

Comparisons of Student Performance in Similar Courses prior to, during, and after Online Instruction Due to COVID-19 Pandemic

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Abstract

Most universities stopped face-to-face instruction in March 2020 due to the COVID-19 pandemic and completed the spring 2020 semester through online instruction and assessment. At our institution, the online instructions continued until the summer of 2021. In fall 2021, the university decided to delay the full return of faculty, students, and staff to campus for the first three weeks. The first three weeks of instruction of our courses was conducted on-line and then was changed to face-to-face for the remainder of semester. Significant variation in student performance was observed between similar courses offered prior to, during, and after the online instruction due to COVID-19. The passing rates for similar courses offered during this period have been compared in this paper. A gradual decline in the knowledge of prerequisite topics following the first online semester is noticed, which indicates that many students were assessed in such a way that they passed important prerequisites courses with minimum knowledge. The decline is based on several factors that include challenges that students and instructors have faced during the online instructions, as well as the way students' knowledge was assessed, especially with online exams where there has been a notable increase in scholastic dishonesty. The factors that resulted in lower student academic performances are identified.

Introduction

The authors of this paper have been teaching thermal science courses for many years. Through their experience, they have realized that the success of students in their courses mainly depends on students' motivation and commitment in learning the fundamental concepts. Through the years, there have been gradual changes in students' study habits and efforts in learning the course materials. In the 1990s, most students attended classes, read the textbook, resolved or reviewed example problems in the textbook, attempted to solve homework assignments on their own, and met the instructor during the office hours when they had difficulty with a homework assignment. Since the early 2000s, many factors have affected students' approach in studying and learning the course materials. These changes are briefly described in the following paragraphs.

Engineering textbooks contain problems at the end of each chapter to be assigned as homework. The purpose of homework assignments is to provide students educational experience to solve new problems independently and prepare them for engineering employment and practice. In the early 1990s, almost all textbook solution manuals were in print format and the solutions steps were very brief and detailed solution steps were not provided. In most cases, the instructors created detailed solutions steps and made them available to students after the submission of homework assignments.

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To assist instructors, the publishers started to send hard copies of detailed solutions to instructors only. By the early 2000s, most solution manuals became available in digital format. The digital format made it easy for one student who had gained access to a solution manual to distribute it to others. Several studies have examined the effects of students' use of solution manuals on their performance during exams¹⁻⁷. Many instructors have ethical concerns regarding the students' use of solution manuals, while many students do not consider the use of solution manuals as scholastic dishonesty¹. Few studies have shown that the use of solution manual has an adverse effect on students' learning²⁻⁵. Other studies have suggested new strategies for assigning homework problems^{6,7}. With the availability of solution manuals to students, we noticed over time fewer and fewer students stopping by during the office hours to ask questions about homework assignment from instructors or ask questions during the lectures. We also noticed that some students who had almost perfect scores on the homework assignments were incapable of solving exam problems that were very similar to homework assignments. As a result, the authors noticed a sharp increase in the rate of unsuccessful grades (DFW) in their courses. Also, a wide range of grade distribution observed for each exam spreading from grades as low as zero (0) to as high as 100. Now all solution manuals are available on the Internet. In spring 2009 only 44% of students in a second course in thermodynamics (Thermodynamics-II) received passing grades of C or higher.

To address this problem, in 2010, we started to assign problems using Wileyplus⁸ for homework assignments. Wileyplus allowed students to complete their homework assignments online and be graded automatically online. The Wileyplus problems were the same as those given in the textbook, except one or more parameters in the problem statement are randomly changed for each group of students. The WileyPlus system grades the answers as soon as they are submitted by students online. To use Wileyplus more effectively as a learning tool, students were allowed to submit a correct answer after two or more trials and receive full credit. Originally, the textbook problem numbers were hidden in WileyPlus assignments, pretending that the problems were not coming from the textbook. However, it did not take students too much time to find out quickly that problems are from the textbook. Therefore, for those who had access to the solution manual, all the solution steps were available to them and they just needed to insert different numbers in the equations to get the right answers. In a course survey conducted 2010, 65% of students in several courses indicated that they had been using solution manual to complete their homework assignments³.

Starting in fall 2010, we adopted a new approach in assigning homework problems. We started assigning two sets of homework problems. One set of assigned problems were selected from the textbook, the second set were developed by the instructor, identified as "external problems." Those selected from the textbook carried much lower weight than those written by the instructors. For the problem set designed by the instructors, students were required to show all solution steps, starting with the most fundamental equations and modifying them for specific applications. This requirement also applied to some problems in quizzes and exams. For example, for the evaluation of power requirement of a compressor in a refrigeration cycles, students were required to start with the most general forms of rate equations for mass balance, energy balance, and entropy balance and simplify them for the compressor. Assignment of external problems had positive effects for a few years. However, in a short time a number of on-line tutorial services, such as Chegg⁹ and Course Hero¹⁰, became available. For a subscription cost, students could submit any engineering problem statement to one of these on-line tutorial services and receive solutions within a 24-hour period. In addition,

many video lectures on different engineering subjects became available on the Internet. It was noticed that some students were not reading the textbook or reviewing example problems, and were skipping the lectures. Although, the video lecture tapes posted on the Internet could enhance students' understanding of some of the course topics, the students missed what was actually covered in the course by skipping lectures. Again, we gradually noticed an increase in DFW rates in our classes. To address this problem, we experimented with the Flipped classroom concept¹¹. Students were given reading assignments, review lecture slides, or video tapes of lectures from previous semesters before attending lectures. The idea was to use most of the class time for students to solve problems in class. Unfortunately, this scheme was not very successful, since many students attended class unprepared and the instructor had to use most of class time to lecture the assigned materials. In spring 2016, only 62% of students in the second course in thermodynamics received grades of C or better and approximately the same percentage of students successfully completed a course in Heat Transfer in spring 2018.

Starting in fall 2018 the new University "Instructor-Initiated Drop policy," initiated in fall 2016, was adopted and implemented in three different courses: Thermodynamics I, Thermodynamics II, and Heat Transfer¹². Thermodynamics II and Heat Transfer were taught by the same instructor in two different long semesters in fall 2018 and fall 2019, respectively. But Thermodynamics I was taught by two different instructors during one semester and only one adopted the drop policy. The Instructor-Initiated Drop policy guidelines were specifically listed in the course syllabus of each course. For example, the course syllabus for the Heat Transfer course offered in fall 2019 listed the following statements:

This course uses Instructor Initiated Drop policy for students who exceed the absence or missed assignment limit. Students will be dropped when either the attendance or the homework assignment limits are exceeded. The limit for each category is listed below:

- Being absent four (4) times. Arriving 5 minutes after the start of class or leaving before the end of class will be considered being absent. Attendance will be recorded through I-Clicker. If you forget to bring your I-Clicker to class, you must notify the instructor at the start of class to be counted as present (this will be allowed only twice during the semester).
- Missing three (3) assignment sets (include Wileyplus Homework sets, other assignment sets, and take-home exams). Attempting less than 75% of problems in each problem set will be considered a missed assignment in this policy.

The implementation of the Instructor Initiated Drop policy improved the passing rates in all three courses. The passing rate in Thermodynamics II increased from 62% in spring 2016 to 79% in fall 2018. For the Heat Transfer course, the passing rate increased from 65% in fall 2015 to 82% in fall 2019.

Student performance during on-line instruction

In March 2020, the University suspended in-person face-to-face instruction due to the COVID-19 pandemic and students completed the spring semester through online instruction and assessment. The online instructions continued until the summer of 2021. During this period, instructors were given the option of offering live online lectures or recording their lectures and making them available to

students. For live online lectures, instructors were required to record their lectures and make them available to students to account for cases in which students lost internet connectivity or could not participate in lectures due to uncontrollable factors. The greatest challenge for some instructors was maintaining academic integrity during exams. A sharp increase in cheating has been detected in recent years^{13,14}. Examples of Scholastic dishonesty had included copying solution manuals for homework assignments, using phones, text, and apps to share answers; using phones to take images of exam questions, sending them to external tutoring services, and copying solutions received from the external tutoring services. Some of the department faculty members have identified such cheating methods and have penalized students who had copied solutions received from such tutoring services (e.g., Chegg⁹).

In spring 2020, the authors conducted their first exams in person on campus. After going on-line later in spring 2020 instructors had very limited control for proctoring exams. Therefore, the integrity of online examinations could not be guaranteed. The second midterm exam in Thermodynamics II was conducted online, using the Webex platform. Students were asked to activate the video function of Webex while taking the exams, but many students claimed that they did not have a camera on their computer. One student, who received the lowest grade in the first exam, received a perfect score on the second exam. For the final exam all students were required to use their computer camera or use an external webcam during the exam. The camera could only display the upper body of each student, but could not capture their activities on the computer. Therefore, students could communicate with each other through email or seek assistance through on-line tutoring services.

In fall 2020 and spring 2021, the authors used Proctorio software to monitor their exams^{15, 16}. Students were required to activate their external webcam during the Proctorio exam. Students were instructed to point their webcams to their desk working area, showing their hands, keyboard, mouse, calculator and portion of screen. Proctorio recorded student's activities during the exam. In addition, it recorded the students' computer screen and kept a log of the internet navigation during an exam. After the exam, the instructor had the ability of reviewing all of the recordings to assess academic integrity of their exams. However, in large classes, it took a long time to review the recordings for each student who took the exam. The use of Proctorio discouraged most students from cheating, but it did not completely eliminate it. Despite the faculty efforts, cheating in online course continued to be a significant problem, as the authors could still find their exam problems and solutions posted on Chegg. A number of students were charged by the faculty and sanctioned by the University for Scholastic Dishonesty Infractions. It should be noted that only a few instructors in the program chose to employ Proctorio to monitor their exams.

In spring 2021, the University announced that campus would be open in fall 2021 for in-person activities. The instructors were given the choice of teaching their fall semester courses either in-person or continue teaching on-line. The authors chose the face-to-face modality. However, during the summer, the University decided to delay the full return of faculty, students, and staff to campus in fall semester due to spread of COVID- Delta variant. The University announced that, with few exceptions, all campus activities would be conducted on line for the first three weeks of semester. After three weeks of on-line instruction, the authors began teaching their courses in person on campus and gave all their exams in classrooms. Starting in fall 2020, it was observed that more and more students were struggling with the courses due to lack of sufficient knowledge in prerequisite topics. Therefore, the rate of unsuccessful attempts (grades of DFW) increased every semester. Tables 1 and

2 present the rates of ABC and DFW grades given in Thermodynamics-II and Heat Transfer course, respectively, for few semesters. The two sections of these courses were taught either by same instructor or two different instructors. In cases when two different instructors were teaching two sections of the same course, a common course syllabus was used for both section and the same grading policies were employed. In addition, common exams were given to the students outside of the regularly scheduled class time. Both instructors shared the responsibilities of grading the exams for both sections and each instructor graded the same problem on the exams for both sections.

Table 1. Comparison of student passing rates in Thermodynamics-II course offered in five different semesters under various circumstances

| Semester | Number of sections | Total enrollment | ABC rate | DFW rate | Drop policy | Exam mode | Sections Instructors |
|-------------|--------------------|------------------|----------|----------|-------------|-----------------------------|----------------------|
| Fall 2015 | 2 | 156 | 62% | 38% | No | Common, in person | Different |
| Spring 2016 | 2 | 157 | 62% | 38% | No | Common, in person | Different |
| Fall 2018 | 2 | 127 | 79% | 21% | Yes | Common, in person | Same |
| Spring 2020 | 2 | 92 | 70% | 30% | No | Common online not proctored | Same |
| Spring 2021 | 1 | 43 | 56% | 44% | No | Online Proctorio | One section |

A few years prior to 2015 passing rates in Thermodynamics-II were in a range of 80 to 90%. Fall 2015 and spring 2016 represent a period of declining passing rates that started a few years earlier. During this period, many students stopped reading the textbook or reviewing the textbook example problems, and began using solution manuals when solving homework assignments, or stopped solving the homework assignments at all. Also, the student attendance in large classes was dropping during that period. Some students were relying on lecture video tapes available on the internet, but they were not aware of the materials covered in the class. With the implementation of the Instructor Drop Policy, in fall 2018, attendance was vastly improved and most students completed their homework assignment. As a result students passing rate vastly improved in that semester. With the spread of the COVID pandemic and the requirement for offering online instruction, and conducting exams online, the Instructor Drop Policy could no longer be implemented, since the University policies during this period were not to enforce class attendance and be flexible in accepting late assignments, due to possibility of Internet conductivity. Therefore as shown in Table 1, the passing rates in Thermodynamics II courses began to decrease steadily in spring semesters 2020 and 2021.

Table 2 displays passing rate results in Heat Transfer courses very similar to those presented in Table 1 for Thermodynamics II. A vast improvement in passing rate can be observed in Table 2 with the implementation of the Instructor Drop Policy in fall 2019. The passing rate also gradually decreased in fall 2020 and fall 2021. After the start of online instruction, one thing became clear: many students

had shortcomings in the knowledge of prerequisite topics that prevented them from following and understanding the materials being covered in courses. This required that the instructor review the prerequisite topics before starting to lecture on new topics in the course. Therefore, the instructor could not introduce all the course topics that were covered in the past, but only focus on the most important topics in the course. For example, when the conduction was being covered in the heat transfer course, some students could not solve a simple second order ordinary differential equation such as $d^2T/dx^2 = constant$, even though a course covering differential equation is a prerequisite.

Table 2. Comparison of student passing rates in sections of Heat courses offered in four different semesters under various circumstances

| Semester | Number of sections | Total enrollment | ABC rate | DFW rate | Drop policy | Exam mode | Instructors |
|-----------|--------------------|------------------|----------|----------|-------------|---------------------------|-------------|
| Fall 2015 | 1 | 52 | 65% | 35% | No | In person | One section |
| Fall 2019 | 2 | 107 | 82% | 18% | Yes | Common, in person | Same |
| Fall 2020 | 2 | 101 | 76% | 24% | No | Common, On-line Proctorio | Same |
| Fall 2021 | 2 | 87 | 73% | 27% | No | Common In person | Same |

In fall 2021, three mid-term exams and a final exam were given in the Heat Transfer course. After the second midterm exam more than 60% of students were failing the course. The instructor scheduled short meetings with each of those students to find out why they were struggling with the course by asking several questions. When it was asked from students if they read the textbook or reviewed example problems in the book, most responded negatively. Most indicated they only review the lectures posted on line for solving the homework problems. When they were asked if they do their weekly homework assignments, most responded yes. These answers were surprising to the instructor, since approximately eight (8) problems were being assigned each week and it would have taken the instructor three to four hours to solve each weekly assignment set. One thing became obvious that during the pandemic things had been made too easy for students, and their knowledge was not assessed properly in order to pass courses. The instructor advised students that they need to spend more time and effort to study for the course in order to pass. Some students followed the instructor’s advice and as a result, the passing rate was improved by the end of semester.

Summary and Conclusions

In summary, we have described some of the changes that have occurred in student study habits in the past 20+ years. Because of online resources that have become available, some students are not spending sufficient time to acquire in-depth knowledge of technical subjects. The forced online instruction in the past 2 years has made the situation even worse. We have noticed a decline in the knowledge of prerequisite topics during this period, which might suggest that students were not being

assessed properly and some students have passed important prerequisites courses without having adequate knowledge.

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