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Board 77: A Study on Student Success in Circuit Theory with Complimentary Videotaped Problem-Solving Demonstrations in Challenging Times

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A Study on Student Success in Circuit Theory with Complimentary Videotaped Problem-Solving Demonstrations in Challenging Times

Abstract

Circuit Theory is an entry level crucial course in the Electrical and Computer Engineering programs and is a cross-listed course for other engineering programs. In-depth understanding of Circuit Theory is critical for the future success of Electrical and Computer Engineering students as well as other engineering students. However, the students from all the programs face various degree of challenges in mastering Circuit Theory as research shows. Ideally, students learn various techniques to solve circuit problems; it is especially important that they develop the capability to decide which technique will be more efficient or appropriate for a given circuit. The study focuses on how to support student success in the course by creating an archive of videotaped problem-solving demonstrations. In addition to instructors' solutions in the lectures, student-developed problem-solving demonstration videos are provided. The impacts of the video archive are compared in different semesters. The study explores the impact on the success during pre-covid, covid and post-covid times with no video solutions, and with video solutions for both in-person and online classes. With the students' average performance used as an indicator, the results of the study reveal the impact on the students' success by the inclusion of video archive for different modes of instruction.

I. Introduction:

The Covid-19 pandemic created a sudden paradigm shift in instruction mode in most institutions. In the middle of Spring 2020 semester, the classes and labs went online without prior formal training for the most instructors. As the classes switched to a new mode, initially many students struggled, and this might have impacted the learning outcomes; some institutions offered passing grade owing to the sudden change in mode. However, the adaption to the new mode generated new approaches of the instruction. In the fall 2020, classes ran mostly in two different formats: online which could be synchronous or asynchronous, and hybrid which was a combination of online class and in person examinations. The modes helped create electronic resources, e-resources, for the classes. This shift in mode had prompted to new learning tools. The primary focus of the study was to explore the impact of the e-resources on the performance of the students. An average grade is used as an indicator for performance evaluation which is similar to the one in [1].

Circuit Theory course is a required and basic course for many disciplines. In the day and age, vehicle technology is transformed into autonomous vehicle. This transformation became possible because of the multi-disciplinary effort by Electrical, Mechanical and Computer Engineering and Science and it continues [2]. Therefore, the course is of great importance not only in Electrical engineering, but also in other engineering fields. The challenges faced by students are multifarious; however, the non-Electrical engineering student face unique [3] ones because of the

perspective and need of the respective departments. The challenges students face in the course are mostly because of the nature of it. Even though it is an introductory engineering course, it familiarizes the concepts of currents, voltages, powers in terms of basic laws which appears to be abstract to them. In this course, students could try to apply a principle in the wrong scenario without being aware of the constraints, e.g. sometimes students try to apply Ohm's law when they try to find the current of a voltage source; Or wonder why no current through an open circuit; however there could be a voltage across it (they are applying Ohm's law on an open circuit). Students can easily ignore the constraints of the circuit principles. Another example of such issue is that students sometimes apply voltage or current dividers among multiple resistors. However, this technique only works for two resistors and thus cannot be directly applied until proper combining the resistors to only two resistors. An answer to these issues is problem solving which is at the core of science and engineering education. It has been shown that multiple solution to problems can increase competence in mathematical field [4]. Therefore, one way to improve the learning is to provide multiple solutions to many problems.

The students from all the programs face various degrees of challenges. The challenges in Circuit Theory to millennials may vary, but e-learning has been shown to be effective [5]. Considering the video capturing of the problem solution, the students who are visual learners could be benefited the most as well as the others. The method offered in this study combines both e-learning and traditional learning, which can be referred to as hybrid learning in modern days.

II. The study focus

The focus of the approach is to generate resources for the mentioned course and to evaluate the effectiveness of it. Besides assignments, the course has a large number of homework to strengthen the background. Multiple solutions are developed for a large number of problems for the course which are used throughout the course. The students have the opportunity to select the convenient method. This is intended to enhance the learning and increase success rate. It is expected to satisfy not only the students with strong mathematical background, but also the students who have limited one.

In this study, the students were from Electrical Engineering, EE, Mechanical Engineering, and Engineering Technology Management programs; the course was required for them. The impact of learning in the course can significantly affect the success of the later courses for Electrical Engineering students as it is a foundation course for them.

All the other electrical major courses, more or less, depend on the basic understanding of the circuit and circuit analysis. Insufficient or incomplete understanding of these knowledge or skills will significantly affect their understanding of other advanced electrical component behavior and further system design. The frustration from such understanding delay potentially also affects the retention of the sophomore and junior EE major students.
It has been observed by the faculty members that the students who find the course challenging start dropping the course throughout the semester. Therefore, the focus was on how to improve the performance as well as the retention rate. To keep them focused and engaged in learning, the problem selection and solution techniques are perfected through the experience of the faculty.

The method description: establishing the procedure

The instructor created some solution videos for the course in the beginning. To create a large video solution resource, a student researcher was employed to increase the efficiency in utilization of the resources to be generated. The student had completed the same course and the next level course before working on the approach so that the student can add a proper background on the solution provided. The presentation in the video by a student was assumed to connect to the current students well; that was the reason to employ the student for the method.

The student was provided with questions and solutions. The instructor provided the instructions on how to walk through the solutions of the questions. After the student created the videos—e-resources, the instructor reviewed the content. Their effectivity is evaluated. If it is needed, they will be recreated. The workflow for the method is presented in Figure 1.

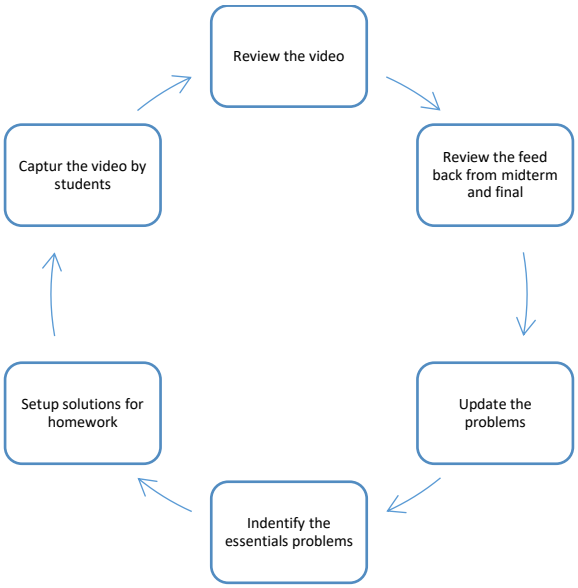

Figure 1. The working process of the approach.

III. The method of solutions and delivery

The method of improving performance includes multiple and multimode solutions. This considers both on paper and video solutions.

(a) Multimode solutions

Students join the class from diverse background; therefore, same format of solutions may not help them in the same fashion. Since a problem in the course can be solved in different ways, from different methods, students can choose the one convenient for them in the beginning.

However, they are expected to be well-conversant with other methods later as well. In order to enhance the learning in the course of the diverse group of students, solutions were provided in multiple forms. Some solutions were provided in paper form, the other in video form and some in both forms.

On paper:

The students with strong background in physics and mathematics appear to follow the solution, in most cases, directly from the solution on the paper which is posted throughout the semester. However, some students might need all the steps or some shown with explanation.

In video:

For these students, some video solutions are posted and that can have impact on their understanding of the new concepts and application. The paper solution might be helpful for students with prior experience in circuits. On the other hand, the video solution can be helpful along with paper version for students without prior experience in circuits. As an example for a video solution, screenshots of it are shown below.

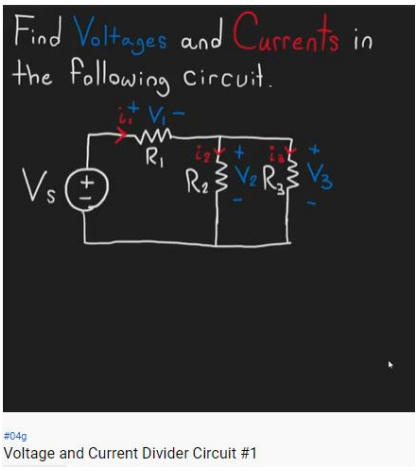

Figure 2.1. Sample problem screenshot.

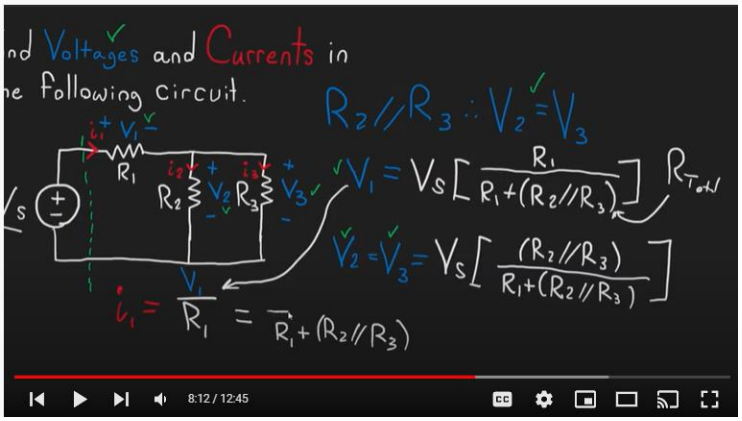

Figure 2.2. Sample solution screenshot.

Video making process for the study:

The recording of videos was done using OBS Studio (Open Broadcaster Software), free software that allows users to record their display, and Microsoft Whiteboard, software that comes with the windows operating system that mimics a whiteboard digitally, to draw circuits. To effectively draw in Microsoft Whiteboard, a Wacom drawing tablet was used instead of having to use a traditional mouse to draw.

Preparation of the recording began by going through all the assigned problems for students and solving the circuits/problems from scratch. Once all the problems were completed, the problems that took longer or required more steps to solve were broken down into a list of steps. This list of steps was not directly shown in videos showcasing how to solve a particular circuit but was used as a guide on the next step during the recording. After all the circuits were solved and broken into a list of steps, it was time for recording. During the recording, the notebook with the solution to the circuit was used as a reference, and a secondary monitor connected to the laptop was used to show the current OBS Studio view for what was being recorded.

This allowed to make sure that the right solution was given, and there were no long pauses between steps of the problem. After the recording, videos were edited with Adobe Premiere. During the editing process, videos' audios were cleaned up and if there were any long pauses or incorrect statements made during the recording process, they were cropped out.

It was paramount to make the videos as simple as possible. This is why equations and relationships were continuously reiterated that may have seemed mundane to students normally like Ohm's Law. The intention was to create videos that anyone with a minimal knowledge of circuits could come to and understand the content. Even more paramount was that students with no prior circuit knowledge could start watching at the beginning and learn basic DC circuit relationships.

(b) A large number of problem solutions for success

Since this is a gate keeper course, to build a better background of the course, a large number of problems are solved for each section or new concepts. Some parts of them are solved during class time and the other are left in the homework and some others they are also supposed to solve themselves.

The delivery of the solutions:

The problems were assigned in the beginning of a semester. Before the completion date, one reminder was provided to the students on the problems. Therefore, there was enough time for the students to try themselves to solve them. Once the deadline is over, both paper and video solutions were posted.

IV. Results and analysis

The video solutions are designed to show the sequential flow of work. In addition, different colors were used during the recording because the idea was that it would be easier for students to quickly understand which elements of the circuit were being solved. This meant associating a color with each element being solved: red signified voltage and blue signified current as shown in Figure 2.1 and Figure 2.2. A lot more colors besides red and blue can be seen in the videos too. Potential differences were made clear if there were different colors touching because each potential was circled using a different color on a lot of circuit problems. These are done to

engage students while focusing on problem solutions. Some theoretical concepts are also explained in the similar fashion.

Comparison of performance between different modes can be challenging; however, it has been revealed that online and in-person class performances have no significant difference [6-8]. It is promising that the passing grade and average final grades do not have significant changes from in-person to online class as reported in [1]. The success was attributed to technological development and additional resources for the students. In this result section, some comparisons are made between online and in-person classes to indicate the effectiveness of the approach.

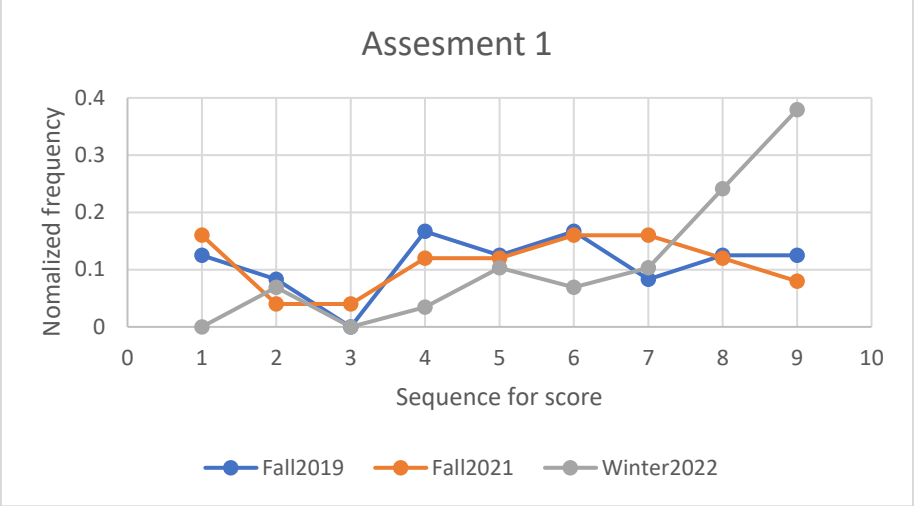

Figure 3. Assessment 1 outcome. The score sequence represents score ranges. Less than 60=1, 60-64= 2, 65-69=3, 70-74=4, 75-79=5, 80-84=6, 85-89=7, 90-94=8 and 95-100=9.

Figure 3 shows the class performance for Assessment 1 which was performed after one month of class. For the better comparison, normalized values are presented in this and the following figures. The results show that Falls 2019 and 2021 carry almost similar outcomes. However, Winter 2022 outperforms the other two. The reason could be resources as well as the adaptation to online materials for the assessment.

Figure 4 shows the student's grade distribution for the classes in 2019 and 2021 Fall. The former class did not receive any video solutions for homework. However, the later one received some video solutions and all paper solutions. The grade distribution indicates that lower and higher grades did not affect, however, the mid-level grade improved. This can be seen as a positive impact on the performance of the students. The weighted average scores for Fall 2019 and Fall 2021 are 2.78 and 2.93.

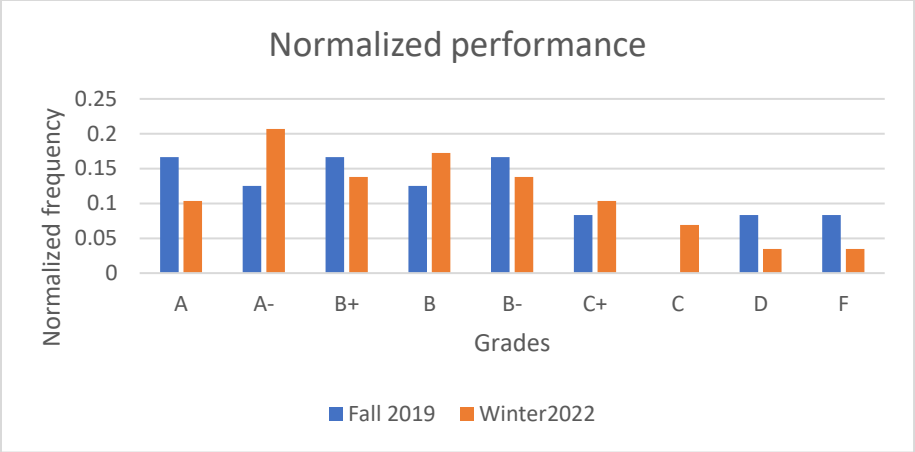

Figure 4. Grade distribution for the classes with limited e-resources and without video solutions

Traditional class with video solution:

The class in Figure 5 was provided with solutions in both paper and video formats. The mode of interaction was fully in person. The trend of the plot shows that the mean of the grades is skewed to the better grades.

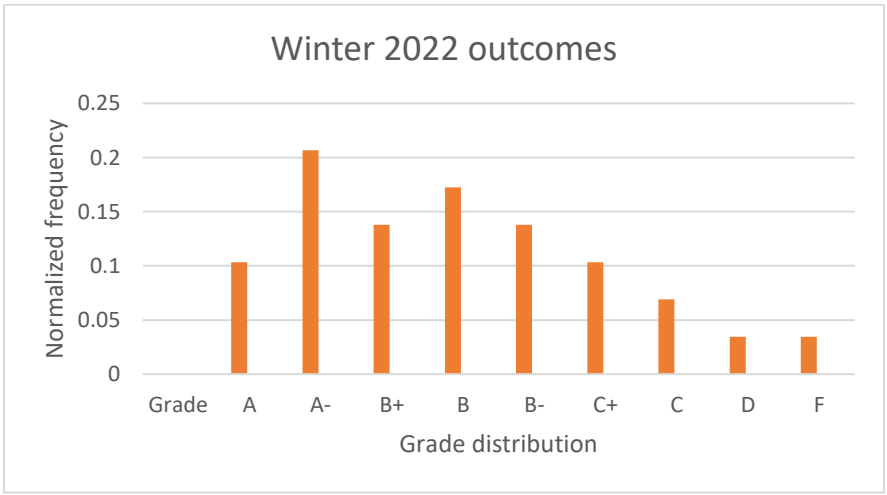

Figure 5. Winter 2022: Traditional class with e-resources

The grades of traditional classes are compared where Fall 2019 had no video solution; however, Winter 2022 had hybrid resources; the graph in Figure 6 shows the difference of the methods.

Fall 2019 had both highest grade and failing rate high, but they were lower for Winter 2022. The impact is observed as the mid-grade improvement for Winter 2022.

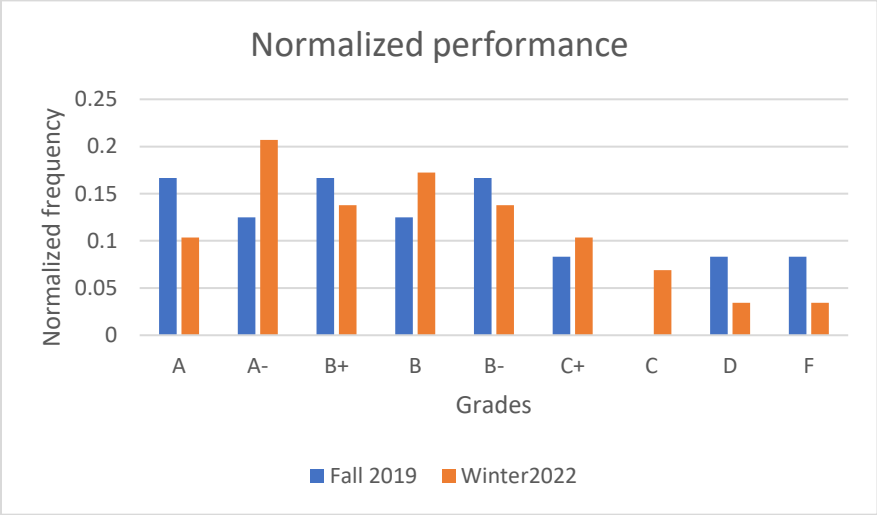

Figure 6. The comparison of traditional classes with and without e-resources.

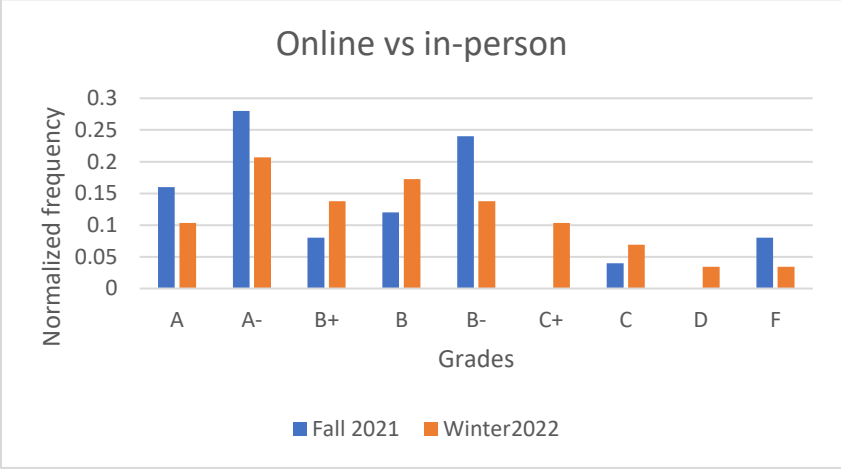

Figure 7. Online vs in-person classes with hybrid resources.

The online course had classes conducted online whereas in-person class had both classes and examinations conducted in person. The result of online classes with limited e-resources for Fall 2021 and in-person classes with e-resources for Winter 2022, in Figure 7, indicates a slight difference in performance in the midgrade. The weighted average scores for Fall 2021 and Winter 2022 are 3.03 and 2.93.

Up to Winter 2022, the in-person class with hybrid resources had, to some extent, normal distribution whereas the class fully online had non-normal distribution; but the mean value did not deviate significantly. The learning outcomes for both in person and online does not have significant difference as reported in [6-8]. The weighted average scores reflect the reported results. The difference in the trend in the figures can, therefore, be attributed to the background of the students.

Assessment 1 and Final grades for Winter 2022 class are not similar. The reason is that, in the other assessments, the class score distribution tends to be normal even though Assessment 1 was skewed to the higher scores; it can be attributed to students' background or the difficulty levels in the other assessment.

The most recent data is presented in Figure 8. One assessment from Fall 2022 and one from Winter 2023 are shown in the figure. The data reflects the performance for the classes with both paper and video solutions for in-person classes.

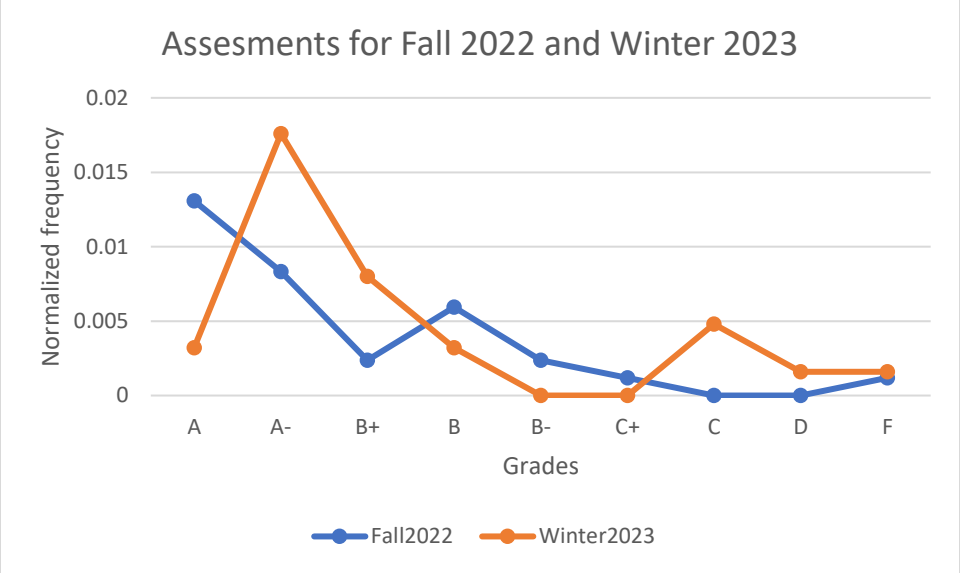

Figure 8: Comparison between two semesters with online resources for traditional classes.

The weighted average scores for the semesters are 3.42 and 3.13 for Fall 2022 and Winter2023 respectively. The scores indicate better performance compared to Fall 2019 and Fall 2021. These classes have mostly traditional students; a few of them are non-traditional. The traditional students were already adapted to online materials in their high school or in the college. The experience might have an impact on the grade; however, their mathematical background and the solution provided could contribute to the improvement as well.

V. Student comments on the resources:

The students generally expressed satisfaction over the resources in interaction during online and in-person classes. The benefits and inconvenience of the resources have been surveyed in the current semester.

Most students prefer the extra resource; however, some other students prefer paper version. Some comments based on feedback are given below.

“Extra resource is always helpful. I personally prefer paper when the steps are present. Easier to follow at my own pace. The positive is it was another example done live.”

“I like having an extra tool, especially when I get stuck. Just having the answer does not help me much.

Ability to see where I went wrong, not just given the answer and expected to get it first try.”

“Any type of problem solving will help learn, does not matter if it is paper or video.”

“Help to understand logic rather than memorize.”

“Help walkthrough problems help learn.”

“Being able to watch multiple times. Video solutions help when I don’t understand a topic right away.”

“Helps to understand where the values come from.”

One question in the survey was: “Does the video solution help learning?”

100% of students responded positively.

Another question was: “Does it complement your learning in the class?”

100% positive answer was received.

Another question was: “Were they more helpful than paper version of the solutions?”

89% of students responded positively. However, there were some comments.

“No, I like looking at work on paper.”

“Both similar.”

“Equally if not more.”

“That depends. It would be different for each question.”

It can be inferred from the survey that the resources created may not be helpful for all students; however, they can assist most of them. Overall, the survey results reveal that the resources have positive impact on the students’ learning.

VI. Challenges and benefits

The video solution in this study requires computer resources and internet access; this could be expensive to students. The video solution also demands time to grasp the material and contents. This can be a hindrance to students with limited time of a semester. Therefore, the video solutions could be beneficial on ad-hoc basis.

The solutions posted helped students as the survey revealed. However, the procedure was one way; to incorporate feedback in the procedure, some additional questions can be introduced. Therefore, to improve learning, video exercise can be paired.

The mentioned course is now offered for four different programs. Because the number of students in the class is relatively large compared to higher level courses, the interaction with all students beyond the classes is challenging for an instructor. However, the interaction is important for most students since success for the remaining semesters and in their career depends on the solid foundation in this basic course. The survey results indicate that the students benefit from the resource, which can build the foundation. These e-resources can complement the need of the continuous interaction with the instructor while they meet the goal of the course.

VII. Conclusion

The pandemic forced us to employ diverse mode of instructions—online, synchronous, asynchronous and hybrid and to find the one that better suit to the most. The learners might have preference for one to the other; however, it may vary on the background of them and material availability. Therefore, comparison between courses offered in different modes can be challenging; however, the comparison between same mode of instructions can be considered and produce reliable outcome. The same mode, in-person classes, in this study indicates the performance improvement with e-resources considering the average outcome of the course.

The survey results indicate that the students mostly prefer the inclusion of the video solutions as they think it can help their learning. The recent data supports the learning improvement.

The comparison between classes may not always reflect the improvement or degradation of an approach since students are being prepared from diverse background and experience. However, a general trend of performance can indicate the effectiveness of an approach. Comparing between the graphs of performances, it can be observed that performance improved for both the online class and traditional class with e-resources; the improvement can be translated to one grade change even though the difference is not very large in terms of weighted average. Therefore, one can state that the impact of COVID was devastating, however the adaptation to the newer approach was effective and weathered through pandemic time.

This study overall describes experience and experiment to adapt and to perfect for the basic course with new resources in the critical period. The results presented in the bar plots showed how classes survived in the pandemic time, and how the pandemic have impacted students' performance.

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