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# Impact of Online Worksheets Versus In-class Printed Worksheets on Students' Learning Outcomes and Content Mastery

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# Impact of Exercising Online Worksheets versus In-Class Printed Worksheets on Students' Learning Outcome and Content Mastery

Abstract

Developing problem solving skills and engaging students in critical thinking are essential parts of engineering/ engineering technology courses which require high levels of interaction between students and instructors. This highly interactive nature of engineering/engineering technology courses makes teaching them in an online format extremely challenging for the educators. As the COVID-19 pandemic began, online delivery of courses became a critical platform for instructors to delivery course content. It is now a necessity, not an option to improve online teaching techniques as this mode of delivery will continue. In an engineering/engineering technology course, inquiry-based tools such as worksheets are shown to be effective in keeping students engaged and helping them develop problem solving skills. Worksheets also provide a real-time assessment tool for the instructor to determine the learning outcome and the right pace for the class. The intent of this work in progress study is to evaluate the distinction between students' learning outcomes when administered online worksheets versus in class printed worksheets. This is one of many steps necessary in examining the impact of online versus face-to-face delivery of course content in engineering technology courses. Our hypothesis is that administering online worksheets versus in class printed worksheets impacts learning outcomes.

The data were collected in a Digital/Microprocessor Basics course (EET2141) which is a part of the electrical Engineering Technology degree program at Michigan Technological University. This study reports the comparison of learning outcomes and content mastery in EET2141 between two groups of students. The first group of students attended EET2141 in Fall 2019 and they were administered real-world problems to solve in the form of printed worksheets handed out after each class lecture. The printed worksheets were related to that day's lecture material and were collected in class. The second group of students attended EET2141 during Fall 2020 semester and after each class session they were assigned the same worksheets but only available online (on Canvas Learning Management System). Students submitted their completed worksheets online via the LMS. The recitation sessions for both groups were held face to face in order to evaluate the absolute impact of physical and online worksheets between the two groups. The student survey on printed and online worksheets are included in this study. It is important to acknowledge that Michigan Tech allowed face to face sessions for smaller classes in which proper social distancing was achievable and of course with proper face covering during fall 2020.

## 1. Introduction

Due to the hands-on nature of engineering disciplines and the need for student instructor interaction to encourage critical thinking and the time commitment and increased workload for the faculty in developing online curriculum, prior to the COVID-19 pandemic, the number of online ABET accredited undergraduate engineering programs has been limited [1,2,3]. As the

COVID-19 pandemic forced almost all instructors to make the transition from face-to-face teaching to an online format, the importance of examining the student's success in attaining desired learning outcomes in an online learning environment compared to a face-to-face environment has become more critical. It is more vital than ever to understand the impact of the online environment on learning outcomes.

There are many barriers to delivering engineering /engineering technology courses online such as lack of personal interaction and engagement with the students and lack of feedback on teaching and learning which often leads to the challenge of keeping students engaged or helping them build problem solving skills [2,4,5]. Many methods have been examined to keep engineering students engaged and motivated in an online course such as introducing online flipped classrooms and creating multi-media contents. A large number of studies have been focused on evaluating the effectiveness of online delivery of engineering courses; but very few have focused on measuring the impact of changing one aspect of the classroom to online. There are even fewer studies which have focused on the impact of online daily worksheets versus printed daily worksheets, therefore, in this study, we are assessing this impact and sharing our findings [1,4,6,7,8].

In engineering disciplines, most of the core course objectives circle around learning a theoretical subject and then applying it to real-world problems. Therefore, critical thinking and developing problem solving skills are essential parts of engineering curriculum [9,10] and this goal should be achieved regardless of the content delivery method. Only when students attempt to apply their knowledge and answer a problem on their own do they have the opportunity to think, learn and often times realize that there might be parts of the subject they haven't fully comprehended. Recently we are observing more investigations on the impact of transitioning from traditional lectured-based classrooms to learner-centered classrooms. Placing the learner at the center of the classroom helps them build necessary skills to solve real-world problems. Studies on problem-based learning and inquiry-based learning in STEM education has shown these to be effective tools to help students develop problem solving skills and engage students in critical thinking [10,11,12]. Inquiry based learning focuses on engaging students by asking questions which connects the real-world problems to the STEM subjects [4,13]. We have been using worksheets as an inquiry-based tool to support a transition to a learner-centered classroom. Worksheets not only are useful as a guide for students to identify which part of the subject they are struggling with, but they also provide informative feedback to the instructor.

There have been studies which show that using more problem-solving assignments in online courses could be an effective method in keeping students engaged [11,12,13]. Therefore, the worksheets could be potentially a great tool to increase teaching effectiveness in online courses. But before any conclusion we need to measure the impact of having online worksheets. It is not unusual for a change in instructions to be unsuccessful if the instructor changes too many factors at once [14]. Therefore, our approach to understanding the impact of online learning on students learning outcome is focusing on altering one factor at a time.

This work in progress research is intended to measure and compare the difference in students learning outcomes between two groups of students who took EET2141 in Fall 2019 and Fall 2020, respectively, at Michigan Technological University. The first group of students attended this course in person and were given printed worksheets after a face-to-face lecture to complete in class and turn in to the instructor before leaving the classroom. The second group participated in this course also in person and after the face-to-face lecture they were assigned to complete the same worksheets online and submit them electronically in the Canvas Learning Management System. The only changed factor between the two groups was the worksheet formats. The comparison between the two groups is based on the average grades in learning objectives through assessment measures such as exams and laboratory experiments which was kept similar for the two groups. The assessment measures and tools are explained in detail in the next section.

## 2. Methodology and approach

In this section we have provided information about the Digital/Microprocessor Basics (EET2141) course and introduced assessment tools and analysis methods used to measure students' learning outcome. The desired learning outcomes and quantifying methods used in this study are adopted from our departmental assessment process. We have also introduced new approaches to analyze the outcome such as the probability distribution function of students' grades in different learning outcomes.

### 2.1. Digital/Microprocessor Basics:

Digital/Microprocessor Basics (EET2141) is a required 4-credit course in the Electrical Engineering Technology (EET) curriculum at Michigan Technological University. In this course (and many other courses in the EET program) the grades for the laboratory experiments are combined with the lecture to create a 4-credit course and it is counted as one 4-credit course. In this fundamental course, students are expected to learn a large range of theoretical content, practice critical thinking and apply their knowledge to solve problems. The enrollment in this course is typically under 15 students, therefore student-instructor interactions is easily achievable. In this course, students learn about combinational logic functions, truth tables, timing diagrams, Boolean algebra laws and logic circuits. Students are expected to develop skills to evaluate the output of sequential logic systems including synchronous and asynchronous operations and analyze logic circuits such as counters, flip flops, decoders and multiplexers. Student are also expected to develop skills to design simple logic circuits using basic logic components such as AND/OR gates using Karnaugh maps.

Traditionally, this course has been taught at Michigan Technological University with homework, lab assignments and exams. Since 2019 we have introduced inquiry-based worksheets to this course. The worksheets are participation-based assignments for every session and constitute 5% of the students' final grades. The intent of the worksheets is: 1- To keep them motivated to think and solve real-world problems 2- To assess students' learning outcome every session and on every subject. These worksheets are designed by the instructor and intend to include problems that students will face in the laboratory, real world, future jobs and industry. We also often use these worksheets to help students draw interesting conclusions about the material on their own.

In 2019 these worksheets were printed by the instructor and distributed in the classroom after a face-to-face lecture and during the last 20 minutes of the class time, the sheets were completed by the students and physically turned in to the instructor at the end of the class period. In 2020, after the COVID-19 pandemic revealed the importance of online delivery, the instructor changed one factor which was the format of the worksheets. The same worksheets as 2019 were assigned to students online to be completed and submitted after each face-to-face lecture on the same day of the lecture via the learning management system. The instructor kept everything else the same in order to measure the impact and difference of changing the format of the worksheet. In both cases students worked on the worksheets individually. The class time usage in both formats (in person and online worksheets) is outlined in Figure 1. It is important to mention that Michigan Technological University allowed for classes with small number of students in which social distancing was possible to have face to face instructions upon the instructor's decision. We decided to keep EET 2142 face to face with proper social distancing and face covering. The number of students enrolled was under 15 which allowed us to appropriately practice social distancing in the classroom. The two groups of students who participated in this study took the same pre requisites courses and were registered in their second/third year of Electrical Engineering Technology program at Michigan Technological University. The number of students enrolled in fall 2019 and 2020 was between 12-15. We also have asked both groups of students to complete a survey and we have provided their responses in the result section.

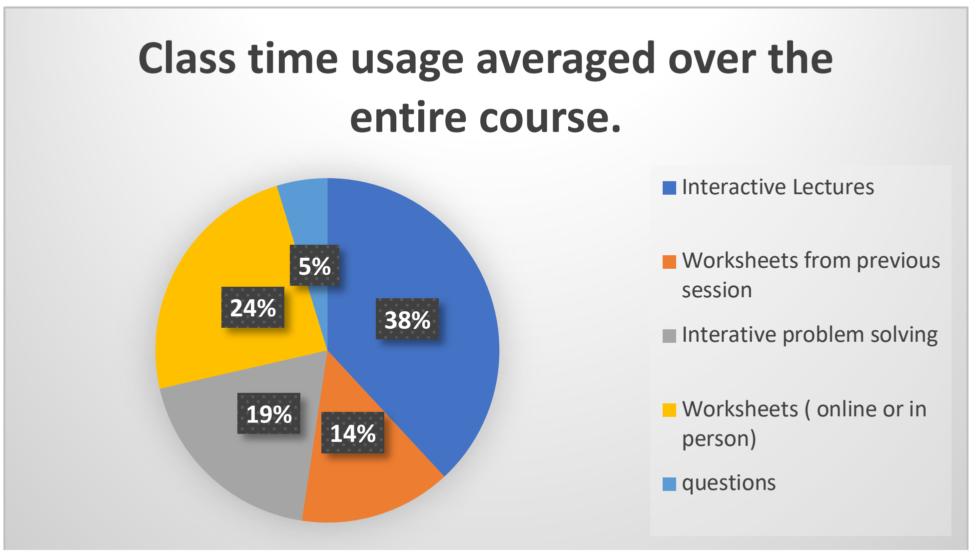


**Figure 1. Class time usage in EET2141**

2.2. Assessment tools

The course objectives in EET2141 and assessment tools for Fall 2020 and Fall 2019 are listed in the table below. Students average grade using the assessment measures is listed for each objective under the "results" sections and used to do a statistical comparison between learning outcomes in Fall 2019 and Fall 2020. The learning outcomes and the provided measuring tools for each are adopted from our departmental process which is required for ABET accreditation. In this process the learning outcome is assessed through different questions on the exams and different laboratory experiments. For example, "knowledge of the basic operation of logic gates and identify their symbols." is assessed through Exam 1 questions: 9, 10 and 11(Exam 1(9,10,11),) and the laboratory experiments 1,2 and 5 (Lab (1,2,5)).

**Table 1. Learning outcomes and assessment tools for EET 2141**

| Learning outcomes | Fall 2019 | Fall 2020 |
|---|---|---|
| knowledge of the basic operation of logic gates and identify their symbols. | Exam 1(9,10,11), Lab (1,2,5) | Exam 1 (5,6,7), Lab (1,2,5) |
| Ability to create combinational logic functions, truth tables, timing diagrams, and logic circuits. | Exam 1 (8), Lab (3), Exam 2 (1,5) | Exam 1 (6,7), Lab (3), Exam 2 (1,2,3) |
| Ability to simplify complex logic circuits by applying Boolean algebra laws and theorems and Karnaugh mapping. | Exam 2(5), Lab (8,9,10) | Exam 1(5,7), Exam 2 (1, 2), Lab (8,9,10) |
| Ability to evaluate the output of basic counters, decoders, multiplexers and arithmetic circuits. | Exam 3, Lab (4) | Exam 3, Lab (4) |
| Ability to convert between the decimal, binary, hexadecimal, and perform binary addition, and multiplication numbers. | Exam 1(4,5,6,7), Lab (7,6) | Exam 1 (1,2,3,4,), Lab (7,6) |
| Explain the basic functions of SR, JK and D flip-flops. | Exam 2 (2,3,4) Lab (7,8,9) | Exam 2 (3,4) Lab (7,8,9) |
| Ability to evaluate the output of sequential logic systems including synchronous and asynchronous operations. | Exam 2(5), Exam 3, lab 7,8,9,10 | Exam 2 (3,4,5), Exam 3, lab 7,8,9,10 |

### 2.3. Statistical tools

In this study, we have utilized innovative assessment tools such as the probability distribution function of students' grades in each objective for Fall 2019 and Fall 2020. We have analyzed the difference between students' grades in each objective individually and we also have looked at the average grade of students in each objective. The Kolmogorov–Smirnov test (K-S test) and hypothesis test statistic ($t$-test) were the statistical tests we have employed to analyze our data sets. A probability level of $p \leq 0.05$ was used for all tests to indicate statistical significance.

The K-S test is used to quantify the difference between distribution functions of two data sets. The null hypothesis of the K-S test performed here was that the two sets of data came from the same continuous distribution functions. The result of the test can be categorized as: 1- There is 95% chance that there is no significant difference (NSD) between the distribution functions of the two data sets and 2- There is a 95% chance that the continuous distribution functions are not similar and there is a statistical difference between the two distributions. In other words, there is less than or equal 5% chance ($p \leq 0.05$) that any differences between the distributions is due to chance alone.

The $t$-test was used to test that within a 95% certainty limit, if the two data sets are independent and have equal means. There are two outcomes with this test: 1-There is 95% chance that the two samples come from the population where there is no significant difference (NSD) in their means. 2- There is 95% chance that the two-data set have unequal means.

## 3. Results

In this section we are presenting the result of our analysis comparing the learning outcome of two groups utilizing *t*-test and the K-S test. At the end of this section, we have also provided the responses to surveys which was given to the both groups of students.

### 3.1. Statistical analysis:

It is important to recognize that students in both groups achieved our Departmental goal of 70% of all students achieving each objective. The average of the final grade in the Fall 2019 and Fall 2020 was 96.1% and 91.3%, respectively. The results of the *t*-test and the K-S test indicated that with 95% certainty that neither the average grades, nor the distribution of the grades, have statistically changed as a result of online worksheets. The average grade of all students in each learning objective is listed in Table 2. The average grade for students in the Fall 2020 dropped in five objectives and increased in the remaining two, which raises the possibility that in 2020 the students may have done generally better at the subjects that were covered in the first month of the semester (mostly included in objective number 1) and their performance dropped in objectives that are covered later in the semester, such as objectives 3, 5, 6 and 7, which require critical thinking. This is aligned with studies that it is challenging to keep students motivated and engaged in an online setting and for online assignments and it is only a matter of time before they lose momentum [5,6,7,8]. To examine this hypothesis, we used student grades in each objective as a data set and performed a statistical analysis on all seven sets of data to examine for differences. The result is displayed in Table 3.

**Table 2. Average grade of students in each learning objective in fall 2019 and 2020.**

| Learning outcomes | Average in 2019 | Average in 2020 | Difference |
|---|---|---|---|
| 1. knowledge of the basic operation of logic gates and identify their symbols. | 94.1% | 91.2% | -2.9% |
| 2. Ability to create combinational logic functions, truth tables, timing diagrams, and logic circuits. | 86.4% | 93.9% | +7.5% |

| | | | |
|---|---|---|---|
| 3. Ability to simplify complex logic circuits by applying Boolean algebra laws and theorems and Karnaugh mapping. | 95.2% | 85.8% | -9.4% |
| 4. Ability to evaluate the output of basic counters, decoders, multiplexers and arithmetic circuits. | 92.7% | 92.8% | +0.1% |
| 5. Ability to convert between the decimal, binary, hexadecimal, and perform binary addition, and multiplication numbers. | 93.1% | 85.4% | -7.7% |
| 6. Explain the basic functions of SR, JK and D flip-flops. | 94.2% | 87.2% | -7% |
| 7. Ability to evaluate the output of sequential logic systems including synchronous and asynchronous operations. | 95.1% | 93.3% | -1.8% |

**Table 3. KS-test and t-test results for two sets of data: students' grade in an objective fall 2020 and student grades in an objective in fall 2019.**

| Objectives | *t*-test | K-S-test |
|---|---|---|
| 1- knowledge of the basic operation of logic gates and identify their symbols. | NSD | NSD |
| 2- Ability to create combinational logic functions, truth tables, timing diagrams, and logic circuits. | NSD | NSD |
| 3- Ability to simplify complex logic circuits by applying Boolean algebra laws and theorems and Karnaugh mapping. | NSD | NSD |
| 4- Ability to evaluate the output of basic counters, decoders, multiplexers and arithmetic circuits. | $p<0.05$ | $p<0.05$ |
| 5- Ability to convert between the decimal, binary, hexadecimal, and perform binary addition, and multiplication numbers. | NSD | NSD |

| | | |
|---|---|---|
| 6- Explain the basic functions of SR, JK and D flip-flops. | NSD | NSD |
| 7- Ability to evaluate the output of sequential logic systems including synchronous and asynchronous operations. | NSD | NSD |

These results suggest that the means and distributions of the data from the two years is similar in six out of the seven objectives. This suggests overall there is not much difference statistically between the two data sets and we can conclude that the performance of students in Fall 2019 and Fall 2020 are similar except some variations due to randomness.

3.2 Students survey results:

Students were given a survey in both semesters related to the worksheets. The responses to the specific questions along with the percent of students' responses is provided in figure 2,3 and 4. Note that the students' options for each question was: 'strongly agree', 'agree', 'neutral', 'disagree' or 'strongly disagree' for questions 1-5 but the 0% responses are not shown in the tables. The student responses shown in figure 2 indicate that they find worksheets of value to their learning and a useful tool which helps them prepare for the exam in both years.

The last question (figure 3 and 4) of the survey was different for each year. We asked the students who were given the worksheet in class (fall 2019), if "The worksheets would have been more helpful to their learning if they were assigned online via CANVAS". 17% disagreed, 33% were neutral and 50% were agreed. And we asked students who found and submitted worksheets online (fall, 2020) if "The worksheets would have been more helpful to their learning if they were printed and distributed in class and they were given 15 minutes in class after the lecture to complete them." 60% of students agreed (or strongly agreed) and 40% were neutral. The two sets answers are interesting and worthy of investigation. However, this is beyond the scope of this paper, but it is worth acknowledging that 50% or more of students are interested in the format that they were not given.

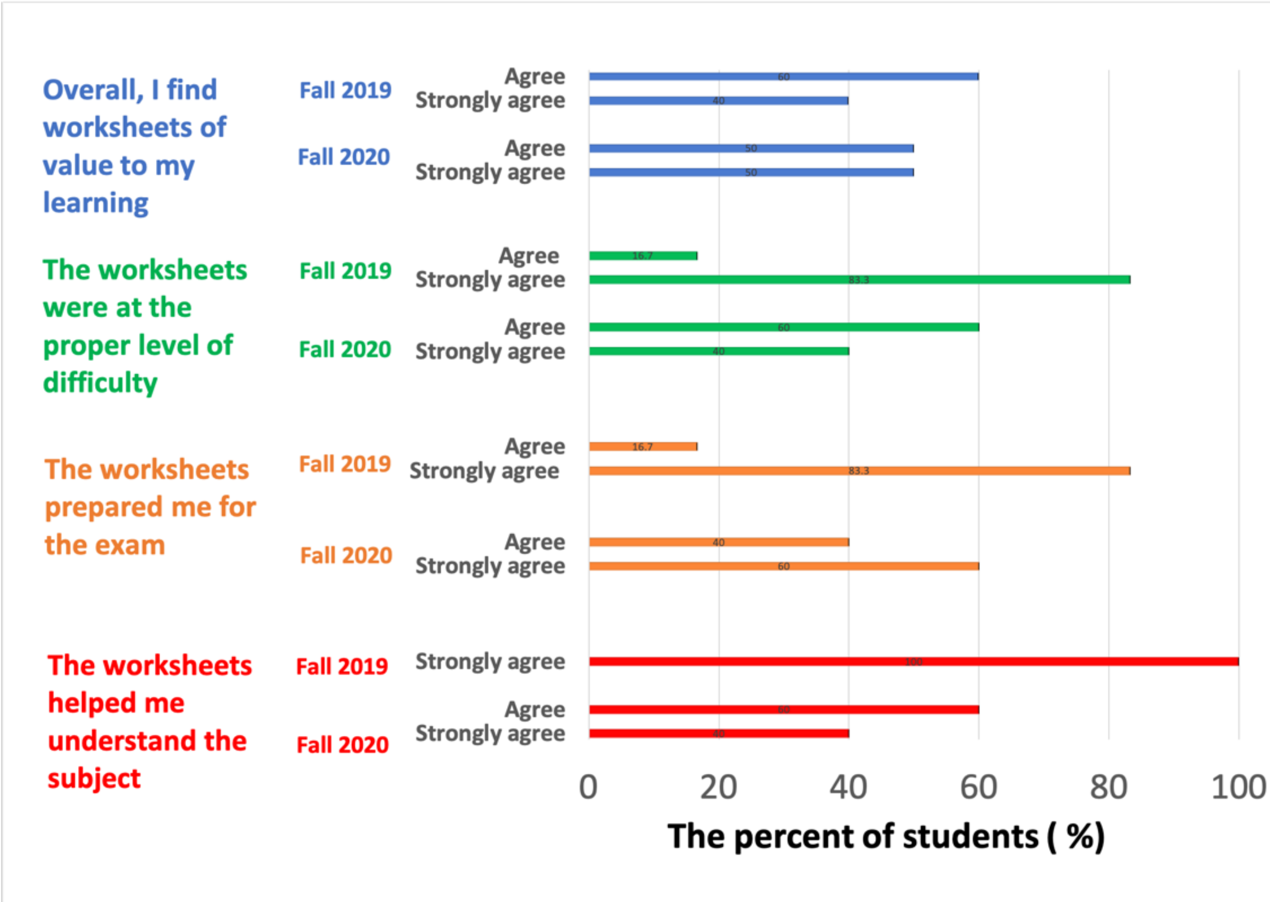


**Figure 2. Student responses to four questions: "The worksheets helped me understand the subject.", "The worksheets prepared me for the exams.", "The worksheets were at the proper level of difficulty." and "Overall, I find worksheets of value to my learning."**

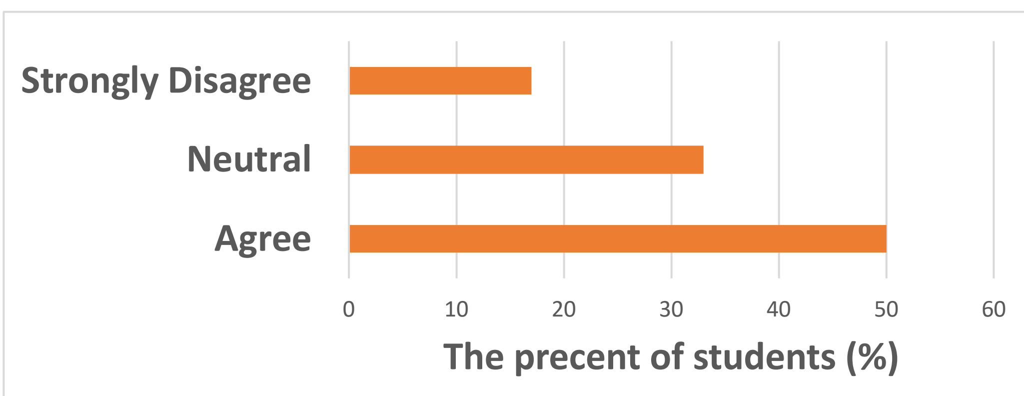


**Figure 3. Student responses to "The worksheets would have been more helpful to my learning if they were assigned online via CANVAS." Fall 2019.**

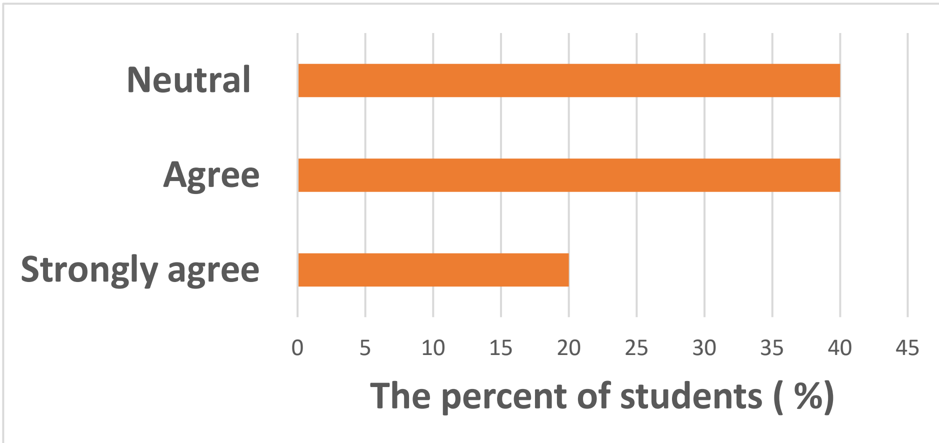


**Figure 4. Student responses to “The worksheets would have been more helpful to my learning if they were printed and distributed in class and I was given 15 minutes in class after the lecture to complete them.” Fall 2020.**

4. Conclusion and Recommendations

In a teacher-center classroom, the instructor spends most of their time talking and students take notes. In this class, we use worksheets as a student-centered activity and integrate them into class time to help students reach the learning goals. In light of the pandemic, the need for online delivery of engineering courses and the impact of it on student learning outcomes are more critical than ever, but switching everything from face to face to online at once is not a useful method to assess what works and what doesn’t. In this study, we focused on analyzing the impact of online worksheets versus in class worksheets while keeping the lectures face to face.

Our results indicate that with 95 % certainty that the worksheet format, printed and distributed in class versus assigned online, did not make a statistical difference in the students learning outcomes. Although the average grade in the Fall 2020 class (online worksheets) was lower in 5 objectives than those in the Fall 2019 cohort, the results of the K-S tests and *t*-tests indicate that this difference is likely due to random variation. This is an encouraging outcome for instructors and students who are interested in moving towards online delivery of engineering and engineering technology classes as the engagement method, which was an inquiry-based worksheet, resulted in the same outcomes for both online and face to face formats. All of the students enrolled in this course in both Fall 2020 and Fall 2019, met our internal requirements of 70% or higher average grade every objective.

We cannot yet conclude that worksheets are the best method to keep online delivery of engineering/engineering technology courses as effective and interactive as possible but we can certainly decide that modifying printed worksheets to an online assignment did not impact these two groups of students’ learning outcome negatively. Therefore, the online worksheets could be an applicable method to keep students engaged during online courses but to examine the impact of them in a fully online setting further investigation is needed. We recommend for instructors to consider worksheets as an engagement tool in online and/or face to face teaching environment. Our sample sizes in this study were small, as this course has a small number of students enrolled each year. If any instructors are interested to replicate this study, we suggest to expand on the sample size. Also, it could be interesting to study the impact of reducing the number of worksheets to once a week or once every other week.

We intend to repeat this research in the future in interest of having a larger sample. We will also continue this research altering different factors one at a time to examine the impact of different aspects of the online environment such as online homework, online exams and online lectures.

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