Impact of Active Learning on Student Grades and Instructor Rating

Dr. Anu Aggarwal, University of Illinois at Urbana - Champaign

Anu Aggarwal is an Assistant Professor at the University of Illinois, Urbana Champaign. She secured her PhD in Electrical and Computer Engineering from the University of Maryland College Park under the supervision of Prof Robert W Newcomb in the area of Neuromorphic VLSI and Computational Neuroscience.

Dr. Christopher D. Schmitz, University of Illinois at Urbana - Champaign

Christopher D. Schmitz received his Ph.D. in Electrical and Computer Engineering from the University of Illinois in 2002.

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Abstract. The objective of this work was to use active learning techniques, especially in-class group work using the gradual release model to improve student learning, grades and quality of teaching. This intervention was applied in an advanced logic design course. During the intervention, for every new concept taught in class, three problems related to it were covered. The first problem was solved by the instructor, the second problem was solved by the instructor jointly with the students and the third problem was assigned to groups of 2-3 students to be solved in class. This was followed by the instructor going over the third problem in class with the students. Student groups were required to submit the solution to the third problem by the end of the day of class. Early formative feedback available based on student performance on the third problem was used to modify future lecture content. The intervention resulted in better grades for students and better teaching evaluations for the instructor as compared to a similar offering of the course in the previous semester. Therefore, it is highly recommended.

1. Introduction

The course redesign approach of this project focuses on active learning using in-class groupwork and formative feedback. In a challenging course, it is important that students understand underlying concepts and not just procedural methods of problem solving. Schwartz [1] discusses how groupwork demands that students resolve multiple viewpoints in the process of communicating. Students learn to "span superficial differences" and produce solutions that are both abstract and insightful. Proper application of formative assessment to that groupwork further strengthens the results. According to [2], there are four key elements to formative feedback. They include 1) identifying a learning gap, 2) feedback both to the teacher (for continued assessment of the learning gaps) as well as to the students (improving motivation and self-efficacy) 3) student involvement in the learning process where their active role in discussions increases their metacognitive learning processes, and 4) providing a measure of learning progression through clear short-term goals and the course's big picture objectives. Formative assessment with timely feedback to which the instructor responds in a clear-and-evident manner are critical features of our approach to groupwork through active learning.

Active learning in its various forms has been shown to enhance learning, improve grades by nearly half a standard deviation [3] and narrow achievement gaps for underrepresented students [4] in undergraduate science, technology, engineering, and math (STEM) courses. In our study, we used in-class problem solving with the 'I do, we do, you do' gradual release model [5]. The model helps students understand concepts by first observing problem solving by instructor, then learning by solving problems with the instructor, which is finally followed by problem solving with peers. The method enhances instructor-to-student and student-to-student learning. It also reinforces concepts because several problems are solved for the same topic. The solution to the third problem is then covered by the instructor as well. This timely feedback allows students to reflect on the activity soon after completion.

In this work, the gradual release model has been applied in a VLSI (very large scale integrated) circuit design algorithms course where it improved student grades and instructor teaching evaluations. The latter may be surprising when considering the novice learners studied by

Deslauriers, et. al., in [6] who held a somewhat contradictory view of the value of active learning. Both [6] and Oakley, et. al., in [7] emphasize careful design and scaffolding for younger students being introduced to active learning to reduce the occurrences of negative responses. In this study, students were "upper level" undergraduate and graduate students whose maturity may have contributed to their positive perception of the changes. However, we also suspect that the careful design of the questions and gradual release of the task to solve serves as scaffolding that might even work for younger students.

2. Methods

We used active learning methods, especially the technique of in-class problem solving using the gradual release model to enhance student learning in an advanced logic design course. The course teaches VLSI design algorithms. The course content was based on the textbook: "Logic Synthesis and Verification Algorithms" by Hatchel and Somenzi. It was a 3 credit senior level course with two hour forty minutes of lectures every week. The course content included teaching Boolean algebra, combinational logic minimization using Karnaugh maps, Quine McCluskey algorithm, branch and bound method, unate covering problem, Heuristic minimization of two level circuits, Binary decision diagrams, synthesis and verification of finite state machines, multilevel logic minimization, automatic test pattern generation and technology mapping. The course included 9 homework assignments, 2 midterm exams and 1 final exam. An end-of-term optional project was also offered using industry standard software.

The technique of in-class problem solving using the gradual release model was applied in Spring 24 semester and continued in Summer 24 semester. One offering of the course (without the intervention) was provided in Fall 22. Classes in Fall 22 and Summer 24 semesters were offered online while those in the Spring 24 semester were offered in-person. Students enrolled in the class were either juniors, seniors, or graduate students in all 3 semesters. Enrollment in Spring 24 was 10% higher than Fall 22 and in Summer 24 was 30% lower (which is typical of a summer term).

As part of the intervention, after every algorithm taught in class, the instructor went over one problem in class, the second problem was solved by the instructor with student participation, and the third problem was assigned to a group of 3-4 students to solve in-class. This was followed by the instructor going over the third problem with the students in class. By the end of the day of the lecture, the students had to submit the solution to the third problem to the course website. This was graded for a small credit in overall grade (around half a point for each problem). Based on the student solution to the problem and their grade, the lectures were readjusted, if required.

Due to this structure of the lecture, a separate set of slides was used in class (Fig. 1). This slide deck did not have solutions to problems. The solutions to the problems were written on the slide while teaching in class and projected to the screen in class. Slide deck with solutions was then posted on canvas to provide students full access to solutions. Solutions to in class problems were posted to canvas in type-written format as worksheet solutions (Fig. 2). The in-class problems supplemented (and did not substitute) the homework, midterm and final exams. In addition to the in-class problems, the students were also given one homework assignment almost every week other than the weeks of the exams. Midterm exams were given every month, and the final exam was administered at the end of the course. An optional project was also provided for a small extra credit. The in-class problems were used to collect formative feedback on student learning

based on which future lectures were adjusted. Exams were used to assess student learning and collect summative feedback.

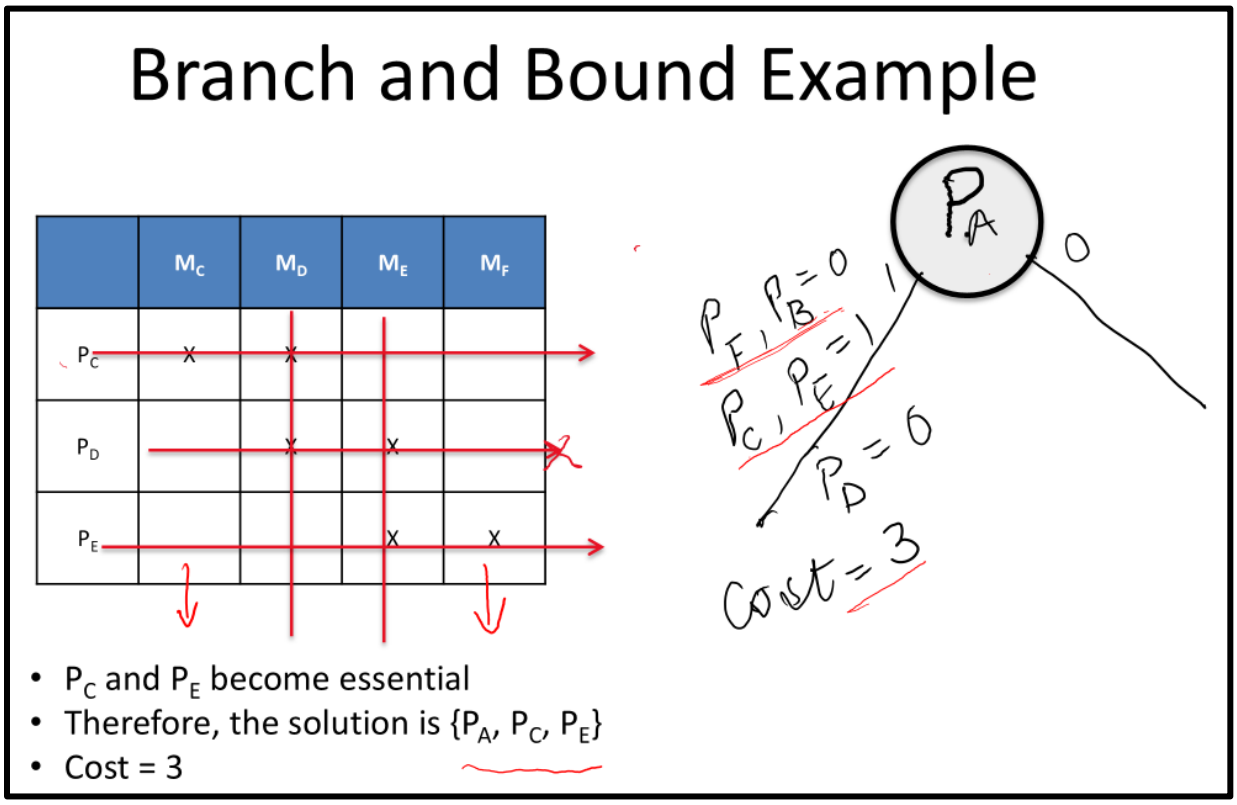

Fig. 1 An example in-class problem that the instructor went over. Slide with typed information was projected to the board. Then the instructor wrote on the slide. Here, all the handwritten portion was worked through with the students. The annotated slide was then posted to canvas for student review.

WorkSheet 9

Calculate the LB, UB and choose a splitting variable for the following:

	M1	M2	M3	M4
P1	1	1		
P2			1	1
P3	1		1	
P4		1		1
P5	1			1
P6		1	1	

UB = 6 + 1 = 7

LB = 1 + 1 = 2

SV=P1 (or any PI)

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
P1	1			1								1	
P2	1	1											
P3		1	1										
P4			1	1									
P5					1				1	1	1		1
P6					1	1		1					1
P7						1	1				1		
P8							1	1		1			1
P9						1			1	1			
P10					1			1	1				
P11								1	1		1	1	

UB = 11 + 1 = 12

LB = 4 (M1, M3, M7, M5)

SV = P5 (most min term coverage)

Fig. 2 An example of a neatly typed solution to one of the third problems (that was worked over by student groups in class and then by the instructor) that was posted to course website.

3. Results

In this study, we have results from three semesters of offering of the same course, one of which was without the intervention and two with it. The student population across the semesters was similar. Only one of the three semesters was offered in-class while the other two were offered online. Classes were synchronous for all the semesters. Therefore, we are in a good position to evaluate the outcomes from different perspectives – with intervention or without, online or in-class. As a result of the intervention mentioned above, there was an improvement in student learning as assessed by improvement in grades and student motivation. Due to the better class preparation and engagement with students, the instructor evaluation also improved substantially.

A. Impact on grades

The student grades are presented for the three different semesters that the course was offered- in Fall 2022 (before the intervention) and in Spring and Summer 2024 (after the intervention). The gradual release model improved student performance in class and on exams as seen from the grades (Fig. 3). In the Spring 24 semester, 70% of the students received an A grade of some kind and all the students got a grade of at least a B-. In the Summer 24 semester, 65% of the students got an A while the rest got a B. None got C, D or F grades. This was an improvement over the Fall 22 semester, where a similar cohort of students received a range of grades from A to F (6%

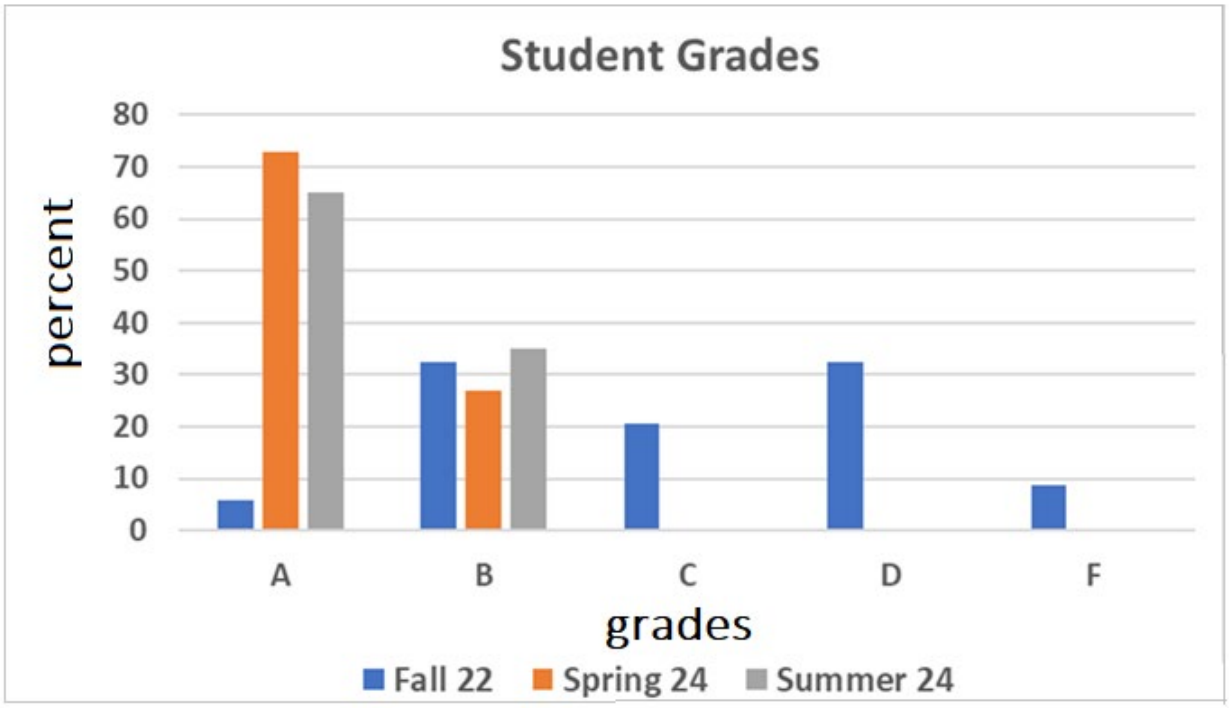

Fig. 3 Histogram of student grades over the Fall 2022, Spring 2024 and Summer 2024 semesters. Y-axis is percentage of students getting the grades. Indicates improvement in student grades from the pre-intervention semester with most students getting B and D to all students getting A and B in the post-intervention semesters. No students secured C, D or F grades in Spring and Summer 2024 semesters post-intervention.

A, 32% B, 21% C, 32% D and 9% F). Summer 24 courses were held in the synchronous online mode while Spring 24 were in-person. The fall in 'A' grade from Spring to Summer could be due to this. If we compare online offerings in fall 2022 (without the intervention) to summer 2024 (with the intervention), the student grades follow similar trend as for Spring 2024 (in-person with the intervention). We could say that in-person modality is slightly better over online for student grades. Overall, substantial impact on grade improvement seems to come from the gradual release intervention applied here.

B. Impact on teaching evaluations

The intervention improved teaching evaluations for the instructor, which went up from an average of 3 in the Fall 22 semester to an average of 4+ (Fig. 4) in the Spring 24 and Summer 24 semesters on all criteria. Examining individual parameters in the teaching evaluations, there is higher improvement in scores related to instructor performance in class. Especially presentation, statement of objectives, and vocal delivery did not change over the semesters, but the students

perceived it to be better in the semesters with the intervention. Most interesting change was observed in the perception of instructional materials: textbook. Even though the textbook for the course was not changed over the semesters, it was scored better in the semester with the intervention.

Surprisingly, the intervention did not have significant impact on overall learning, as rated by students even though they did mention in answers to the open-ended questionnaire that the instructor made sure that we learn. That could be because this criterion already received very high scores in the Fall 22 semester before the intervention.

Also, evaluation scores for assessments (which mean exams in the teaching evaluation form) did not change much except for in the Summer 24 semester. In the Summer 24 semester, one of the midterms was longer than usual which could have led to a slight drop in evaluation. No significant change was seen in evaluation for homework. This could be because homework and exam styles were not changed much through the 3 semesters.

The instructor sometimes used the blackboard in class when solving problems or explaining concepts during the Spring 24 semester which increased the evaluation scores for the item 'blackboard/projection' score. The other two semesters were offered online. So, blackboard was not used. Scores for student responsibility have remained similar in one semester with intervention but became better in the other. This is surprising and difficult to understand.

During the teaching evaluations, we administered additional questions to the students regarding the in-class problems. We asked them if the problems helped them learn the material better. 80% of the students said it did, while 20% felt it helped only as much as the homework problems.

To see the impact of online versus in-person teaching mode, let us compare the Spring 24 and Summer 24 semester teaching evaluations since both of these semesters were offered after the intervention. Evaluations for most of the parameters are similar in both semesters except for better performance on vocal delivery, clarity of presentation and answering questions. This could be because of cumulative effect of intervention with instructor experience in teaching the course. Whereas there is a significant improvement in most of the factors in Spring and Summer 24 semesters (with intervention) over the fall semester (no intervention) except for on homeworks, overall learning, and assessments. This is reasonable because these factors did not change much over the three semesters. Assessments on these factors were already very high in Fall 22 semester (without intervention). This indicates there is higher impact of intervention than of learning modality – online versus in-person.

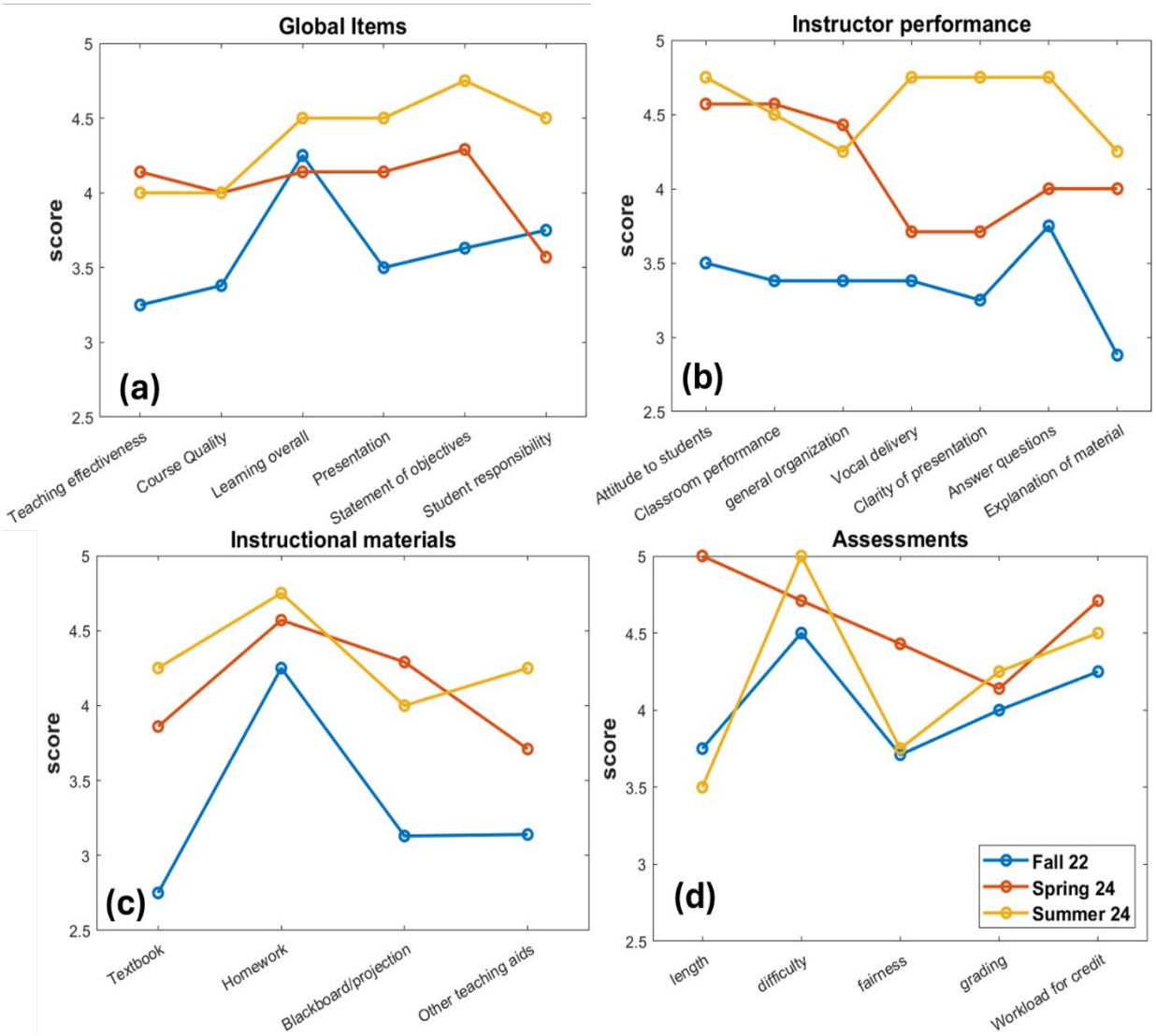

Fig. 4 Showing change in different parameters on teaching evaluation over the 3 offerings of the course (on a scale of 1-5).

C. Impact on Student Motivation and Learning

Based on informal discussion with students, we found that the students looked forward to in-class problems as an opportunity to do problem solving in a safe and secure environment (solving with the instructor and peer group and for a very small credit towards overall grade). Due to the model, the students could go over three different problems on each topic. They could see the instructor working through a problem in class, so they learnt how to logically solve it. The second problem was solved jointly by students with the instructor that enhanced their confidence in solving it. Solving the third problem themselves with peers provided hands-on experience in problem solving with peer support. Thus, the students were learning both from the instructor and from each other. Students were better prepared for the next class as they had to go over the lecture material to solve the problem by the end of the day even if they missed the lecture. The in-class problems prepared the students for the homework and exams. Because problems had to be solved in a group, there was better attendance. So, class participation

improved. Since the in-class problems were based on the current lecture, students paid more attention to the lecture and asked more questions to clarify doubts. Solutions to the problems had to be submitted by the end of the day, so it ensured students were better prepared for the next lecture. This did not change in the Summer 24 semester when the course was offered online with the intervention.

D. Impact on Instructor Performance: self-reflection

Based on self-reflection, we feel that this model improved the instructor's performance. The instructor planned for aligning the in-class problems, lectures and homework for the next week and realigned the future lectures based on student understanding of the material taught in the past week. The in-class problems provided formative feedback for every lecture while homework provided weekly, and the midterms provided monthly summative feedback. For any meaningful intervention in future lectures, early formative feedback was helpful. Thus, the intervention improved their lecture preparedness. Because the students paid more attention to the lecture and asked more questions, it improved the instructor's explanation of concepts.

E. Challenges

The modality adds some overhead to course delivery. Before the intervention, the course content included solving a couple of problems in-class by the instructor to teach how to logically problem solve. However, it was not very interactive. For instance, earlier the instructor would go over 1-3 problems during the lecture without student involvement. But now, the instructor demonstrated problem solving for the first problem, involved students in solving the second problem and allowed them to work in groups to solve the third problem. Each problem was chosen such that it touched a slightly different aspect. For instance, the first problem could be based on 3-variable, second on 4-variable and third on 5-variable k-maps. The extra time required to go over the third problem in groups of students was generally compensated for by having better and more concise lecture delivery or by moving exam review lectures to extra hours outside the class.

Around the middle of the Spring and Summer 24 semesters, as seen in Fall 22 semester, the attendance started dropping because students got busy with other class assignments. However, their teammates started disciplining them for not coming to class and affecting their grade. Also, in-class attendance was enforced to reduce the impact on grades of those attending. Due to the dual pressure, the students started coming to class again.

Another issue that came up was how to work with your team during online classes in Summer 24 semester. This was resolved by using the breakout sessions in zoom. One breakout session was created for each group where they could work on the problem with their peers. Some students were working in industry during the Summer 24 semester. For their convenience and to ensure working with their peers, everyone was allowed to submit their work before the next class session as opposed to the evening of the day of lecture.

4. Discussion

In this study, we discussed about successful implementation of active learning principles using in-class problem solving with gradual release model and studied its impact on improving student performance and instructor evaluations. This intervention was applied to a senior level course which is taken by junior, senior and graduate students. In the Fall 22, Spring 24 and Summer 24 semesters, the class sizes were around 45 students. In the current (Spring 25) semester, the class size is 60 students and we are successfully using the model. We feel that it can be scaled to bigger class sizes equally successfully. The instructor does not need

to do anything differently. They have to create 3 in-class problems for each topic, go over one of them in front of students, the second one with students and the third one has to be assigned to groups of students. The only variation required could be number of groups. In classes as big as 45-60, we keep group size to 3-4 which results in about 15 groups. In bigger class sizes, say 100, we will require 25 groups. At our university, we get additional grader support based on number of students enrolled. Therefore, this model can be extended to bigger class sizes with more grader support.

For adopting the model for a freshman or a sophomore class- we think this gradual release model will still work because the approach provides a lot of structured guidance and peer support. As opposed to a flipped model of active learning where students are expected to watch lecture recordings or read material on their own before coming to class and then do in-class problem solving, the instructor also goes over the material in detail in-class in the gradual release model. This provides a good support mechanism for students.

While it might be of interest, we can't say whether the non-native English speakers or disadvantaged students will benefit more or less from this intervention. Even though this approach reinforces the concepts and provides opportunities to learn from peers yet we don't expect to see much of a difference. This is because the learning is still offered using English language. In this course, we did not see any advantage to non-native speakers over others. Similarly, we did not have data about students from disadvantaged background to assess results for them.

Now we would mention a little more about offering this learning strategy to classes taught in online mode. This model was also offered in the online Summer 24 semester with similar success. Some strategies were modified for the online offering. Instead of in-person, zoom based lectures were offered. These were recorded and video recordings were made accessible to students. Similar teaching strategies as in-class were used. The instructor wrote on the power point slides which were projected to the online zoom meeting (instead of using a projector in-person in Spring 24 semester). Since some students taking the online class were working in the industry during summer, the worksheet deadlines were extended to the day after the class for all students. The lecture notes and lecture recordings were made available online. Exams were taken online over zoom. The exams were proctored by instructor and course staff. Timings for the exams were adjusted according to convenience of most students. Conflict exams were administered for those who could not take the regular exam. Based on student performance and instructor evaluations, it appears that this intervention will work as effectively for courses offered online as for courses offered in-class.

5. Conclusion

The active learning model enhanced student performance as determined by better student grades, class participation and student motivation. It also enhanced teaching evaluations, especially the items related to instructor's in-class performance. On the teaching evaluations, it helped improve scores even on subjects where no intervention was applied like the textbook, vocal delivery, and statement of objectives, perhaps due to a better perception of the course by students. Most of the evaluation items were not affected by the mode – online or in-person of the class offering. On self-reflection, it improved the instructor's weekly and daily lecture planning. Overall, the active learning model adopted for this course not only helped the students learn better, but also helped the instructor teach better. Even though this intervention was applied to a lecture-based course, one can envision its utility for a lab course as well. In a lab course, the instructor can demonstrate one of the experiments, help student groups with the next experiment and then let student groups work over the next one themselves. The only courses where this might not be applicable are the seminar courses where students are presenting papers in the class, or a guest speaker is

presenting their work or research-based courses. Therefore, we highly recommend this model for nearly every class.

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