Alternatives to Textbook Homework Assignments

Dr. Amir Karimi P.E., University of Texas, San Antonio

Amir Karimi, University of Texas, San Antonio Amir Karimi is a Professor of Mechanical Engineering at The University of Texas at San Antonio (UTSA). He received his Ph.D. degree in Mechanical Engineering from the University of Kentucky in 1982. His teaching and research interests are in thermal sciences. He has served as the Chair of Mechanical Engineering (1987 to 1992 and September 1998 to January of 2003), College of Engineering Associate Dean of Academic Affairs (Jan. 2003-April 2006), and the Associate Dean of Undergraduate Studies (April 2006-September 2013). Dr. Karimi is a Fellow of ASEE, a Fellow of ASME, senior member of AIAA, and holds membership in ASHRAE, and Sigma Xi. He has served as the ASEE Campus Representative at UTSA, ASEE-GSW Section Campus Representative, and served as the Chair of ASEE Zone III (2005-07). He chaired the ASEE-GSW section during the 1996-97 academic year.

Dr. Randall D. Manteufel P.E., University of Texas, San Antonio

Randall Manteufel is Associate Professor in Mechanical Engineering at the University of Texas at San Antonio. He teaches thermal-fluid courses.

Alternatives to Textbook Homework Assignments

Abstract

Ever since the solution manuals have become available in digital format, they have become widely available, despite instructors' attempts to keep them away from students. Now it is common for students to consult the solution manual or internet resources when completing their homework assignments. As a result, there has been a steady decline in students' ability to set up and solve problems, especially when there is no access to the solution. To improve students' ability to solve engineering problems independently, the authors have attempted several schemes when teaching thermal science courses. These efforts included developing and assigning their own homework problems, increasing the frequency of quizzes and exams, using classroom electronic response devices, assigning group and individual projects, using the flipped classroom concept, and offering mandatory recitation periods. This paper briefly describes the teaching and learning schemes attempted, the advantages and disadvantages of each scheme, and the effectiveness of each scheme. The most promising scheme has been unique homework problems, and this is supported by comparing exam grades when homework problems were assigned from the textbook.

Introduction:

Preparing graduates for engineering employment and practice is the most important function of engineering education. Graduates are expected to have the basic knowledge, and the ability to solve new engineering problems that they might not have seen before. The traditional approach in preparing graduates for engineering careers is to require students to attend classes, listen to instructor's lectures explaining the basic theories and concepts related to the subject; and observe or participate in solving example problems during lectures. Students are also asked to read the content of the required textbook describing the theories and concepts.

Textbooks used in undergraduate engineering course cover basic concepts and theories in each chapter and provide several example problems to help students gain a better understanding of the theory and engineering applications. At the end of each chapter, textbooks frequently include a large set of problems to be used as homework assignments. The purpose of homework is for students to gain the experience of solving new problems without having access to the solutions. The main aim of homework assignments is to prepare graduates for engineering employment and practice where the employees are expected to solve problems that no solutions may be available in advance. Textbook publishers also provide solution manuals as a resource for the instructors.

Historically, some students have always been eager to use solution manuals for their engineering courses. Up to early 1990s, most solution manuals included very brief solutions to the textbook problems and only consisted of only a couple of lines. In order to make the solutions more understandable, instructors had to rework and expand the solutions to the assigned textbook problems before making them available to their students. To help the instructors, the publishers began to provide detailed solutions, and some were presented in type-set with excellent graphics. Up to that point, few students could get access to solution manuals of engineering textbooks. In early 2000s, publisher started to provide solution manuals in digital format, which made it much

easier to be distributed among all students once one student got hold of the course solution manual. Ever since the solution manuals have been provided in digital format, the authors of this paper have realized that solution manuals are available to and used by almost all students in completing their homework assignments.

There have been several studies in recent years examining the ethics and effects of students' use of solution manuals on their performance during exams [1-6]. One study surveyed the faculty and students in a large mechanical engineering department to seek their perspectives on the ethics and the educational values of employing solution manuals in solving textbook homework assignments. Many instructors had ethical concerns regarding the students' use of solution manuals, while many students did not consider the use of solution manuals as scholastic dishonesty [1]. Few studies have shown that the use of solution manual has an adverse effect on students' learning [2-4]. Other studies have suggested few new strategies for assigning homework problems [5, 6].

The authors of this paper have been teaching engineering courses for many years both at the undergraduate and graduate levels, mainly in the thermal science area. In their institution, a two-course sequence in thermodynamics and a course in heat transfer are required for an undergraduate degree in mechanical engineering. One of the authors periodically teaches undergraduate courses in statics and fluid mechanics as well. Starting in early 2000, it was observed that fewer and fewer students visited faculty during the office hours to seek assistance in solving homework assignments. Also, it was noticed that students seldom would ask questions during the lectures about the homework problems assigned from the textbook. In addition, a decline in the pass rate and a wider spread of exam grades were noticed.

Table 1 compares the grade distributions for two sections of the second course in thermodynamics taught by the same instructor at six different semesters. The first five columns present the grade distribution in the course offered between fall 1998 and fall 2004 when very few or none had access to the textbook solution manual. The last column displays the grade distribution for the same course taught in spring 2009 when there were good indications that a large number of students were using the textbook solution manual for completing their homework assignments. Only grades of C or better are considered a passing grade in the mechanical engineering program at the authors' institution. A grade of W indicates that student has withdrawn from the course, after the census date (approximately two weeks after the start of a semester). In most cases students who receive a grade of W drop the course during the semester when they realize that they don't have any chance of passing the course. Figure 1 compares the weighted average grade distribution in the course taught by the same instructor between fall 1998 and fall 2004 with the grade distribution in spring 2009. The figure shows a sharp increase in the DFW rate. Figure 2 shows the grade distribution in the second exam given in the second course in thermodynamics in spring 2009 [3]. It displays a wide point spread among students, ranging from low 20s to scores as high as 100. Since the exams given in the course were very similar or sometimes exactly the same as the problems assigned as homework with small modifications, the students' grade distribution in Fig. 2, it suggested that a large number of students taking the course were either using the solution manual in completing their textbook homework problems, or were not doing their homework at all.

Table 1. Grade distribution comparison in the second course in thermodynamics taught by the same instructor in six separate semesters

Grade	Limited or no Student Access to Solution Manual					Large percentage of Students Using Solution Manual for Assignments
	Fall 1998 (N=38)	Fall 1999 (N=24)	Spring 2000 (N=35)	Fall 2000 (N =39)	Fall 2004 (N=40)	Spring 2009 (N=56)
A	17%	29%	17%	8%	28%	12%
B	31%	13%	20%	41%	35%	14%
C	26%	38%	31%	21%	15%	19%
D	17%	8%	6%	15%	15%	15%
F	9%	4%	11%	5%	0%	10%
W	0%	8%	14%	10%	8%	31%
DFW	26%	21%	31%	30%	23%	56%

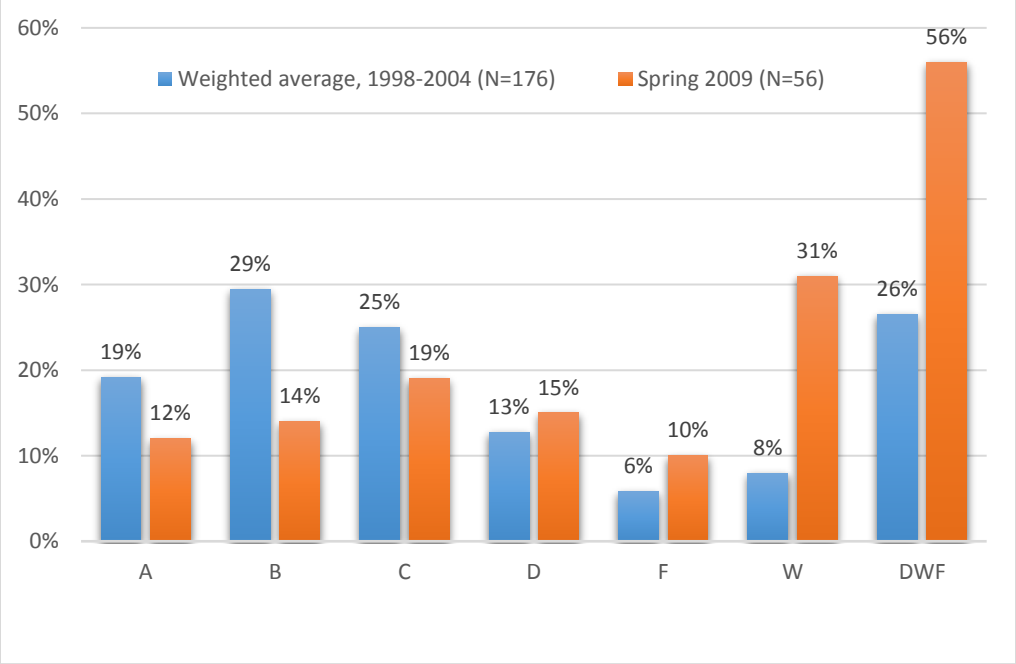


Fig 1. Grade distribution comparison in the second course in thermodynamics taught by the same instructor. For each grade the first bar represents the weighted averages for fall 1998 through fall 2004 and the second is for spring 2009.

Anonymous surveys were conducted in 2010 in three different thermodynamic classes to seek students' feedback regarding the availability and the use of solution manuals in engineering courses [3]. Table 2 presents the summary of the results for some of the questions asked in the surveys. Students were asked whether they agreed with the statements presented in the survey questionnaire. Numerical values were assigned to answers as: 5 = strongly agree, 4 = agree, 3= neutral, 2 = disagree, and 1= strongly disagree. The last column in Table 2 gives a weighted

average for the responses to each statement. It indicates the strength of student agreements with the statements. The number of respondents to each question is represented by the value of N in the table.

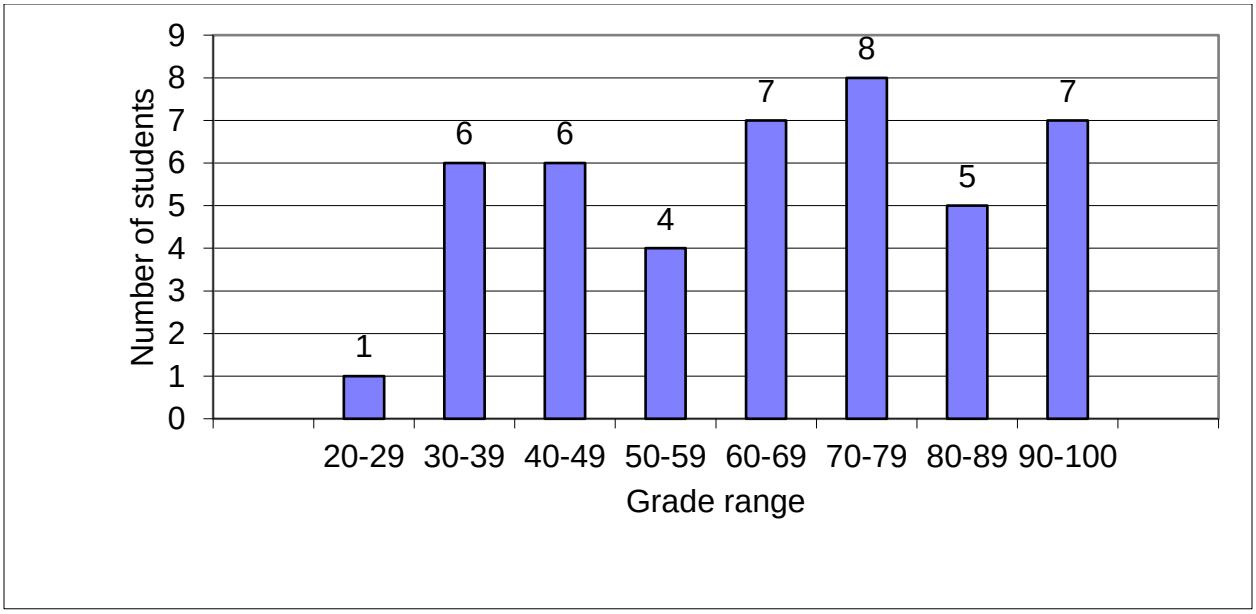


Fig. 2 Students' grade distribution for the second exam in Thermodynamics-II course offered in 2009 [3]

Even though it was suspected that a high percentage of students had been using solution manuals in their engineering courses, the numbers were much higher than what expected. The results were similar to those from two other earlier studies conducted on this subject by others [1, 2]. The survey results showed that that 75% of students agreed that solution manuals for most engineering textbooks were readily available to students. Even a higher percentage (92%) agreed that there were resources other than the solution manuals that provide solutions to engineering textbooks problems.

Even though 97% of respondents either agreed or strongly agreed that the main purpose of homework assignments is to give them an educational experience to solve problems independently, 60% of students indicated that they had either used or were planning to use the solution manual to do their homework assignments. Forty-one percent (41%) of respondents believed that using solution manuals in completing homework assignments has the same learning benefit as solving problems independently; 57% of students indicated that using solution manual while doing homework assignments provides the same educational experience as solving the examples in the textbook; and 95% indicated that solving homework problems is essential for learning the materials and succeeding in the courses they were enrolled in.

Table 2. 2010 anonymous course surveys conducted in three different thermodynamic classes: 5 = strongly agree, 4 = agree, 3= neutral, 2 = disagree, and 1= strongly disagree [3]

	Statement	5	4	3	2	1	Weighted Average
1	Copies of solution manuals for most engineering textbooks are readily available to students (N =180)	29%	46%	9%	6%	11 %	**3.76**
2	There are resources other than the solution manuals that provide solution to engineering textbooks problems (N =114)	40%	52%	7%	1%	0%	**4.32**
3	You have used solution manuals in other engineering courses (N =180)	33%	40%	15%	6%	6%	**3.88**
4	You have used or are planning to use solution manual to do your homework for this class (N =114)	11%	49%	20%	11%	9%	**3.42**
5	Access to the solution manual helps you learn the material (N =114)	44%	42%	11%	3%	0%	**4.28**
6	When solution manuals are available, it is difficult to avoid using them (N =114)	18%	21%	42%	15%	4%	**3.36**
7	Getting a high grade by any means is more important than learning the materials (N =114)	2%	6%	43%	42%	7%	**2.54**
8	Solved textbook example problems help you understand the material (N =180)	62%	29%	6%	3%	0%	**4.50**
9	The main purpose of homework assignments is to give you an educational experience to solve problems independently (N =114)	68%	29%	3%	0%	0%	**4.65**
10	Using solution manuals in completing homework assignments has the same learning benefit as solving problems independently(N =114)	8%	33%	28%	25%	6%	**3.11**
11	Using solution manual in completing homework assignments provides the same educational experience as solving the examples in the textbook (N =114)	20%	37%	24%	15%	5%	**3.52**
12	Solving homework problems is essential for learning the materials and succeeding in this course (N =114)	80%	15%	5%	0%	0%	**4.75**

The availability of solution manuals has caused a steady decline in students' ability to set up solutions to those problems when they have no access to the solution manual. To improve students' ability to solve engineering problems independently, the authors have attempted several schemes in teaching thermal science courses. These efforts included developing and assigning their own homework problems, increasing the frequency of quizzes and exams, using electronic response devices during the class periods, assigning group and individual projects, using the flipped classroom concept, and offering mandatory or voluntary recitation periods. The followings are brief descriptions of the teaching and learning schemes attempted; the advantages and disadvantages of each scheme; and the effectiveness of each scheme.

Increase in Frequency of Exams and Quizzes

Since there is a common knowledge among the engineering faculty that solution manuals are readily available for student use, many instructors have decided that to either not assign any homework problems from textbook, or to assign textbook homework problems but not collect them for grading. However, we have always been valued homework assignments as an important part of engineering education. Up to the early 2000s, the homework grades counted at least 20% of the final grade in most engineering courses and up to 40% is the second course in thermodynamics. The second course in thermodynamics covers the analysis of complex power, refrigeration, and heat pump cycles. Each thermodynamics cycle consists of several components such as multiple turbine stages, pumps, compressors, condensers, evaporators, closed and open feed-water heaters, reheat stages, and regeneration devices for energy recovery. To complete the analysis of a complex thermodynamics cycles, students must spend several hours of calculations that include the evaluation of thermodynamics properties at each state within the cycle. Therefore, the knowledge and the skills of students in analyzing the entire complex cycles cannot be assessed in a typical 50 minute exam.

To address the problem of student access to solution manuals and to be fair to those students who completed their homework assignment without using solution manuals, the weight of homework scores on the final grade was gradually reduced from 20% to 5%. At the same time, the frequency of exams and quizzes was increased. Since only a few points for the homework assignment contributed towards the final grade, some student did not attempt to solve any homework assignments. To encourage more students to complete their assignments, for several semesters penalties were imposed for not doing homework assignments. A policy was adopted that a grade of F was assigned if the total points earned for homework assignments fell below 30% of possible points, regardless of student performance in the exams. An automatic grade of D was assigned if the points earned for homework assignments fell between 30% and 40% of possible points and if the students were earning an equivalent grade of D or better in their exams [4]. The policy also rewarded students who completed their homework assignments and performed well in exams. For average exam grades above 70 points, the percentage of homework grades counted towards the final grades were doubled. This policy showed little or no improvement in student performance, or student behavior for using the solution manuals. Every semester more and more students were using solution manuals to complete their homework assignments. Even though the increase frequency of the exams forced student to study for the course on a more regular basis, it also reduced the lecture time available to cover the required course materials.

To reduce the pressure of using the solution manual in completing homework assignments, a revised policy was employed in spring 2010, giving no weight to the homework assignments unless students earned grades of 70% or higher on their exams. This resulted in a large number of students not attempting to solve or submit homework assignments, since solutions to assignments were being provided after assignments were collected.

Use of Electronic Homework Package

In the spring semester of 2010, Wiley-Plus [7] was employed for some of the homework assignment associated with the textbook used for the first course in thermodynamics. The Wiley-Plus is an online resource that allows students to complete their homework assignments online and be graded automatically. At the time, the problems were the same as those given in the textbook, except the different values were being assigned to each subscriber for some of the parameters given in the problem statement. The Wiley-Plus system grades the answers as soon as they are submitted online. The system provides several options for the grading process which can be set by the instructor. The instructor can set up the system such that students can submit their answers only once for credit or accept the correct answer after several attempts for full or partial credits. If students are allowed to provide a correct answer after more than one trial, the instructor can set up the system such that after the first trial with a wrong answer, students are provided with hints and references to appropriate sections of the textbook that can be accessed online. The flexibility of giving students several chances to find a correct answer is a very useful feature which provided an excellent learning tool for students. The instructor also had an option of hiding the problem number in the textbook, pretending that the problem was not coming from the textbook. We tried this feature, but it didn't take too long for students to figure out that the problems were from the textbook. Therefore, for those students who had access to the solution manual, there was no difference in the solution approach, except for plugging new numbers in equations given in the solution manual. In addition to entering the numerical values of answers to each part of problem on Wiley-Plus, students were also required to submit a hard copy of their solutions. Since Wiley-Plus did not include all problems in the textbook, additional problems were also assigned from the textbook which students were required to submit hard copies of the solutions.

Even though Wiley-Plus was a good learning tool, it did not reduce the number of students using the solution manual. In fact, the largest number of students were referred (approximately 10%) to the University's Office of Student Conducts for plagiarism. Most of the students charged with plagiarism were using solutions supplied by Cramster.com (it is now chegg.com) [8]. The number of students referred to the Office of Student Conducts represented only a small percentage of students who were using the solution manual in completing their homework assignment. They included only those who directly copied the solution manual. Others were making sufficient changes to the solution steps which made it more difficult to prove that they were using the solution manual.

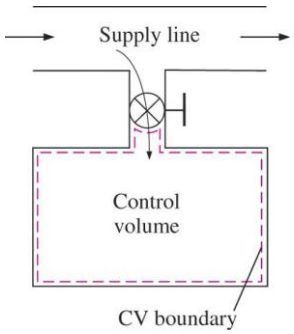
External Problems

In the fall semester of 2010 a new approach was adopted for assigning and grading homework problems in the second course in thermodynamics. Two different sets of homework problems were assigned. One set was assigned from the textbook which carried no weight on the final grade except for giving students an opportunity to earn bonus points based on their performance in each examination. For each exam grade, exceeding 70 points, up to 5 bonus points were awarded based on the number of textbook homework assignment attempted and completed. Students were advised at the beginning of the semester that solving textbook homework problems independently is an important part of the learning process and the reason for not

awarding any direct points to those problems was to reduce any pressure for using the solution manual or similar resources. The second set of homework assignments, called "external problems," was developed by the instructor and carried 10% of the final grade. This policy produced a much better result, as the class passing rate increased from 44% in spring 2009 to 71% in fall 2010. Also a much higher percentage of students received grades of A and B (53% in fall 2010 as compared to 29% in spring 2009). There was still a flaw with this policy as a number of students attempted very few problems assigned from the textbook. Of the 34 students enrolled in the course, one (3%) received a grade of F and 9 (26%) received a grade of W. On the average, these students received only 16% of possible points for external problems, ranging between 0% and 66%.

External problems were designed for two major purposes. The first was to force student to solve homework problems without the aid of solution manuals. The second was to reinforce fundamental concepts. For the external homework problems, students were required to start with the most fundamental equations and show all the steps in modifying them for specific applications. This requirement also applied to some of the problems given in quizzes and exams. For example, for the evaluation of power requirement of a compressor, students were required to start with the most general forms of equations for the mass balance, energy balance, and entropy balance, and simplify them as they were applied to a compressor. They had to include all the steps required to show whether the changes in entropy during the process were positive, negative or equal to zero. The following is an example of the statement for an external problem.

A rigid**,** insulated tank of volume 5 m^3 is connected through a valve to a steam line through which superheated water vapor flows at 4 MPa and 500 ^oC. The tank is initially contains water at 1 bar and a quality of x = 0.5. The valve is opened allowing steam to flow into the tank until the pressure inside the tank reaches 4 MPa.



a) Write down the most general form of **rate equations** for the conservation of mass, energy (first law), and second law for a control volume. Ignoring the kinetic and potential energy effects, simplify these equations for the control volume shown in the figure
b) Convert the rate equations written in part (a) into equations for a process taking place between the initial and the final states. You must show all steps involved in completing the conversion of rate equations into corresponding equations for the process.
c) Evaluate the initial and the final mass of water inside the tank, in kg.
d) Determine the amount of mass entering the tank, in kg, the final temperature, and the entropy generation, in kJ/K for this process

The anonymous course surveys conducted at the end of semester sought students' feedback regarding the homework assignments. The results of survey are summarized in Table 3. The results indicated that, in general. Students believed that the external problems had positive impact on their learning of the course material. Ninety five percent (95%) of students thought that the external problems prepared them for the exams and 82% believed that by the external problems requiring them to show step-by step solutions give them a better understanding of thermodynamics.

In the spring semester of 2011 the homework grading policy was modified again for the first course in thermodynamics. Again, two different sets of homework problems were assigned. One set was assigned from the textbook which carried a weight of 4% on the final grade and other set created by the instructor (external problems) carried 6% of the final grade. Since the textbook had excellent problems and students benefited greatly if they completed those problems independently, up to 5 bonus points (depending on the percentage of points received for the textbook homework assignments) were added to the semester score, if students received an average score of at least 70 in all exams given in the course. With this policy the student attempt in solving textbook problem was improved.

Table 3. Anonymous surveys conducted in the second course in thermodynamic in fall 2010: 5 = strongly agree, 4 = agree, 3= neutral, 2 = disagree, and 1= strongly disagree, N = 22 [3]

	Statement	**5**	**4**	**3**	**2**	**1**	**Weighted Average**
1	In this course it was important to do the textbook homework problems, even though it counted only when you passed the exam related to that homework set	59%	14%	27%	0%	0%	**4.3**
2	The main reason you did not submit too many textbook homework problems was because it counted only when you passed each exam	5%	18%	9%	32%	36%	**2.2**
3	You completed more external homework assignments because it counted as a part of grade with no conditions	36%	27%	0%	27%	9%	**3.6**
4	You completed more external homework assignments because each problem had 40 to 100 points assigned to it	14%	36%	9%	27%	14%	**3.1**
5	The external problems were challenging	41%	45%	14%	0%	0%	**4.3**
6	Completing external homework assignments prepared you for the exams	59%	36%	5%	0%	0%	**4.6**
7	By requiring you to write the most general fundamental equations (1^{st} law, 2^{nd} law, etc.) and simplifying them for specific applications, the external problems gave you a better understanding of thermodynamics	77%	5%	14%	5%	0%	**4.6**

Table 4 shows the results of a course survey conducted in the first course in thermodynamics in spring 2011. Similar to the earlier survey in fall 2010, students had positive feedback about the external problems. Ninety five percent (95%) of the respondent believed that the external problems were challenging; 90% indicated that the requirement of showing step by step solutions of external problems in detail helped them to get a better understanding of thermodynamics; and 84% of respondents indicated that the external problems prepared them for exams.

Since the assignment of external problems showed a positive effect on student learning in two different courses offered in fall 2010 and spring 2011, one of the authors decided to assign external problems in all courses that he was going to teach in the future. Surveys conducted periodically to learn about students' perception on the effectiveness of the external problems on the learning. In general, students have given positive feedback regarding external problem assignments. Most have believed the external problems have helped them to prepare for exams. However, respondents to the last survey conducted in two sections of the first course in thermodynamics offered in fall 2017 were not as positive about the external problems as those in earlier semester. Table 5 shows the results of survey regarding the homework assignments. Ninety nine students participated in the survey in fall 2017. More students thought that the textbook assignments helped them more with their performance in the exams, than the external problems. However, those students who attempted more than 60% of external problems, had a more positive view of external problem. It should be noted that that in fall 2017, much fewer students attempted to solve external problems as compared the homework problems assigned from the textbook. Also, the instructor decided not to post the solutions to external problems, but offered students to ask any questions they had about how to solve external problems, either in class or during the office hours. Even though the external problems have been very similar to the problems in the textbook, many students thought that they were much harder than those assigned from the textbook. One reason for such perception is that students do not have access to the solution of the external problem. In fact the external problems should be much easier, since the problem statement guides students through solving the problem step by step.

Table 4 Results of the survey conducted at the end of the spring semester 2011 regarding external problems. 5 = strongly agree, 4 = agree, 3= neutral, 2 = disagree, and 1= strongly disagree, N = 71 [4]

	Statement	**5**	**4**	**3**	**2**	**1**	**Weighted Average**
1	The external problems were challenging.	58%	37%	4%	1	0	4.5
2	By requiring you to write the most general fundamental equations (1st law, 2nd law, etc.) and simplifying them for specific applications, the external problems gave you a better understanding of thermodynamics	56%	34%	6%	3%	1%	4.4
3	Completing external homework assignments prepared you for the exams.	52%	32%	8%	4%	3%	4.3

Table 5. Results of the survey conducted at the end of the spring semester 2017 regarding homework assignments: 5 = strongly agree, 4 = agree, 3= neutral, 2 = disagree, and 1= strongly disagree, N = 99

	Statement	**5**	**4**	**3**	**2**	**1**	**Weighted Average**
1	Completing textbook assignments helped my performance in the exams	34%	38%	21%	5%	1%	4.0
2	Completing external problem assignments helped my performance in the exams	27%	22%	38%	9%	3%	3.6

Below are a list of some of the comments written in course surveys conducted since 2010

First course in thermodynamics, (Spring 2011):

- External problems are an excellent idea since there is no solution available to the problems. The only drawback with external problems is that, from what I hear, students pass down old copies of old test and old homework assignments to the upcoming students upon request. If you have the time and energy to create new external problems every semester, this would be the best way to see which students are actually learning the material.
- I am sure you were able to see that some students get 100/100 on textbook homework assignments and a poor score on your external problems. It was also a great idea to not have the textbook homework count as a grade. This will ensure that the assignments are for the students learning benefit only and it would be pointless to copy the solution manual. This semester's method of grading was the best thus far.
- Writing the first law and second law really helped me learn the material. I got a C in thermodynamics I and being getting decent grades probably due to the fact of writing the first law and second law every time. Make sure you emphasize this still.
- I am glad that you require us to write the general fundamental equations and then simplify based on the specific problem. Other students who have taken thermodynamics were not required to do this and they have a much harder time working problems than we do. They were taught that specific equations apply to specific examples, whereas we were taught to start with the most basic, and then eliminate variables that we didn't need. I know a lot of students complained about this but it really was for our own good.
- I do feel that writing out the 1^{st} and 2^{nd} laws was helpful but it was also a big part of what made test taking such a lengthy process.

Graduate course in Advanced Thermodynamics (Spring 2016)

- Your external problems are wonderful. Please give more external.
- Problems in the external sections were very good.

First course in thermodynamics (Fall 2017)

- Agree with use of external problems, however should have the same weight as textbook problems
- External problems are confusing
- The external problem solutions should be posted.

Project Assignments

Thermodynamics problems involving cycles with numerous states and components are especially difficult for students to master as well as for instructors to assess student mastery of the material. It is common practice to assign homework problems which take the average student several hours to complete. An example is a vapor power cycle with multiple turbine stages, reheats, pumps, and feed-water-heaters. For a 50 or 75 minute exam, it is especially challenging to test student knowledge concerning cycles. When grading homework, it was common to find correct solutions to complex cycles and then observe incoherent exam results for the same student.

Anonymous student feedback collected at the end of the semester increasingly complained that the exams were too long and impossible to complete in the allotted class meeting time. Exam problems were often abbreviated and the majority of the cycle state properties provided. Students were only asked to calculate selected state properties and evaluate component energy transfers using the properties provided or calculated. Many students succeeded in these exams since they knew how to perform the calculations. Yet increasingly more students could not perform the calculations and consequently earned low grades. Therefore, the instructor began giving project assignments instead of homework and exams. At first, the project assignments were presented as a continuation of the in-class exam, where at the end of the exam a take-home portion was handed out and due on the next class meeting. The projects were individual effort, yet could be team effort depending on the instructor. The project assignments are increasingly being used to replace both homework (as a percentage of the final course grade) and in class exams. Some might describe the assignments as take-home exams which are at the same level as challenging homework problems.

Student feedback has been positive, with a few examples provided:

- "I recommend since the course is not easy to add couple more design projects and minimize the percentage of midterms. In my opinion, the exams is not the perfect way to diagnose the student knowledge of the course, because some student like me has anxiety …"

Since enrollments are high, many required classes have two or more sections per semester. For a number of reasons, it is impossible to have common exams in the evenings or on Saturdays. Student feedback has been increasingly directed at the difference in exams given to different sections, such as:

- "There were inconsistencies in the difficulties of exams between class periods. It may have been just bad luck that the afternoon class received difficult tests but it is evident that their exams were more difficult in the statistics of exam grades."

The instructor has increasingly adopting project assignments. The effort to create one assignment is more substantial since they are developed using unique values for each student. This is similar to electronic homework packages where each student is provided different input values. For longer problems, it is more challenging to randomize input yet check that the problem is solvable and has no inconsistencies. An example for a cycle is provided below:

Water is the working fluid in a vapor power cycle that generates $\dot{W}$= _____ MW net power. Steam enters the first turbine stage of a vapor power cycle with reheat and regeneration at P_1=_____ MPa, T_1 =_____ °C, and expands to P_{cfwh1} =_____ MPa. A portion of the flow is diverted to a closed feed-water heater operating at P_{cfwh1} =_____ MPa, and the remainder is reheated to T_{rh} =_____ °C before entering the second turbine stage. Expansion through the second turbine stage occurs to the second closed feed water pressure at P_{cfwh2} =_____ MPa, where another portion of the flow is diverted to a second closed feed-water heater at P_{cfwh2} =_____ MPa. The remainder of the flow expands through the third turbine stage to open feed-water heater pressure at P_{ofwh} =_____ MPa, where a portion of the flow is diverted to an open

feed-water heater operating at $\mathbf{P_{ofwh}}$ =_____ MPa, and the rest expands through the fourth turbine stage to the condenser pressure of $\mathbf{P_{cond}}$ = _____ kPa. Condensate leaves each closed feed-water heater as saturated liquid at the respective extraction pressure. The feed-water streams leave each closed feed-water heater at a temperature equal to the saturation temperature at the respective extraction pressure. The condensate streams from the closed feed-water heaters each pass through traps into the next lower-pressure feed-water heater. Saturated liquid exiting the open heater is pumped to the steam generator pressure. If each turbine stage has an isentropic efficiency of turbine η_t =_____ %, and the pumps operate isentropically.

A table of unique values for each student was provided for the information left blank in the problem statement. The given properties for the problem were identified for each student through students ID.

Unique values for problem

Student ID	$\dot{W}$ **MW**	P_1, **MPa**	T_1, **°C**	P_{cfwh1}, **MPa**	T_{rh}, **°C**	P_{cfwh2}, **MPa**	P_{ofwh}, **MPa**	P_{cond}, **kPa**	η_t
Abc111	400	24	700	8	560	2	0.3	6	75%
Abc112	300	24	700	8	560	1.5	0.1	8	87%
Abc 113	525	20	600	4	540	1	0.1	10	80%
Abc 114	600	28	740	4	600	1	0.3	10	87%

The above problem is modeled from a textbook problem and a similar example problem was already solved during lecture.

Student feedback has been positive since the time allowed to solve the problem has been increased to one week, instead of being due the next class period. The project assignments typically have 2 to 4 problems which will require the average student about 8 hours to complete. Those students who haven't been solving the assigned homework problems will probably require more time. The goal is to give these assignments more frequently throughout the semester. There have been 5 to 6 assignments in recent semesters. The same assignment is given to multiple sections and there is no need for make-up exams due to sickness. Sick students can be given extra time without having to construct a new exam. The instructors still requires a comprehensive final exam, but it is more focused since cycles have been tested in the project assignments. Overall, there has not been a significant change in course pass rates, but this has resulted in more positive student feedback with less concern about students copying solutions for textbook problems.

Flipped Classroom Experiment

Wikipedia describes flipped classroom as "an instructional concept that reverses the traditional method of teaching by providing instructional content in advance outside of the classroom and bringing some of the outside activities such as homework into the classroom. In a flipped classroom, students may be required to read the textbook material or watch lectures online before each class period. In turn students spend some of the classroom time to solve problems, engage in classroom discussion under the guidance of the instructor, or answer quiz questions." [9] The flipped classroom concept was experimented in two sections of the first course in

thermodynamics offered in fall 2017 [10]. Both sections were taught by the same instructor. The enrollment included 70 students in the first section and 60 students in the second section. Initially, students were given reading assignment from the course textbook [11] before attending each lecture period. Students were encouraged to use other learning resources available to them. The available resources included the textbook's Student Companion site [12] and the lectures recorded on YouTube by one of the authors when he taught the course in previous semesters [13, 14]. Student feedback on recorded lectures continues to be overwhelmingly positive as it allows students to review, pause and replay sections of lectures. Students are encouraged to not remain passive while reviewing lectures but to become more active in completing the steps required to solve problems, especially if data is to be retrieved from tables in the back of the textbook. The textbook companion site provides such learning resources as lecture power point presentations, animation of thermodynamics systems and processes, tutorial for using steam tables for the evaluation of thermodynamics properties, and the Interactive Thermodynamics (IT) software program that can be used for property evaluation and solving complex problems.

Electronic respond devices such as I>Clickers are very useful in taking attendance, give short quizzes, or use as a student learning resource tool, especially in classes with large enrollment [15]. In fall 2017, I>Clickers were used in the first course in thermodynamics to gauge students understanding of assigned reading material and engage them to participate in the classroom activities. During lectures, the instructor asked students questions related to the topics that was being discussed and students registered their responses through I>clicker devices. The instructor would explain the topics in more detail when students had difficulties with the specific areas of questions asked during the class. A quiz was given at a later date to see if the students' understanding of the materials had improved.

The Power Point presentations of lectures included some of the slides provided by the publisher, as well as additional slides prepared by the instructor. They included basic definitions of thermodynamics systems, some of diagrams from the textbook, results of equations derived during the lectures, and solutions to the example problems solved during the lectures. The presentation did not include the detailed steps used in deriving formulas during the lectures. The presentations posted in advance included the problem statements for the examples used during the lectures, but did not include the solution to the example problems. The presentations were updated with the solutions after students helped solving the example problems during the lecture. The presentations of lectures were updated with the solution of example problems and posted on Blackboard.

A survey was conducted near the end of semester to seek student feedback on their experience with the flipped classroom concept. A total of 99 students enrolled in two sections of the course participated in the survey. In the first part of the survey, students were asked to identify the percentages of time that they had completed the reading assignments or reviewed the lectures prior to the time that the material were discussed in class. Students were given the following choices as: 80-100%, 60-79%, 40-59%, 20-39%, and less than 20% of the time. The results of the answers are presented in Fig. 3. As shown in the figure, less than 25% of students completed more than 60% of reading assignments and less than 55% of students viewed more than 40% of the power point presentations posted on blackboard before the topics were presented and discussed in class.

Through a number of statements, the survey questionnaire also sought students opinion regarding the effectiveness of the reading assignments, presentations, and the use of I>Clickers as a learning tool. Students were asked to use the following scales to rank their agreements with each statement in the survey: (5) = Strongly agree, (4) = Agree, (3) = Neutral, (2) Disagree, and (1) Strongly disagree. The results of student rankings for each statement are summarized in Table 6. Some of the survey questions had been asked in a survey questionnaire conducted earlier in a heat transfer course in fall 2016 [14]. For comparison, the results of the earlier survey are also presented in Table 6.

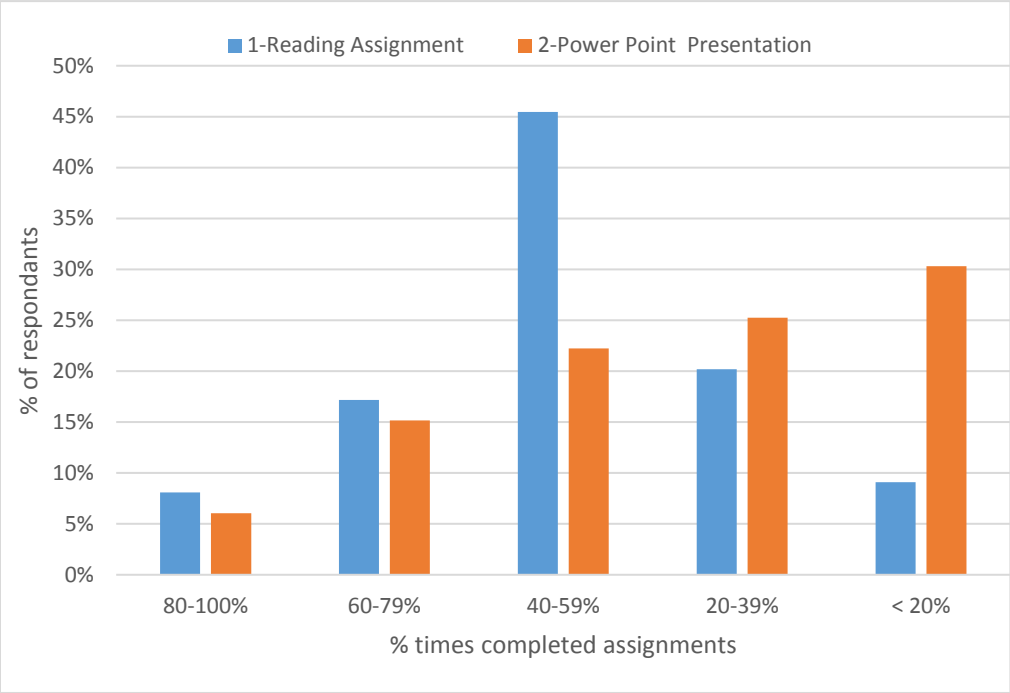


Fig. 3. Percentage of times the reading assignments completed and power point presentations reviewed: 1-Reading assignments, 2-Power Point presentations

Almost in all areas, students participating in the fall 2016 survey had a more positive view of using the I>clickers than those participated in the fall 2017 The following factors might have contributed to the differences in students' point of view. For the first time in fall 2017, students had to register their I>Clicker devices through I>Clicker Cloud (www.Iclicker.com), instead of the "Blackboard Learn" as it was done in the past. This created some confusion and delays at the beginning of the semester. The heat transfer course in 2016 had much lower enrollment than the sections of thermodynamics course offered in fall 2017. In smaller class setting, more students have the opportunity of participating in the class discussions than those in the courses with larger enrollments. Students in the heat transfer course were more advanced in their academic educations than those in the introductory thermodynamic courses. Students in heat transfer had already completed courses in Thermodynamics-I and Fluid Mechanics, and some had completed

Thermodynamics-II. Many of students in heat transfer course had already taken a course from the instructor, while none students in the fall 2017 class had taken any courses from the instructor before. Student academic performance in the course may also influence their responses to the survey questions. The heat transfer course had a much higher passing rate than each section of the thermodynamics course.

Table 6. Summary of student responses to the level of their agreements with the statements in the survey questionnaire: 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree

	Statement	Fall 2017 Survey							2016 Survey	
		5	4	3	2	1	N	Ave	N	Ave
1	Reading assignments in advanced helped my understanding of course material	15	34	30	16	4	99	3.4	-	--
2	Review of power point presentations in advance helped my understanding of course material	7	19	36	28	9	99	2.9	-	-
3	I>Clicker is a good tool to assess student knowledge	21	31	22	14	11	99	3.4	27	3.8
4	Use of I>Clickers helped me be alert in the class	19	35	19	16	10	99	3.4	27	4.1
5	Use of I>Clickers helped me to participate in the class activities	23	36	21	14	5	99	3.6	27	4.1
6	Use of I>Clickers helped me to find out immediately if my answers were correct	45	30	12	5	6	98	4.1	27	4.0
7	Use of I>Clickers in this course helped me to learn new concepts	9	18	35	21	16	99	2.8	27	3.6
8	Use of I>Clickers in this course helped me to attend class on regular basis	25	23	24	15	12	99	3.3	27	3.6
9	Results of I>Clicker quizzes should be used as a part of semester grade	9	15	27	23	25	99	2.6	-	-
10	Continue using I>Clicker in the courses as a part of the teaching/ learning process without using the results for contribution towards the final grade	21	31	22	14	11	99	3.4	27	3.7
11	Continue using I>Clicker in the courses for short quizzes	19	35	19	16	10	99	3.4	27	3.7

The results in Table 6 indicate that more students agreed that the reading assignments helped them more to understand the course material than reviewing the power point presentations posted in advance. It should be noted that more students also completed the reading assignments than viewing the power point presentation of lectures. The majority of students had the opinion that results of I>clicker quizzes should not be used as a part of the semester grade.

The flipped classroom experiment was not as successful as was originally hoped. The success of the concept depends on the students' willingness to participate in the experiment. This requires that students to complete the assigned task before attending class. In our experiment, a large number of students did not complete the reading assignments or view the presentation of lecture slides in advance. Therefore a good percentage of time was used by the instructor to review the course materials, before students being ready for solving problems in class.

Supplemental Recitation Sessions:

In 1998 a survey was conducted [16] to determine student opinion on the effectiveness of the existing foundation course work in the engineering curriculum. A total of 114 UTSA students participated in this survey. The majority (110) were upper division (91) or graduate students (19). In responding to the statement for the identification of major factors influencing the learning process in the engineering foundation course work, students selected the following choices: "good teachers (94%), "good textbook" (78%), problem solving sessions (70%), "small class size" (65%), and "student interest" (63%).

In 1999 a number of engineering foundation courses in which students had more difficulty were identified. The general engineering courses included Statics and Engineering Analysis courses (applied mathematics). Three introductory mechanical engineering courses were also among the identified courses in which students often struggle to pass. They were: Kinematics and Dynamics, Thermodynamics I, and Solid Mechanics. These are foundation courses in the mechanical engineering curriculum and strong preparation in these courses is essential for student success in the upper level courses.

It was decided that an efficient way to improve student success was to provide additional academic support systems which included adding mandatory recitation hours to those foundation courses having high failure rates. One hour recitation was added to each course although the number of semester credit hours didn't change. The recitation sessions were planned for a small classroom setting to help students learn problem-solving techniques and encourage cooperative learning. Several recitation sessions were offered for each course and the enrollment for each recitation section was limited to 20 students. No new materials were covered in the recitation periods. Instructors or teaching assistants used these periods to answer questions, solve example problems, and involve students in cooperative learning. For courses requiring mandatory recitation hours, students had to register for one hour of scheduled recitation session. Attendance to recitation sessions was encouraged and some faculty made it a course requirement by assigning grade points to the recitation attendance.

The experimentation with the mandatory recitation session in the first course in thermodynamics started in fall 2000 and continued until summer 2006. Figure 4 provides a comparison of grade distributions for periods prior to the requirement of mandatory recitation sessions with those during the implementation of mandatory recitation sessions. Only those sections of the first course in thermodynamics taught by the authors are included in the figure for the following reasons. The DFW rates for the sections taught by theses instructors were very similar. In additions, these two instructors were the only two who taught the course prior to and during the implementation of mandatory recitation sessions.

The data in Fig. 4 shows an improvement in student passing rate during the fall 2000 through summer 2006 period suggesting that the mandatory recitation had positive influence on student success. Figure 4 shows a 7 % increase in passing rate when the mandatory recitation session was in effect. The table shows that the major change was the increase in the percentage of grade C (from 21% to 29%).

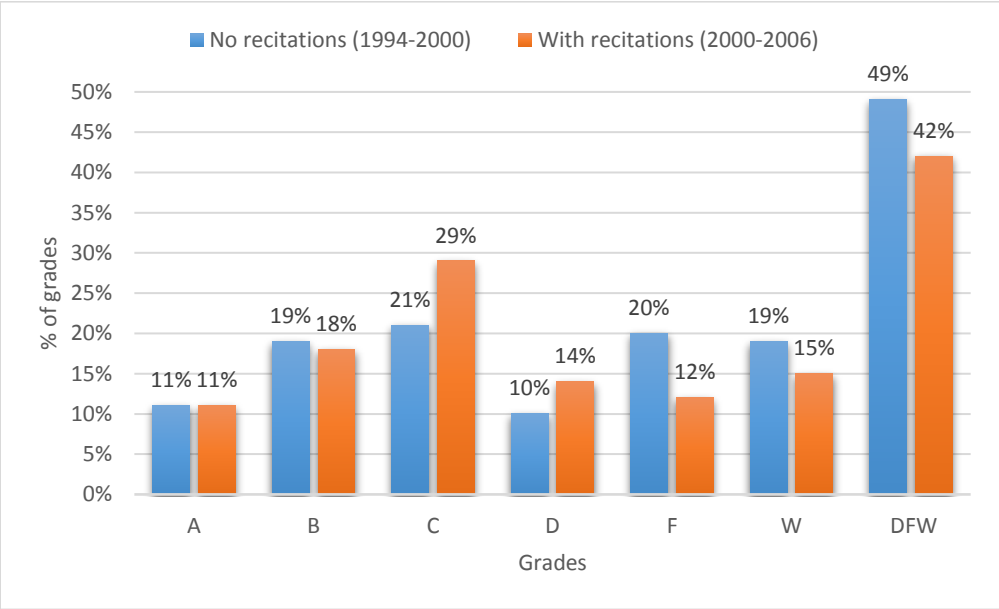


Fig. 4. Grade distribution for the first course in thermodynamics: no recitation (Fall 1994 through Summer 2000), with recitation (fall 2007-summer 2006)

As the enrollment in the program increased, it became increasingly more difficult to schedule recitation hours that did not conflict with other courses students needed to take during a given semester. As a result, the faculty decided to drop the mandatory recitation sessions. Instead, it was left to the faculty to offer voluntary recitation sessions. The mandatory recitation sessions were not offered after summer semester 2006. Some faculty members have decided to continue offering one or two recitation hours per week. The shortcomings of voluntary recitation are that it is difficult to schedule recitation sessions accommodating all students enrolled in the course; it cannot be included as a course requirement; and weaker students who potentially would benefit from the recitation sessions typically do not attend.

Summary

- To improve students' ability to solve engineering problems independently, several schemes were attempted when teaching thermal science courses. These efforts included:
  - developing and assigning their own homework problems
  - increasing the frequency of quizzes and exams
  - use of electronic homework packages

- external problems
- employing classroom electronic response devices
- assigning group and individual projects
- using the flipped classroom concept
- offering mandatory recitation periods.

The effectiveness, advantages and disadvantages of each method was discussed. Table 7 summarizes the advantages and shortcomings of each method discussed. The most effective scheme has been unique homework problems assigned by the instructor, yet this requires more effort from the instructor compared to assigning problems from the textbook. The second most effective scheme appears to be increasing the frequency of quizzes and exams. In both cases, students had to develop problem solving skills in order to do well in the course.

Table 7. Summary of advantages and shortcomings of each method discussed

Method	Advantages of Benefits	Shortcomings or Limitations
Increase in frequency of exams and quizzes	Forces students to study on a more regular basis	Reduces the lecture time for covering the course materials
Use of electronic homework packages	Assignments are graded automatically and student can see the results immediately. If it is set-up for multiple attempts for correct answers, it gives students a chance to review the material again and solve the problem again, if their initials answers were wrong.	Additional cost for subscription. Most problems are the same as those in the textbook; therefore, students who have a copy of the solution manual can just insert values in the equations used in the solution manual. Also, not very user friendly for problems that require derivation of formulas.
External problems	Forces students to solve problems on their own, since there is no solution is available in advance.	Requires extra effort by the instructor to develop new problems every semester and create solution to each problem. There are students who do not attempt solving these problems
Project assignments	Uses the same concept as electronic homework packages Useful for replacing complex exam problems that require extensive time for their solution.	Requires extra effort by the instructor to develop new problems, test the problem for parameters assigned to each student. Integrity of exams cannot be validated, since projects are done outside of the class regular time.
Flipped classroom concept	Effective only if students complete the assigned tasks prior to attending the lecture period.	In our experiment, a large number of students attended the lecture unprepared.
Supplemental Recitation Sessions	Effective, if the sessions are organized in small class sizes and conducted either by the course instructor or a teaching assistant who knows the course content very well. Can be utilized as a flipped classroom concept.	Require additional resources that includes extra cost to department, scheduling sufficient number of sections that do not conflict with scheduling other require courses, and availability of classrooms.

References

1. Shollenberger, K., & Widmann, J. (2006, June), "Student Use Of Textbook Solution Manuals: Student And Faculty Perspectives In A Large Mechanical Engineering Department," *Proceedings of 2006 ASEE Annual Conference & Exposition, Chicago, Illinois*.
2. Widmann, J., & Shollenberger, K., & Kennedy, J. (2007, June), *Student Use Of Author's Textbook Solution Manuals: Effect On Student Learning Of Mechanics Fundamentals*, Proceedings of 2007 ASEE Annual Conference & Exposition, Honolulu, Hawaii.
3. Karimi, A. and Manteufel, R., (2011, June), "Does Student Access to Solution Manual Pose a Challenge?*" ASEE-2011-2753, Proceedings of the 2011 ASEE Annual Conference*, Vancouver BC, Canada.
4. Karimi, A. and Manteufel, R., (2012, June), "Assessment of Student Learning Outcome in an Introductory Thermodynamics course.*" ASEE-2012-5503, Proceedings of the 2012 ASEE Annual Conference*, San Antonio, Texas.
5. Gehringer, E. F., & Peddycord, B. W. (2013, June), *Teaching Strategies When Students Have Access to Solution Manuals* Proceedings of 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia.
6. Habibi, M., & Roti Roti, A. S., & Alaei, M. (2015, June), *Are Solution Manuals Detrimental to Student Learning?* Proceedings of 2015 ASEE Annual Conference & Exposition, Seattle, Washington.
7. https://www.wileyplus.com/
8. https://www.chegg.com
9. https://en.wikipedia.org/wiki/Flipped_classroom
10. Karimi A. and Manteufel. R., (2018, April), "An Experiment with Flipped Classroom Concept in a Thermodynamics Course," *Proceedings of the 2018- ASEE-GSW Section Annual Conference*, , Austin, TX.
11. Moran M.J., Shapiro, H.N., Boettner, D.D, and Bailey, M.B., *Fundamentals of Engineering Thermodynamics, 8th Edition*, John Wiley and Sons, Inc., New York, 2014.
12. http://bcs.wiley.com/he-bcs/Books?action=index&itemId=1118412931&bcsId=8892
13. Manteufel, Randall D, 2018, "Home Randall Manteufel", https://www.youtube.com/channel/UC56czEa9fgGKCHV-Lz-RZUQ.
14. Manteufel, Randall D, 2016,"ME 3293 Thermodynamics Summer 2016," https://www.youtube.com/playlist?list=PL_ZIJMd-rNhU06ftounT8CVKy6gZ2uxg4.
15. Karimi A. and Manteufel. R.,(2017, June), "Use of Adaptive Questions and Electronic Pooling to Promote Mastery of Fundamental Thermal Science Concepts," *Proceedings of the 2017- ASEE Annual Conference and Exposition*, Columbus, OH.
16. Karimi, A., (2002,June), "Does Problem Solving Recitation Session Improve Student Retention and Success?," *ASEE 2002-2793*, Proceedings of the 2002 ASEE Annual Conference, Montréal, Quebec Canada.