects.[17] Given the experience in AE 30 during Spring 2020, it would seem that exam wrappers are suitable for online modalities as well.

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Appendix: "AE 30 Post-Exam 2 Reflection" survey

This is a metacognition exercise to help you learn about your learning process and help you improve your performance in AE 30 in preparation for the final Exam. You will receive extra credit points towards Exam 2 when you complete this activity.

1) How do you usually prepare for AE 30 lecture? (Please select all that apply)

- ☐ Read the textbook
- ☐ Review slides
- ☐ Make notes from textbook

- ☐ Watch videos
- ☐ Work example problems from textbook
- ☐ Reach out to my team
- ☐ Review/read notes
- ☐ Other (please specify) _____

2) During AE 30 lecture, what do you usually do?

- ☐ Take selective notes of things missing on slides
- ☐ Take regular notes
- ☐ Work on in-class activities
- ☐ Other (please specify) _____

3) How do you usually spend your time after AE 30 lecture (this can include your time during lab)? (Please select all that apply)

- ☐ Do labs
- ☐ Do examples in the textbook
- ☐ Do practice problems
- ☐ Rewrite problems on a board
- ☐ Make notes based on slides
- ☐ Record own questions
- ☐ Bring problems questions to office hours
- ☐ Find examples online
- ☐ Find help online
- ☐ Ask my own questions
- ☐ Read all sections covered in text
- ☐ Read text only on topics I did not understand
- ☐ Review slides
- ☐ Review notes
- ☐ Review examples in the textbook
- ☐ Review lab solution
- ☐ Review previous quizzes
- ☐ Review videos
- ☐ Re-do examples
- ☐ Re-do previous labs
- ☐ Re-do examples in notes
- ☐ Re-write the lecture notes
- ☐ Problem solving in groups

- ☐ Re-do examples individually and then in groups
- ☐ Ask questions to peers and/or discuss in groups
- ☐ Study in groups
- ☐ Other (please specify) _____

4) How did you prepare for AE 30 Exam 2? (Please select all that apply)

- ☐ Go over everything (pre-lecture activities, textbook, quizzes, notes, slides/lecture notes, and labs)
- ☐ Watch videos
- ☐ Review previous class material
- ☐ Made flash cards
- ☐ Review notes
- ☐ Re-write notes
- ☐ Review slides
- ☐ Read the textbook
- ☐ Study a few hours
- ☐ Rework examples and/or labs
- ☐ Problem solving in groups
- ☐ Study in groups
- ☐ Search for related videos on Youtube
- ☐ Review Solutions
- ☐ Other (please specify) _____

5) Based on your AE 30 Exam 2 grade, did your preparation/study methods work?

- ○ Yes
- ○ No

The following question, # 6, displays to students only if the answer to # 5 (above) is "No":

6) Why do you think your preparation/study methods for AE 30 Exam 2 did not work? (Please select all that apply)

- ☐ Did not ask questions
- ☐ Did not read textbook (enough)
- ☐ Did not have the textbook
- ☐ Did not study enough
- ☐ Did not do the labs
- ☐ Did not put enough time
- ☐ Did not have enough time (to complete the exam)
- ☐ Did not finish the exam

- ☐ Did not study theory, only problems
- ☐ Underestimated the difficulty
- ☐ Rely too much on the videos
- ☐ Unfocused/distracted studying
- ☐ Incomplete notes
- ☐ Lazy behavior
- ☐ Not much interest in the field
- ☐ Re-write/rework notes
- ☐ Unfamiliar with instructor
- ☐ Previous class too long ago
- ☐ Watch lecture videos
- ☐ Forgot to finish
- ☐ Forgot fundamentals
- ☐ Unsure of the material to cover
- ☐ Cannot keep up with terminology
- ☐ Not sufficient problem solving practice
- ☐ Lots of little mistakes
- ☐ Course load/time management
- ☐ Other (please specify) _____

7) If anything, what will you do different in your preparation for AE 30 Exam 3? (Please select all that apply)

- ☐ Better time management
- ☐ Start studying/working in groups
- ☐ Take better notes
- ☐ Watch videos
- ☐ Take notes while reading the text
- ☐ Review before lecture
- ☐ Review after lecture
- ☐ Work practice problems
- ☐ Review and/or re-write notes
- ☐ Pay more attention in class
- ☐ Re-work lab assignments/practice problems
- ☐ Study solutions
- ☐ Be more systematic/regular in the study
- ☐ Make notes from text
- ☐ Read text and notes before lecture
- ☐ Spend more time to read text

- ☐ Review slides
- ☐ Spend more time to read the text
- ☐ Spend more time to review examples, labs
- ☐ Spend more time to for problem solving
- ☐ Spend more time to reviewing slides
- ☐ Spend more time to to study more days
- ☐ Spend more time on theory in depth
- ☐ Spend more time to reviewing notes
- ☐ Spend more time to doing example/practice problems
- ☐ Spend more time doing labs
- ☐ Spend more time to study in general
- ☐ Spend more time to study in groups
- ☐ Re-do the exam
- ☐ Look for help online
- ☐ Study individually first then in group then solo
- ☐ Ask questions to myself
- ☐ Study earlier
- ☐ Ask notes to peers
- ☐ Learn from many different approaches to solutions
- ☐ Look for additional examples
- ☐ Other (please specify) _____

8) What might you need to perform better in AE 30 Exam 3 than in Exam 2? (Please enter your answer below)