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The Impact of Cambridge Supervisions on Student Performance in a Dynamics Course

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Abstract

One of the most effective methods for teaching nearly any engineering course is to have students apply their knowledge to solve problems. Engineering instructors encourage students to spend more time solving problems (time-on-task) through grade based incentives. While a variety of techniques for assigning points to student efforts have been employed, traditionally the number of points a student receives is primarily based on the "correctness" of their solutions. There are a variety of problems with simply collecting and grading student homework including the time students wait for feedback, the limited amount of feedback provided on assignments (typically a few short written comments), and the inability to discuss the feedback provided. In this work we present an alternative to traditional grading motivated by cognitive research on student learning from feedback. The results of a pilot study of this method indicates that the new method has the potential to increase student persistence and improve student obtainment of learning objectives.

Introduction

Many engineering educators believe that time-on-task (practice) is important for obtainment of learning objectives by students. This is evidenced by the focus on problem based learning[1]. It is common for instructors to encourage students to solve engineering problems outside of the classroom by rewarding them for their efforts. Traditionally, the instructor assigns a set of problems and asks students to turn in their solutions. The instructor or a grader will evaluate all or a random selection of problems and assign the solutions points based on their correctness[2]. While there has been research on adjusting a student's score based on their teamwork skills, it is usually a small portion of their grade[3].

The traditional method of handing in homework to be graded is not unlike the cruel tutelage of Pai Mei in the movie "Kill Bill". The character Pai Mei hits his student each time she makes a mistake and provides little, if any, corrective feedback. Similarly, the method most commonly used by engineering educators to teach students using problem sets involves deducting points from a student's grade for making a mistake and providing a brief, often ambiguous comment about the mistake. This seems ridiculous in the movie and should be just as ridiculous in education. Research shows that constantly providing feedback in the form of low grades is discouraging and can result in students investing less time in learning[4]. Evidence collected by the author indicates that many students use a crutch, such as a solution manual or another student's solution, to ensure they get the correct answers. Such crutches allow students to find the correct solution without understanding the reasoning behind each step. Moreover, the brief and ambiguous comments provided on the graded assignments can be difficult to understand if they are even read by the student[5,6].

The objective of this work is to present a new method for giving students feedback on problem sets that increases student persistence, helps students obtain course learning objectives, and encourages a deeper understanding of the material by reducing student use of crutches. This new method is based on the supervisions, sometimes referred to as tutorials, used at Cambridge and Oxford Universities[7]. These institutions assign problem sets to students, but do not grade them. Rather students complete the problem sets to prepare for a supervision where they present their solutions. Students that fully participate in the supervisions receive full credit for the problem sets even if there are errors in their solution. This allows mistakes made by the students to become learning opportunities that do not cost them their grade. The decision to adopt supervisions was motivated by cognitive research conducted into how feedback can be used to enhance student learning. This research finds that process feedback is most beneficial to student learning. Specifically, when the feedback is given in the form of cues which direct students in the correct direction[6,8]. Moreover, research also indicates that this type of feedback is best when decoupled from feedback on self, in this course grades[4,6].

The supervisions were piloted in a dynamics course during the spring of 2014. The course was selected because it has had a relatively high number of students that fail to complete the course with a C or better, a requirement to avoid retaking the course. The impact of the supervisions was measured through the use of final course grades, student performance on summative assessments, and surveys. The results show that supervisions positively impacted student success and persistence, but there is some concern with its effects on student self-efficacy. In addition, it was found that supervisions did not affect student use of crutches.

Supervisions

Cambridge and Oxford Universities both assign problems to students that become the focus of small group discussions called supervisions. The discussions are facilitated by a supervisor. Typically, the supervisor a graduate student, post-doctoral researcher, or professor (reader, lecturer, or professor). While the exact format of the discussion varies by discipline, in engineering it is common to have students present their work to the group. The supervisor uses inquiry to highlight important concepts and help students identify errors in their solutions. Students are expected to complete the problem sets prior to the supervision and participate in the discussion. Failure to do so is reported to their college. A more detailed description of supervisions, also referred to as tutorials, is provided in Ashwin, 2004[7].

The supervisions used in this study are based on those described above. In this study, the supervisions involved 3-4 students meeting with a supervisor to discuss a set of assigned problems. The supervisors consisted of a diverse set of junior and senior engineering students that received a B or better in dynamics. At the beginning of the meeting the supervisor would look over each student's homework to ensure they attempted all the problems. Then each student was asked to present a portion of their problem set. The problems selected by the supervisors for students to present were those that required the application of important and difficult concepts covered in the course.

Each student in the group would be asked to present a portion of their solution using a whiteboard. The portion assigned was selected so that the presentation would require about ten minutes. Students were allowed to use their notes, but expected to explain each step and the reason that the step was taken. The supervisor would ask the students questions to ensure that the others in the group understood important points and common misconceptions. When an error occurred, the supervisor would make it a learning opportunity by starting a group discussion on the step in question. The supervisor might ask another student in the group, "Is that what you got

Sally?". This would start a discussion on the error. Eventually, in almost all cases, the students in the group would come to a consensus and correct the error. In the rare cases where the group failed to correct the error, the supervisor would use inquiry to direct the group to the correct next step in the solution.

The inspection of the homework and presentations typically consumed about 40-45 minutes of the one hour supervision. The remaining time was allocated to answering student questions about the problem set. Often students would ask for the group to go over a problem that confused them or one where they were not confident in their solution. The interesting thing was that the supervisors reported students usually came to consensus on how the extra time should be used immediately.

Session Grading

After the session was completed the mentors filled out a grading sheet. Students could receive up to twenty points for a supervision. Ten of the points were for attendance and participation, the remaining points were for completing the homework and presenting a portion of the solution. Initially, the grading sheet contained three blanks. One for the student's name, another for the score, and the last for comments explaining why students received less than the full twenty points. This was quickly found to be inadequate because students did not feel the supervisors were grading uniformly.

Name	Prep.	Part.	Name	Prep.	Part.
Comments:			Comments:		
Name	Prep.	Part.	Name	Prep.	Part.
Comments:			Comments:		

Figure 1: The grading sheet used by the supervisors. The supervisor would place the preparation score in the box below "Prep." and the participation score below "Part.". Supervisors used the comment block to explain the reasoning behind the score given or to praise a student's effort when they were particularly helpful in explaining things to others in the group.

The new grading sheet shown in Fig. 1 was created to help address this issue. This grading sheet came with additional training for the supervisors. During these training sessions a rubric was established for grading students. Ten points would be assigned to participation and the remaining points would be given for preparation. The participation points were further broke down with five points being given for attendance and the remaining five for making constructive remarks during the discussion. In addition, the preparation points were also broken down so that students received five points for having attempted all the problem before arriving and five points for the presentation of their solution.

Group Formation

One of the most important pieces to making supervisions work was the grouping of students. The supervisions take place outside of class time. So students must be grouped in such a way that each group has common open times in their schedule when they are willing to meet. In addition, the author also wanted to make sure that students from underrepresented groups and women where not outnumbered in any supervisions[9]. Research indicates that this helps such students feel less isolated and encourages participation[10]. To accomplish this, the TeamMaker software provided at www.catme.org was used[11]. The software has each student fill out a survey asking them for demographic information and their schedule. Then it groups them based on the responses to the survey.

Supervisors

The supervisors were junior and senior engineering students. To be a mentor, the student had to have received a B or better in dynamics. Students from underrepresented groups and women were encouraged to apply. Three supervisors were hired. One of the students identified as coming from an underrepresented group in engineering. Each supervisor had three to four groups to meet with on a weekly basis. Groups that contained students from underrepresented groups were paired with a similar supervisor when possible. This decision was based on research with peer mentoring programs which indicated that such peers became role models to the students and aided in persistence[9,12].

Prior to meeting with the students, supervisors attended a training session. The training session began with an explanation of the program. During this explanation the instructor emphasized that the supervisions were intended to be a positive learning experience for the students. Mistakes should be used to help teach students and should not be penalized. In addition, the training session also provided the supervisors with information on common learning problems they may observe and resources on campus for student with learning problems. This was followed with instruction on how the mentoring sessions should be conducted. Special focus was given to the proper way to use inquiry to help students identify problems with their solution. This training session was followed by a short weekly meeting with the instructor to discuss any issues that occurred during the prior week.

Method

The study includes three sections of the dynamics class taught in the spring semester of 2014. Each section was assigned the same problems from the book. In two of the sections the homework problems were graded for correctness in the traditional manner using undergraduate graders. The total number of students in the two sections was 59. In the third section, supervisions were used in place of grading. There were 36 students in the section that used supervisions.

The students in traditional and modified sections were similar. The students in the modified section had been in school, on average, one semester less than those in the traditional sections. Most of the students in both the traditional and modified sections were mechanical engineering students with the second largest group being petroleum engineers. There was also a small number of civil engineering students.

To measure the ability of supervisions to meet the stated objectives—increased persistence, improved student learning, and reduction in the use of crutches—two sets of data were collected. The first set of data collected was student performance on summative assessments (exams) and final course grades to help in measuring persistence and student obtainment of learning objectives. To make the data collected more meaningful, the same exams were used in each section. In addition, surveys (See Appendix A for copies of the instruments) were given to students after they completed their final. The surveys asked students to indicate their expected final course grade and their confidence level in using the concepts in dynamics to solve engineering problems. This was used as another measure of student obtainment of learning objectives. In addition, the surveys were used to measure crutch use by students on the homework. The survey asked students to indicate what percentage of the homework problems that they used either a solution manual or another student's solution to help them solve the problem.

Results

One of the objectives of this work was to improve student learning through feedback. One method to gage student learning was student obtainment of the learning objectives. The data on this is provided in Table 1. In this table students were divided into three categories. The first, successful, represents those students that received a C or better in the course. Students that do not receive a C must retake the course. The second group, completed unsuccessfully, represents the group of students that completed the course, but did not receive a C or better. The last group of students represents those that did not complete the course. These are the students that did not take the final for whatever reason.

Table 1: Summary of Student Success.

	Traditional		Supervisions	
	# of Students	Percentage	# of Students	Percentage
Successful	41	69%	33	92%
Completed Unsuccessfully	10	17%	2	6%
Did Not Complete	8	14%	1	3%

There are several interesting findings in these numbers. First, the number of students that withdrew was exceptionally high in the class that used traditional homework. It indicates that the supervisions were helpful in increasing student persistence. While no follow-up was done with the students that did not complete the class, the numbers agree with past research that feedback on self can discourage students and result in them disengaging. In addition, the number of students that failed in sections that used traditional homework was nearly triple that of the one that used supervisions.

The traditional and supervision versions of the course both relied on exams for summative assessment of student obtainment of learning objects. There were four exams given in each section of the course—three one hour exams and one two hour final exam. The exams used in each section were identical. In addition, the students in the section of the course that utilized supervisions took the exams prior to those in the traditional section so any communication of exam content between sections would positively impact the score in the traditional sections. There were 35 students in the supervision section that took each exam. The number of students in the traditional sections did decrease over the semester with 51 students taking the final. The exams were graded by different instructors. The instructors did consult one another to try to generate a general rubric as to what was expected of students. Even with a general rubric, expectations and grading style can differ.

The results of the study, shown in Table 2, were rather surprising. Students that had supervisions performed significantly better on all but the second exam. In fact there was almost a ten percent improvement in student performance. Based on the size of the difference and the increase in student persistence and success shown in Table 1 it is likely that the supervisions had an impact on the ability of students to obtain the course learning objectives.

Table 2: Summary of Student Success.

	Exam 1	Exam 2	Exam 3	Final
Traditional	72%	69%	68%	67%
Supervisions	81%	73%	80%	79%

The results of the surveys, shown in Table 3, told a slightly different story. Nearly all the students that elected to take the survey felt that they would be successful in meeting the learning objectives of this course. The interesting part of the data collected on student assessment of their own abilities came when they were asked how confident they were that they could use the material in the course to solve engineering problems. More than 50% of the students that took the survey in the traditional homework course were very or extremely confident that they could solve engineering problems using concepts from the course. Those in the modified version of the course were just as likely to indicate that they were not or somewhat not confident as to say they were very or extremely confident. This finding was surprising because research has indicated the peer mentors, not significantly different from supervisors, should positively affect student feelings of self-efficacy[9,12].

Table 3: Summary of Student Success.

	Expected Grade		Confidence		
	A,B,C	D,F	Extr., Very	Confident	Somewhat, Not
Supervision	23	1	7 (29%)	10 (42%)	7 (29%)
Traditional	33	3	20 (56%)	8 (22%)	8 (22%)

The survey contained an additional surprise as can be seen in Table 4. One of the objectives of the supervisions was to discourage students from using crutches so that they would gain a deeper understanding of the solution process. As can be seen from the data, students from the traditional sections of the class were twice as likely to complete their homework without a crutch, while students in the supervision section were twice as likely to have used a crutch on 60% or more of the homework problems. One possible reason for this may be the differences in the population that took the survey. Only one of the students that took the modified section of the class did not take the final, while more that 20% of those in the traditional section did not complete the course. Another reason for the difference maybe the instructor of the traditional sections policy of giving no credit for an assignment that contained evidence of crutch use. Moreover, the homework problems assigned included all of those that contained errors in the solution manual to make detection of copying from the solution manual easier. No such penalty was explicitly outlined in the modified course.

Table 4: Summary of Student Success.

Percentage of Homework Completed without a crutch	Number of Students	
	Supervision	Traditional
0-20%	1 (4%)	0 (0%)
20-40%	1 (4%)	1 (3%)
40-60%	3 (13%)	2 (6%)
60-80%	10 (43%)	9 (26%)
80-100%	8 (35%)	22 (65%)

Discussion

This work presents a preliminary study on a transformative change in the way that problems sets are used to help students learn. The results suggest that this change deserves further evaluation. They indicate that supervisions had a positive impact on student persistence and success. It reduced the number of students that were unsuccessful or did not complete the course to one third that of the traditional sections. In addition, student performance on the summative assessment instruments demonstrated that students from the modified section had met more of the desired learning objectives than those in the traditional sections. This was somewhat expected due to past studies on the use of feedback for helping student to learn. Moreover, just forcing the students to sit down for an hour a week and discuss dynamics likely has a positive effect on student performance.

The supervisions did not reduce student use of crutches to complete the homework. This was somewhat surprising because students were expected to explain the solution process used. One of the likely reasons for increased use of the crutches is that the penalty in the supervisions for students that could not present their solutions was only 25% of the possible points for the problem set. Students that used crutches in the traditional sections risked loss of all their points if it was suspected that a solution given came from the solution manual. To encourage students in supervisions to reduce their reliance on crutches a more significant penalty should be used with those students that cannot explain their solution in any real detail. For example, the loss of all preparation points or all points associated with the supervision.

One area that was not addressed in the results was a dislike of supervisions by some students. Supervisions required an hour of student time outside of class. A small but significant number of students indicated to the instructor both in person and on the course evaluation forms that they did not appreciate the additional time requirement. They thought that a warning should be given to students so that they could enroll in a traditional section. Furthermore, they indicated that if the course is to use supervisions in the future, the course credit should be changed to match the increased time requirement.

Lastly, training is an important part of the supervision process. The training should include a detailed description of how a supervision is conducted and the grading process to ensure that the supervision experience is independent of the supervisor conducting it. Early in this study students were upset by differences in the way the supervisors conducted supervisions. For example, initially there was not a standard policy on student use of notes during the presentation and how many points students got for each step of the supervision. These issues were quickly addressed through the weekly supervisor meetings.

Future Work

While this pilot study indicated that supervisions may have a significant positive impact on student performance and persistence additional studies are needed. Specifically, conducting a test with one instructor teaching two sections of the same course. One section that makes use of supervisions and another using traditional homework. This would control for small differences in the lecture experience and grading.

In addition, using supervisors or graders does not allow the instructor of a course to collect formative data from student solutions. A formal method should be developed that allows instructors to gather this important information so that the course can be modified to address areas where students are struggling.

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Appendix A: Survey Instruments

Survey for Students that Participated in Supervisions

1. What is your major?

2. What year of your post-secondary education are you currently in?
    a. First
    b. Second
    c. Third
    d. Fourth
    e. I have been in school for more than four years.

3. What grade do you expect to obtain in this course?
    a. A
    b. B
    c. C
    d. D
    e. F or Incomplete

4. How comfortable do you feel applying the material learned to solve engineering problems?
    a. Extremely confident
    b. Very confident
    c. confident
    d. Somewhat confident
    e. Not confident at all

5. How important is dynamics to students in your major after graduation?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

6. What is your best estimate of the percentage of the classes you attend?
    a. 0-30%
    b. 30-60%
    c. 60-80%
    d. 80-90%
    e. 90+%

7. How import do you feel attending class is to understanding the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

8. What is your best estimate of the percentage of the homework you completed? Please do not include those problems that you copied from another student or solution manual.
    a. 0-20%
    b. 20-40%
    c. 40-60%
    d. 60-80%
    e. 80+%

9. How import do you feel completing the homework is to understanding the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

10. Did you work with others in the class when completing the homework?

11. If so, how important is collaboration to gaining a better understanding of the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

12. What is your best estimate of the number of discussions you attended?
    a. 0-2
    b. 3-5
    c. 6-8
    d. 9+

13. How import do you feel attending the discussion sessions is to understanding the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

14. What percentage of the time did you come to the discussion session prepared to discuss the problems?
    a. 0-20%
    b. 20-40%
    c. 40-60%
    d. 60-80%
    e. 80+%

15. What could be changed in the discussion sessions to improve student learning?

16. Would you take another class that used discussion sessions in place of traditionally graded homework? Why or why not?

17. What percentage of the time do you at least scan the material in the textbook prior to arriving at class?
    a. 0-20%
    b. 20-40%
    c. 40-60%
    d. 60-80%
    e. 80+%

18. How import do you feel reading over the material in the book is to understanding the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

19. How import do you feel reading over the material was to getting the most out of classroom activities?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

20. How many times did you ask the mentor questions during the course of the semester? This includes questions asked at the mentoring sessions.
    a. 0-2
    b. 3-5
    c. 6-8
    d. 9-11
    e. 11+

21. How import was interacting with the mentor to understanding the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

22. How many times did you attend the instructor's office hours?
    a. 0-2
    b. 3-5
    c. 6-8
    d. 9-11
    e. 11+

23. How import was interacting with the instructor to understanding the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

24. What change would you make to the class time activities to increase student learning?

25. What changes would you make to the reading quizzes to encourage more students to read over the material before attending class?

Survey for Student in Traditional Sections

1. What is your major?

2. What year of your post-secondary education are you currently in?
    a. First
    b. Second
    c. Third
    d. Fourth
    e. I have been in school for more than four years.

3. What grade do you expect to obtain in this course?
    a. A
    b. B
    c. C
    d. D
    e. F or Incomplete

4. How comfortable do you feel applying the material learned to solve engineering problems?
    a. Extremely confident
    b. Very confident
    c. confident
    d. Somewhat confident
    e. Not confident at all

5. How important is dynamics to students in your major after graduation?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

6. What is your best estimate of the percentage of the classes you attend?
    a. 0-30%
    b. 30-60%
    c. 60-80%
    d. 80-90%
    e. 90+%

7. How import do you feel attending class is to understanding the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

8. What is your best estimate of the percentage of the homework you completed? Please do not include those problems that you copied from another student or solution manual.
    a. 0-20%
    b. 20-40%
    c. 40-60%
    d. 60-80%
    e. 80+%

9. How import do you feel completing the homework is to understanding the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

10. Did you work with others in the class when completing the homework?

11. If so, how important is collaboration to gaining a better understanding of the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

12. What percentage of the time do you at least scan the material in the textbook prior to arriving at class?
    a. 0-20%
    b. 20-40%
    c. 40-60%
    d. 60-80%
    e. 80+%

13. How import do you feel reading over the material in the book is to understanding the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

14. How import do you feel reading over the material was to getting the most out of classroom activities?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

15. How many times did you attend the instructor's office hours?
    a. 0-2
    b. 3-5
    c. 6-8
    d. 9-11
    e. 11+

16. How import was interacting with the instructor to understanding the material?
    a. Extremely important
    b. Very important
    c. Important
    d. Somewhat important
    e. Not at all important

17. What change would you make to the class time activities to increase student learning?