Student Learning Outcomes in Two Fundamental ECE Courses with Multi-Modal Delivery During COVID Response

Prof. Olga Mironenko, University of Illinois Urbana-Champaign

Dr. Olga Mironenko is a Teaching Assistant Professor with the Department of Electrical and Computer Engineering at University of Illinois Urbana-Champaign. She received a specialist degree in Physics from Omsk F.M. Dostoevsky State University, Russia in 2009, and she received a Ph.D. degree in Electrical and Computer Engineering from University of Delaware in 2020. Her current interests include improvement of introductory analog signal processing and power systems courses, training for graduate teaching assistants, and mentoring of under-represented students in ECE.

Prof. Yuting W. Chen, University of Illinois Urbana-Champaign

Dr. Yuting W. Chen received the B.S. degree from University of Illinois Urbana-Champaign in 2007, and the M.S. and Ph.D. degrees from Rensselaer Polytechnic Institute in 2009 and 2011, all in Electrical Engineering. She is currently a Teaching Associate Professor in Electrical and Computer Engineering at University of Illinois Urbana-Champaign. Her current interests include recruitment and retention of under-served students in STEM, professional development for graduate students, service learning, and curriculum innovation in computing.

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Abstract

The purpose of this work is to evaluate the learning outcomes of students in two sophomore-level ECE core courses (signals & systems and introductory programming) at the University of Illinois Urbana-Champaign during COVID response. Both courses were offered in the spring of 2021 with multi-modal delivery. In each course, students were self-selected into either the in-person or online section, and both sections were taught by the same instructor.

We analyze the performance of students attending in-person lectures vs. online lectures in each course. Categories for comparison include scores for homework assignments, quizzes (when applicable), midterm exams, and the final exam. Additionally, we examine students' satisfaction with their final course letter grades by their decision to choose the pass/no-pass grade option.

Our findings show that in both courses, students in the in-person group performed better than those in the online group. Student satisfaction was also higher for the in-person group, as indicated by the percentage of those who chose the pass/no-pass grade option.

Introduction

In the face of a post-COVID pandemic situation, many Electrical and Computer Engineering (ECE) undergraduate students choose synchronous/asynchronous online course delivery over in-person instruction. Some previous studies show that among undergraduate level engineering courses, the overall learning effectiveness of online delivery at least does not degrade relative to traditional face-to-face modality. Moreover, there is either no difference in student satisfaction level or even a bias toward online modality.

For instance, reference [1] shows that for three sophomore, junior and senior level Mechanical Engineering courses the quality of online learning is comparable with the traditional classroom environment. Furthermore, the research highlights that online students are better satisfied with the course and the instructor in comparison with in-person group. In addition, research presented by Ssemakula [2] provides the same observation on learning effectiveness for Engineering Economic Analysis course. Next, findings by Kozak [3] and Douglas [4] show that online students in two mechanics classes performed equally or outperformed in-person group. Similar results are demonstrated by Marriott [5] for two Computer Science courses intended for freshmen, juniors and seniors. Finally, research outcomes presented by Trippe [6] for three Electrical, Computer

and Telecommunications Engineering technical programming courses highlight that students' satisfaction for traditional in-person and for online delivery modes does not differ from each other.

However, other studies show that the online modality results in weaker performance, lower letter grades, and lower students' satisfaction level/higher non-completion rates.

For instance, findings presented by Easton [7] show that in-person students in junior level industrial engineering course performed significantly better than online students. Moreover, research demonstrated by Khraishi [8] indicates that for sophomore-level "Energy, Environment and Society" engineering course online students received lower letter grades compared with in-person group. In addition, it is shown that non-completion rates are higher in online group versus in-person group. Finally, similar conclusions were provided in works by Douglas [4] and Marriott [5] for students in Engineering Mechanics course and in two Computer Science courses respectively. Additionally, Douglas [4] also highlights that online students were less satisfied with the delivery mode compared with in-person students.

This course evaluation work evaluates the learning outcomes and student satisfaction of in-person and online students in two sophomore-level ECE fundamental courses (Signals & Systems and Introductory Programming). Both courses were traditionally intended for in-person delivery. Nonetheless, everything were rapidly shifted online in Spring 2020 and Fall 2020 to address the COVID related risks. As COVID concern eased slightly, a small percentage of the courses at the University of Illinois Urbana-Champaign started to test out a "new normal" in Spring 2021.

The Signals & Systems course was offered in-person again with an option of participating asynchronously. Namely, in-person lectures were recorded by classrooms AV system and available online right after the end of the corresponding lecture. The course instructor used a tablet to annotate the slides and a microphone to ensure good quality of sound in a classroom and on the recordings. The recorded videos captured the annotated slides and the instructor on two parallel screens. Therefore, online students were capable to follow the instructor's written and verbal explanation as well as to maintain a visual contact with the instructor. In addition to the lectures, office hours were offered via Zoom synchronous session for all students. The total number of students was 37, where 15 students (40.5%) attended in-person and 22 students (59.5%) participated online asynchronously.

The Introductory Programming course was offered in a synchronous hybrid format in Spring 2021, where in-person students attended lectures in a classroom while online students participated in a live Zoom session. The course instructor used a two-device setup, in which one device was used to project and share the slides and the other for interacting with online students. Lectures were not recorded for asynchronous access. Besides the lectures, weekly discussion section and office hours were offered via Zoom synchronous session for all students. Overall, 47 students (33.8%) were registered for the in-person section and 92 students (66.2%) registered for the online section.

Since students had the option to choose either the in-person or online section in both courses, we understand that self-selection bias will play a factor in this work. During COVID, students may choose online over traditional in-person learning due to many factors, such as disability, family obligation, on-campus living expense, etc. These can all have an impact on their overall

experience and learning outcome. Even before COVID, students are often free to choose a section that fits their schedules and learning styles if the options are available. Therefore, self-selection bias is difficult to eliminate and we assume that it will always play a part in our courses. In the remaining sections of this paper, students who selected the in-person section will be referred to as the in-person group, and those selected the online section as the online group.

Methodology

To analyze the overall learning effectiveness of online vs. in-person learning, we compare the average score for all homework sets and assessments for in-person and online students in each course. Average scores are also computed for every homework assignment, quiz (only for the Introductory Programming course), midterm, and final exam. In the Signals & Systems course, students completed fourteen weekly homework assignments, three midterm exams, and one final exam. Students in the Introductory Programming course completed twelve weekly homework assignments, six quizzes, two midterm exams, and one final exam. Students in both courses were allowed to work together on all homework assignments. Both group of students in both courses were provided with the same assignments being available and due online at the same times and dates. Besides that, all students were provided with the same assessments , which were proctored online.

Furthermore, to test whether differences in scores are statistically significant between the two groups, we use IBM SPSS [9] to perform Independent Samples T-Test for the Introductory Programming course, and Nonparametric Test (Mann-Whitney) for the Signals & Systems Course due to small sample size.

Last but not least, the percentage of students who received As, Bs, Cs & below, and Pass/No-Pass are calculated. In Spring 2021, due to special circumstances caused by the COVID pandemic, the university offered a choice of pass/no-pass option to overwrite the actual letter grade after final grade release. In both courses, we consider students who selected the pass/ no-pass option as unsatisfied with their final grade. Under this assumption, we compare the percentage of students unsatisfied with the final grade within in-person and online groups to assess the difference in students' satisfaction levels.

Findings in Introductory Programming Course

For the Introductory Programming course, our analysis shows that students in the in-person group outperformed those in the online group overall in homework assignments, quizzes, and exams. As shown in figure 1, average scores for homework assignments, quizzes, and exams for the in-person group is 97.3, 97.5, and 87.6, respectively, while the scores are 94.7, 95.5, and 82.2 for the online group. We found that the difference in average exam scores between the two groups is statistically significant with a p-value of 0.018.

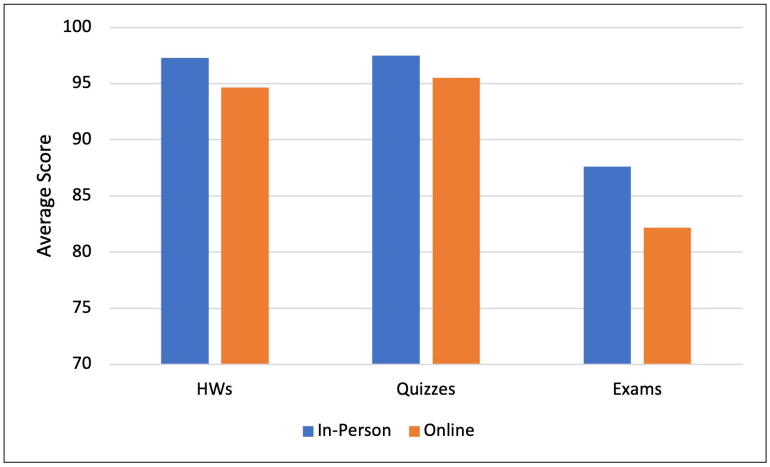

Figure 1: Introductory Programming: average homework, quiz, and exam scores for in-person vs. online students

To closely examine the learning outcomes in homework, average score for each assignment is compared between the two groups, as shown in figure 2. Students are allowed to work with their fellow classmates in their homework assignments, and it's possible that in-person and online students are working together. Overall, in-person students performed better or similarly as compared to online students in all assignments, except for homework assignment 3 and 4, which are elementary C programming problems on data types and loops. Independent Samples T-Test results show that there is a statistical significant difference for scores in homework assignment 1 (p-value = 0.009) and 12 (p-value = 0.013) between the two groups.

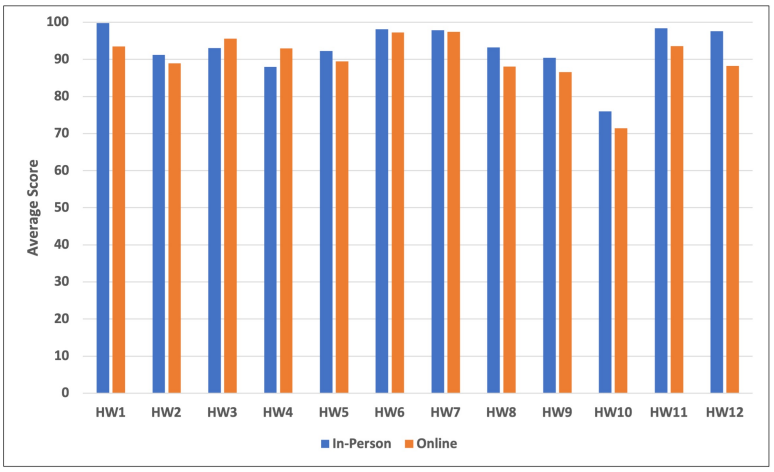

Figure 2: Introductory Programming: average score in each homework assignment for in-person vs. online students

While homework assignment scores may be impacted by the effort of group work, proctored assessments should depict a more accurate picture of individual learning outcomes. Figure 3 and figure 4 illustrate the comparison between the two groups; in-person students scored higher than

online students in all quizzes and exams. Statistical significant difference is found between the two groups on Quiz 4 (p-value = 0.000), Quiz 5 (p-value = 0.013), Quiz 6 (p-value = 0.044), Midterm 2 (p-value = 0.001), and the Final Exam (p-value = 0.038).

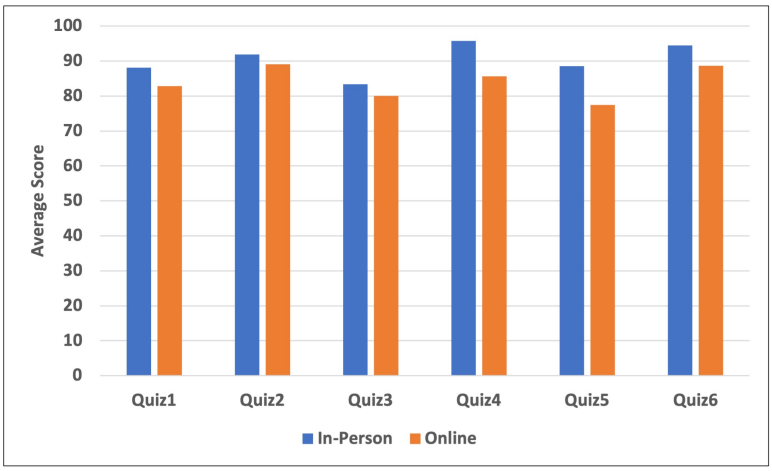

Figure 3: Introductory Programming: average score in each quiz for in-person vs. online students

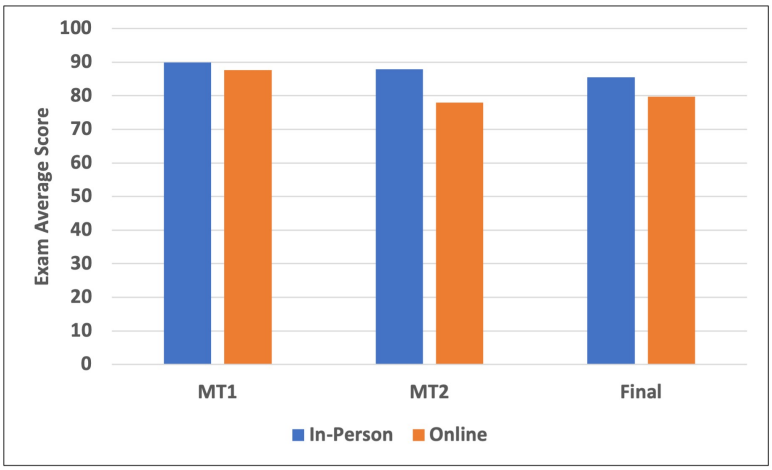

Figure 4: Introductory Programming: average score in each exam for in-person vs. online students

Last but not least, final letter grade distribution is examined among each group, as shown in figure 5. In-person group has a higher percentage of As and a lower percentage of Pass/No-Pass. Both groups have similar percentage for Bs; the in-person group has one student in the the Cs and below category while the online group has two. Results from Independent Samples T-Test also shown that the difference in the total course score between the two groups is statistically significant (p-value = 0.013). It may be worth noting that the lowest quiz score was dropped when we calculate the total course score for each student.

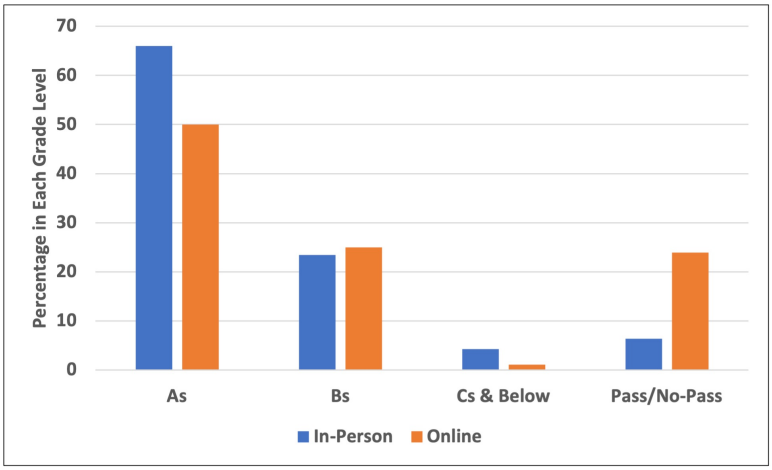

Figure 5: Introductory Programming: letter grade distribution for in-person vs. online students

Findings in Signals & Systems Course

In the Signals & Systems course our analysis shows that, on average, the online group demonstrated lower scores for homework assignments and exams, as shown in figure 6. The average scores for homework assignments are 86.2 for in-person students and 79 for online students. The average scores for exams are 72.9 and 66.4 for in-person and online group respectively. We found that the difference in average homework assignment score is statistically significant between the two groups with a p-value = 0.039.

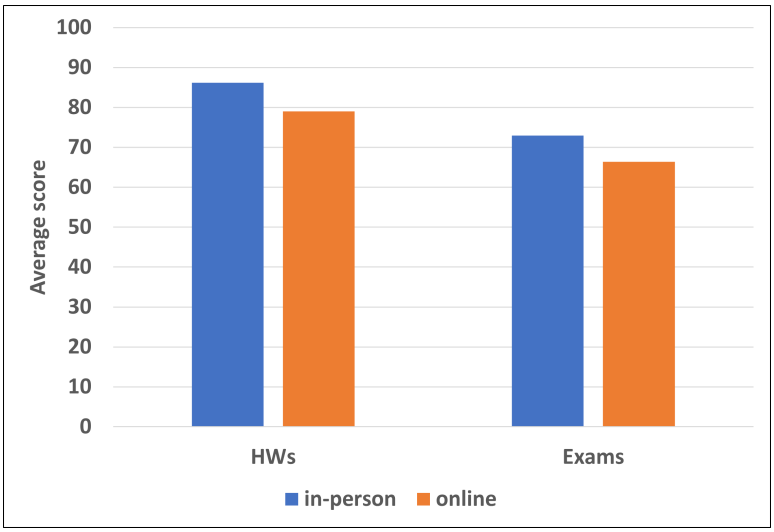

Figure 6: Signals & Systems: average homework and exam scores for in-person vs. online students

Interestingly, students in the online group performed similarly or even slightly better than in-person students in the first three, 8th and 12th homework assignments. However, in-person students performed better in the rest of the homework assignments and in the exams (figures 7

and 8). We attribute higher grades for the first three assignments to the fact that the students has already been exposed to the material covered in a prerequisite course.

However, in-person students performed better in the assignments which covered new material, namely assignments 4-14 except for assignments 8 and 12. In particular, the score difference in assignment 4 is statistically significant (p-value = 0.022). The authors believe that factors such as limited interaction with classmates and the instructor as well as less motivating online environment could negatively affect the learning of a new material in the online group.

Due to relatively similar level of difficulty for all assignments after the 3rd assignment, we hypothesize that the resulting performance on assignments 8 and 12 could be due to a contribution of other factors.

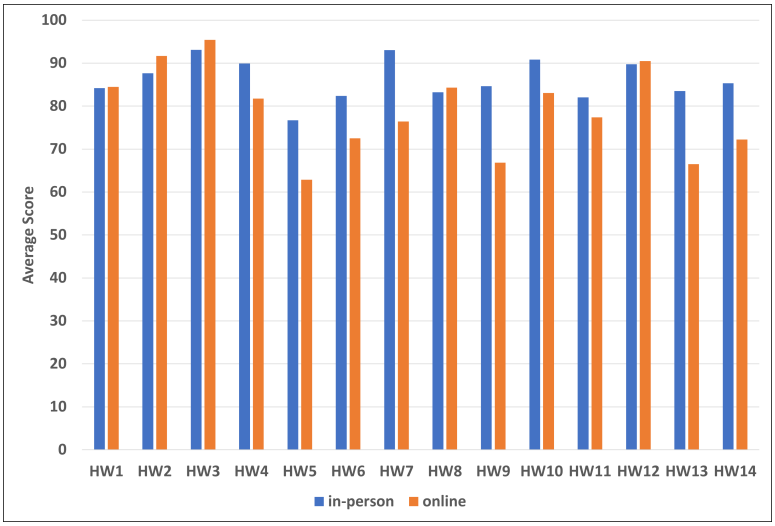

Figure 7: Signals & Systems: average score in each homework assignment for in-person vs. online students

Finally, as shown on figure 9, percentage of As and Bs was higher for in-person group (26.7% and 53.3% for in-person group vs. 4.6% and 40.9% for online group). However, percentage of Cs & Below was higher for online students (0% for and 4.6% for in-person and online group respectively). Moreover, only 20% of students in the in-person group chose the pass/no-pass grade option at the end of the semester versus 59.1% in the online group. It should be noted here that two lowest homework scores were dropped for the final grade calculation. Result of the non-parametric test shows that the score difference in course total between the two groups is statistically significant (p-value = 0.033).

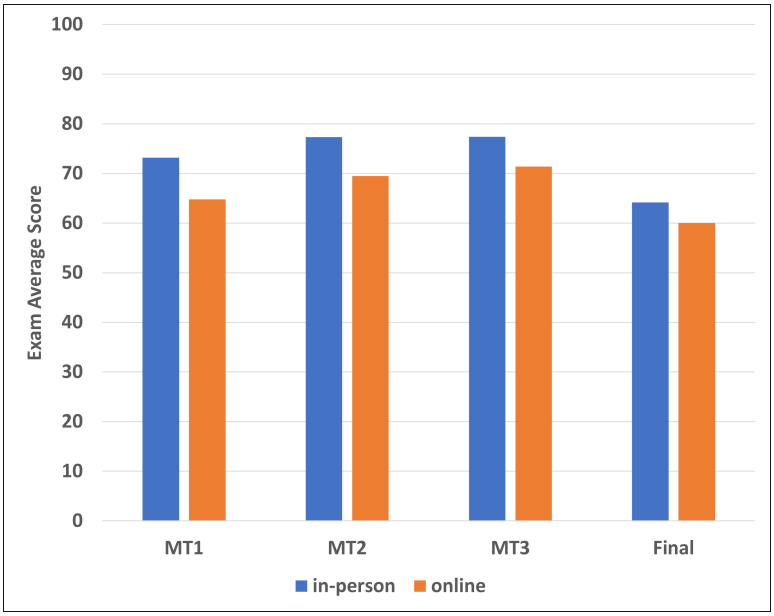

Figure 8: Signals & Systems: average score in each exam for in-person vs. online students

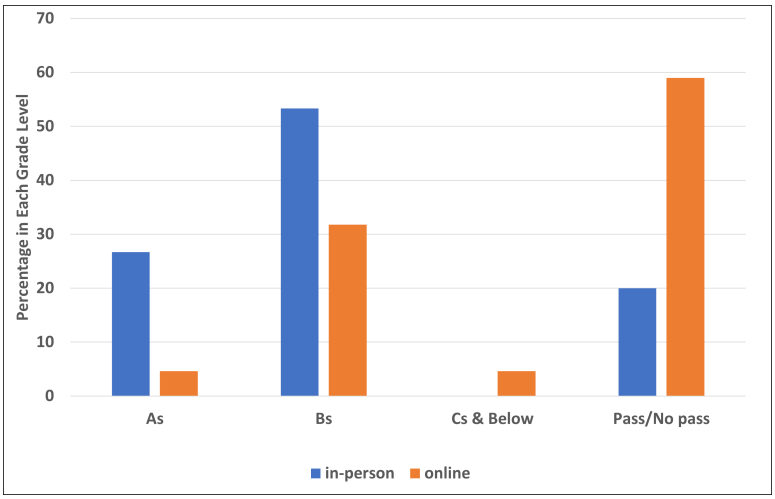

Figure 9: Signals & Systems: final grade distribution for in-person vs. online students

Conclusions

In this course improvement work, we evaluate the learning effectiveness of online vs. in-person modality for two sophomore-level core ECE courses (Signals & Systems and Introductory Programming). Overall and individual average scores are compared for homework assignments, quizzes, and exams for the in-person vs. online groups. In general, students from the in-person group performed better than their peers from the online group in both courses. Our analysis shows that a higher percentage of in-person students received As and Bs than online students (80% v.s. 35% in Signals & Systems, 90% v.s. 75% in Introductory Programming). Additionally, more in-person students are satisfied with their course letter grades than online students (80% v.s.

32% in Signals & Systems, 94% v.s. 76% in Introductory Programming). The difference in course total score between the online group and in-person group is statistically significant in both courses.

We think there are several factors that could contribute to the observed academic performance gap between online and in-person students. First of all, online students may be struggling with a living situation that negatively impacts learning. Those who are able to attend classes in-person are most likely living in a dorm or an apartment on-campus, which could mean less distraction. Furthermore, it's more difficult for online students to interact with their peers and instructors outside of lectures. The perception of lack of support can be a demotivating factor. Last but not least, as we mentioned before, our courses are traditionally designed for in-person instruction. Therefore, it may not be realistic to simply offer a synchronous or asynchronous online delivery method and expect the same learning outcomes.

Based on the issues outlined above, the followings are suggestions to address challenges in online learning. Students should be encouraged to return back to campus if their situations allow. This will reduce the inequity in their learning environments and provide opportunities to access community of support. If some students are unable to return due to individual circumstance, dedicated academic support should be provided to ensure they are still part of a community. For example, the department or college can set up virtual meet and greet with fellow online students and connect them with campus services available online. For long-term planning, course redesign or a new online course offering would be necessary if online learning will continue to play a significant part in undergraduate education.

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