AC 2011-565: UNDERGRADUATE HOMEWORK ASSIGNMENTS THAT ACHIEVE DESIRED LEARNING OUTCOMES

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Abstract

It is well-known that doing homework is an extremely common and useful tool for achieving student learning outcomes and for enabling the instructor's formative assessment. Nevertheless, it is equally well-known that, in general, the students' less-than-optimal approaches to completion of homework assignments diminish achievement of the desired learning outcomes that could be supported by this tool. This study proposes three different interventions to the traditional approach to homework which can effectively achieve student learning intended by practice in problem solving. The first approach uses an oral examination to determine the student's grade on the homework rather than having the students turn in their homework for later grading. The second intervention is similar to the first one but involves the additional requirement of turning in the solved homework as usual. In the third approach, students are requested to work in groups of two or three. Each group's assignment is different and a written solution is turned in for grading. These approaches are strongly supported by principles of how people learn. In order to measure the enhanced learning resulting from the experimental homework approaches, samples of previous year's exams are given to the students and the performance of the study group is compared to that of the previous year's classes. Furthermore, student reflections on those approaches compared to the traditional common homework style are collected and analyzed by an independent evaluator to document the impacts of homework innovations.

Introduction

Homework is defined as instructor-initiated work to be completed by students outside the classroom[1, 2]. It is well-known that homework has become a time-honored widespread learning tool used by instructors, at all educational levels, to improved student learning and achievement. Although homework was originally associated with pre-college education, its propagation into the college/university reflects its effectiveness as a learning tool. The fact that practice is more effective when distributed in small doses over extended periods of days or weeks helps explain the effectiveness of homework as a learning tool[3] .

Typical goals of assigning homework include reinforcing course material, covering more material in class, stimulating intellectual discipline and increasing student independence and responsibility[4]. According to Epstein[5], homework serves as a method to practice skills, increase learning experience, and increase self-confidence and time management skills, while Lee and Pruitt[6] indicate that the purposes of homework include practice, preparation, extension, and creation. Vatterott[7] listed five fundamental hallmarks of effective homework: purpose, efficiency, ownership, competence, and aesthetic appeal. Of particular importance (due to its direct relevance to our study here) is the competence aspect. Homework that is too difficult for the student to complete on their own or with reasonable struggle tends to be discouraging and undermines its effectiveness as a learning tool[8, 9]. Bembenutty[10] found that the active involvement of at-risk college students during homework was significantly associated with their

academic success. Additionally, the later study showed that homework completion is significantly influenced by the student's motivation and self-regulatory capabilities.

In recent years, the effectiveness of homework at the university level, in fact across the board, has come under serious questioning [1, 11]. College instructors, while re-emphasizing the validity and the value of homework as a learning tool, acknowledge the existence of a large gap between the performance of students on homework assignments and that on examinations containing comparable or even the same problems. Furthermore, studies continue to point out a general lack of good conceptual understanding of the main concepts of physics and mechanics in their field of study among undergraduate students[12, 13]. This indicates that the desired outcome of the different learning tools used by the system is not being achieved. Although test anxiety and other factors can contribute to the discrepancy between students' performance on examinations and homework assignments, they do not completely explain the performance gap.

To increase student motivation to complete homework assignments, it has become increasingly fashionable for instructors to allocate a generous percent of the overall course grade to homework. The general viewpoint is that higher reward in terms of grade will better motivate students to complete their homework; hence, students' learning will be enhanced. Nevertheless, incentivising by grading homework has not led to enhanced student learning. This might not be a big surprise if one observes that this approach is rooted in outdated behaviorism learning and motivation theories. Modern theories of motivation are based on the learner's interpretation of worth, expectancy and self-efficacy[14]. If the learner thinks that homework is interesting, worth doing and that he/she can successfully complete it, then the motivation to do homework will be high. On the contrary if the homework is too difficult, boring and there is no value in completing it, then the intrinsic motivation is low.

To understand the gap between the actual and the ideal (desired) learning outcome from homework, it is imperative to look carefully at the current practices and attitudes of both instructors and students towards homework. The typical practice consists of instructors assigning a number of well-chosen problems from the course textbook for homework. The selected problems are supposed to represent a reasonable challenge and to address different levels of difficulty and levels of learning in accordance with the well-established guidelines of effective homework. A deadline is fixed to turn in the solved assignment, which is usually graded by a teaching assistant within a week period or so. For the rest of the article, we will be referring to this approach to homework as the "traditional" approach to distinguish it from the new "experimental" approaches, which are the subject of this paper. Ideally, within the traditional approach, the instructor's expectation is that the students work on their homework over the allotted time for the assignment so that practice occurs over a period of time (typically a week). Doing so would also allow students to seek help towards completing the homework, which helps solidify and reinforce their understanding of the concepts presented in class. In reality, however, the majority of students end up, for different reasons, rushing the homework just so they meet the deadline and avoid the grade punishment associated with missing the deadline. Additionally, because the homework is graded, the students have learned to find easy ways to successfully complete the solutions, which includes copying the solution from different resources available to them. Even if students managed to solve the homework without taking shortcuts, a main objective of homework, practice over a relatively long period of time, is not accomplished. In

any case, the desired learning outcome is defeated in this twisted process. From the Behaviorists' point of view[14], this does not come as a complete surprise because the main motivation, grade reward, can be obtained through easier pathways. Finally, a drawback inherent to the traditional homework approach is the delayed feedback due to the time lapse between the submission of the homework and its return to the student after grading. It is well-known that a main requirement for effective learning is continuous and prompt feedback[15].

In this work, we propose and investigate the effects of different interventions to the traditional homework practice on the effectiveness of homework as a learning tool. The proposed interventions are based on the modern cognitive theories and are meant not only to restore but also to enhance the effectiveness of homework. In the following section we formally introduce the research questions and the objectives of this study along with concepts from learning theories which provided the framework for the proposed innovations aiming at improving homework effectiveness. The Methods section describes the three interventions studied in this work and the data collection and analysis procedure. The results are presented and discussed in the Results and Discussion section. Finally, a conclusion regarding the effect of the proposed interventions is made along with recommendations for future work.

Research Questions, Goals and Objectives

The current study is motivated by the common observation that while homework is a widely used and time-honored instructor-initiated learning tool, its effectiveness is becoming increasing questionable. This observation is reinforced by the wide discrepancy in student performance on examinations similar to homework and increasing evidence of students' lack of conceptual understanding of the basic engineering concepts covered. The study poses three different research questions related to student motivation and student learning from doing homework. The questions are specified as:

- Research Question 1: How do different homework interventions affect student motivation to thoroughly complete their homework?

- Research Question 2: How is student overall learning influenced by the implementation of the interventions proposed in Research Question 1?

- Research Question 3: What new homework strategies are suggested by this research for improving student learning?

The goal of the study is to explore the impact of different interventions to the traditional approach to homework in order to achieve greater learning as desired and expected from homework as a learning tool. More specifically, the objectives of the study are,

1. Define theory-driven innovations in homework implementation to improve learning in Dynamics classes

2. Implement innovations under experimental conditions that reveal impacts of innovations

3. Determine impacts of innovations and information that guides future refinements of homework strategies

The different interventions used are detailed in the Methods section below.

Methods

Description of experimental interventions:
The following three interventions to the traditional approach to homework are tested.

- Experimental intervention 1: As in the traditional approach, the homework is assigned along with a due date. Instead of collecting and grading the homework as in the traditional approach, a number of students are randomly selected and their grade for the homework is determined based on their performance on an oral in-class quiz where the student has to play the instructor role by presenting the problem and its solution while explaining the steps and defending the thinking process followed. From a Behaviorist point of view, this approach ensures that the sought reward (the grade) is only earned if the student has thoroughly completed the homework rather than taking shortcuts and still receiving the reward. Hence, the student is pushed to undertake the practice intended by the instructor and consequently the desired learning will occur. Based on the cognitive apprenticeship model[14], this approach has the benefit of forcing students to think aloud, which helps clarify their thinking process and rectify misconceptions. This in turn leads to better long term memory encoding and retrieving in accordance with the modern cognitive model[16, 17]. Finally, an additional advantage to this approach is that students obtain prompt feedback and assessment of their learning, which is proven to increase learning[15].

- Experimental intervention 2: This intervention is exactly the same as the Experimental intervention 1 above, but with the additional requirement that students turn in their solved homework assignment on the due date. Based on the cognitive learning theories, completing homework in writing is expected to provide an additional positive learning experience, the impact of which would vary based on the particular learning style of different students. It gives the student the opportunity to better absorb, reflect, and detect any misunderstanding or errors which would be exposed by not arriving at the correct final answer.

- Experimental intervention 3: In this intervention, groups of 2 to 3 students are formed and assigned a set of problems, which are different for each group. Students, as a group, are required to submit the homework with the understanding that the homework grading style would not give partial credit; the homework grade will be either 100% or 0. Besides enforcing thorough completion of homework, hence greater learning, the main underlying cognitive basis for this intervention is found in the social cognitive theory[18]: that students learn better in groups where they can observe each other's thinking process, hence, maximizing their learning by comparing, examining, and trying to consolidate their different steps and arguments towards solving the homework problems.

Participants
The participants in this study were students taking the course, Dynamics of Rigid Bodies, MENG0212, at Tuskegee University in fall 2010. This is a 3-credit hour required course in both the mechanical and the aerospace engineering curricula and covers the fundamentals of kinematics and kinetics of rigid bodies. It is a sophomore level course which is known to be especially challenging due to its demand for high analytical skills. It is also known that the performance of students in this course can lead them to question their ability to the extent of rethinking their major and career. The number of students involved in the study was 12 students, which is the typical class size in any given semester. From a statistical point of view, this means that the sample considered in the study is 50% of the population. Additionally, the incoming performance expectation of both groups, as measured by the cumulative GPA, was compared. It was found that the control group had an average cumulative GPA of 2.8 compared to 3.1 for the experimental group. Although the experimental group incoming expectation is large, the expectation difference by itself does not explain the larger differences in performance due to the different interventions as shown in the Results and Discussion Section.

Experimental design and procedure
As mentioned above, the experimental sample was a class of 12 students, which nevertheless represent 50% of the annual class population. Each of the three interventions studied were applied to roughly one third of the semester duration (15 weeks) which ensured that each intervention was applied to at least three homework assignments.

The motivation of students to thoroughly complete their homework was measured through a survey instrument shown in Appendix A. The learning outcome was measured in two ways. Firstly, a learning survey instrument was used (See Appendix B). Secondly, a standard assessment based on examination results was used. A control sample consisting of a previous class taught by the same instructor was used. The control sample size was also 12 students; approximately 50% of the annual student population of the course as with the experimental sample.

The exams consisted of the same problems for both samples and were graded by the same grader with the same style and standards. In the authors' opinion, the experimental group did not have access to those same exam problems given to the control sample. If the experimental group had access to the exam problems (which would also imply that the ideal solutions were available to them as it is the norm to provide such solutions) then their performance on the tests should be drastically better, even closer to perfect. Secondly, the top grades in the experimental group were obtained by the most intrinsically capable students asserting that the students did not have access to the previous exams. To assess the effect of the different interventions on student learning, the performances of the students in the experimental and control samples on those examinations were compared. More precisely, the performance was compared on a problem-by-problem basis as well as on the overall exam. Three exams were compared: two midterm exams and a final exam, each consisting of three problems. This comparison is justified by student demographic data for the two student cohorts in the same department at the same institution.

Results and Discussion

Table 1 compares the performance of the control and experimental student populations on the same examination problems P1 to P9. It also compares the overall performance on three tests: two midterms and a final exam (midterm 1 consisted of problems P1-P3, midterm 2 of P4-P6, and the final exam of P7-P9). As an additional visual aid, Figure 1 presents a bar chart based on Table 1. Performance on examination is currently the dominant assessment instrument used to measure students' learning. From Table 1 and Figure 1, it can be seen that the first two interventions resulted in significant improvements in the average student grade on some of the examination problems, whether measured on a problem-by-problem basis or on exam basis. Although the standard deviation is large, it is practically consistent in all cases indicating that both the control and experimental samples have similar variance and that all the interventions impacted the students in a relatively similar fashion with bias to certain subgroups. Nevertheless, some of the problems' results do not seem to reflect a significant statistical difference between the control and experimental samples, Table 2. Out of the nine exam problems, problems P3, P4, or P7 show an insignificant difference in performance between the two populations. The smallness of the sample size, twelve, calls for caution before generalizing those results. Although further research on classes with larger size would be ideal, a different route must be identified due the inherent small class size at the institution where the study was performed. Nevertheless, claiming that the experimental interventions can potentially lead to improved learning remains plausible.

Table 1, Comparison of performance of control and experimental groups on different examination problems (P1 to P9). "Avg" denotes average and "std" denotes standard deviation. The units are in percentage.

		P1	P2	P3	Mid term 1	P4	P5	P6	Mid term 2	P7	P8	P9	Final
Tradition homework approach (control)	Avg	21.7	31.7	40.8	41.5	38.5	39.7	41.8	43.2	40.0	71.5	29.1	53.3
	std	21.2	33.6	28.0	17.6	23.6	33.0	25.7	20.7	34.5	22.5	18.9	15.5
Experimental homework intervention 1	Avg	70.5	60.4	61.5	57.3								
	std	19.4	25.4	30.8	20.5								
Experimental homework intervention 2	Avg					43.2	67.0	57.0	54.5				
	std					25.8	29.7	31.0	22.4				
Experimental homework intervention 3	Avg									61.3	72.3	44.3	57.8
	std									27.2	31.6	28.0	16.6

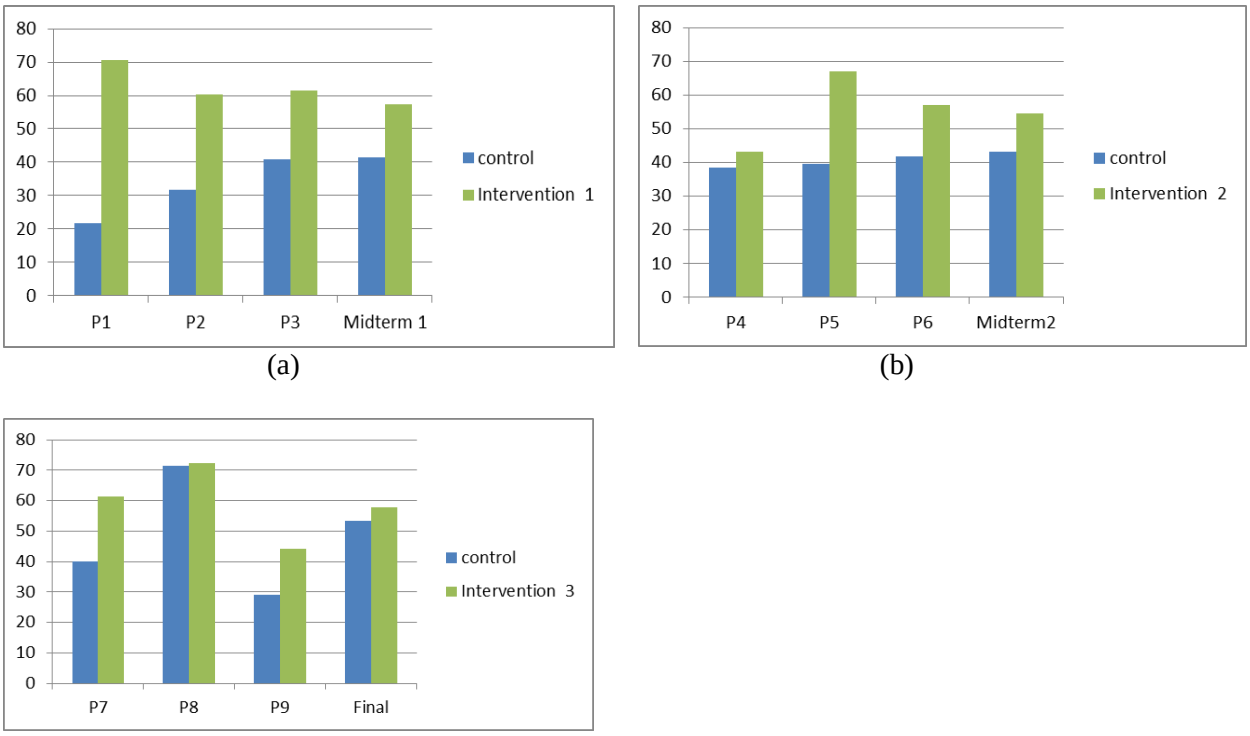


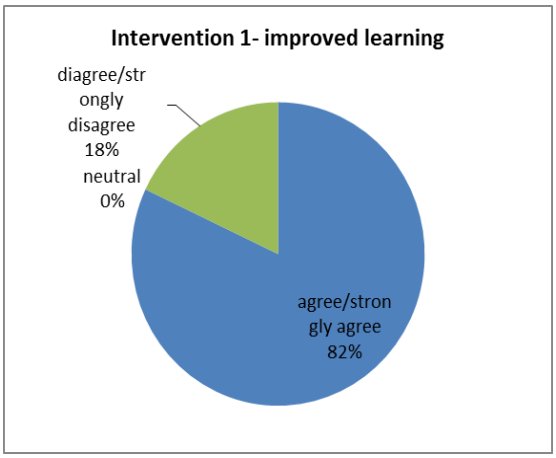
Figure 1, Chart bar comparison of performance of control and experimental groups on different examination problems for (a) intervention 1, (b) intervention 2, and (c) intervention 3.

Table 2, Statistical analysis for the difference in mean between control and experimental samples

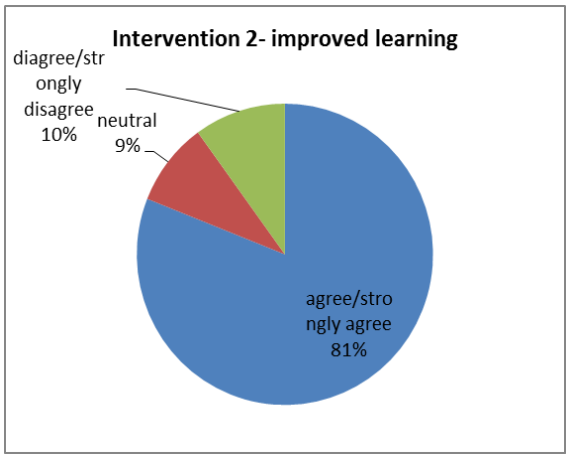
Comparison	t-statistic	Significance
Examination Problem P1: Traditional vs. Intervention 1	5.78	1.0×10^{-5}
Examination Problem P2: Traditional vs. Intervention 1	2.32	0.03
Examination Problem P3: Traditional vs. Intervention 1	0.73	0.47
Mid-Term 1: Traditional vs. Intervention 1	3.31	0.003
Examination Problem P4: Traditional vs. Intervention 2	0.46	0.65
Examination Problem P5: Traditional vs. Intervention 2	2.13	0.04
Examination Problem P6: Traditional vs. Intervention 2	1.29	0.21
Mid-Term 2: Traditional vs. Intervention 2	1.26	0.22
Examination Problem P6: Traditional vs. Intervention 3	1.58	0.13
Examination Problem P7: Traditional vs. Intervention 3	0.07	0.94
Examination Problem P8: Traditional vs. Intervention 3	1.44	0.17
Final examination: Traditional vs. Intervention 3	1.84	0.08

More reliable evidence for improved student learning comes directly from a student learning survey instrument as shown in Appendix B and Figure 2. The survey results indicate that the overwhelming majority of students believe that all three experimental interventions have led to better learning of the course material and concepts. From additional comments made by some

students, it seems that the students felt that greater learning has occurred, although that might not be reflected in their grade.



(a)



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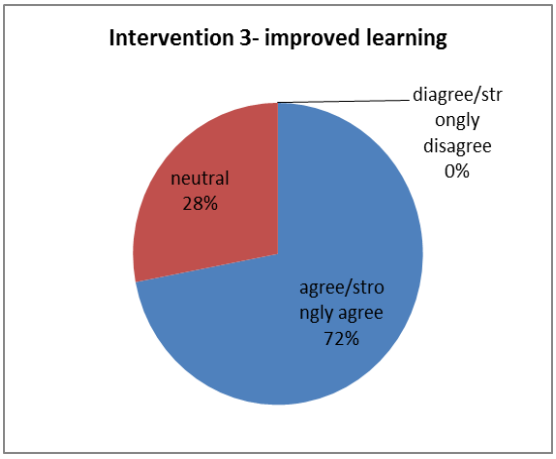

(c)

Figure 2, Student survey results regarding the improved learning due to experimental homework interventions 1, 2, and 3.

To gain more insight into the reasons behind the improved learning, an additional survey, Student Motivation Survey, was designed and conducted. (See Appendix A). The survey results indicate that students did understand the significance of the course subject (rigid body dynamics) and its relevance to their future career, see results for Questions 1, 2, 3, and 9. Furthermore, they also believe in the benefits of doing homework in helping them understand the course material. This indicates that value motivation does exist. Nevertheless, the acknowledged difficulty and time consuming nature of the Dynamics homework and the associated frustration acted as an obstacle to the successful completion of homework, see results for Question 7. As well-known from cognitive theories, low expectations of being successful at completing a task acts as a de-motivator. Besides, the survey indicates that a significant portion of the students, 50%, would be motivated by the grade only if it has to be earned based on merit, which is what the experimental interventions seems to successfully address. Faced by the frustration of difficult and time

consuming homework assignments, students will take shortcuts in order to obtain the ultimate reward: the grade.

Finally, an important observation needs to be made. Looking back at the research questions posed by this study, it can be seen that the questions revolved around interventions to enhance student motivation to thoroughly complete homework. The implied assumption is that this will naturally lead to improved learning. Nevertheless, the results indicate that, in addition to enhancing student motivation, the proposed interventions contributed to improved learning through other venues like active learning, group learning, and prompt assessment and feedback.

Conclusion

Three alternative strategies to the traditional approach to homework were proposed. The bases for these strategies can be found in modern cognitive theories of learning and motivation. The study shows that not only do those strategies have the potential to restore the effectiveness of homework as a learning tool, but they also can enhance learning through different avenues. Besides enhancing student motivation to thoroughly complete homework assignments, the proposed strategies improve learning through prompt feedback, cognitive apprenticeship, and active learning. Additional suggestions to increase the effectiveness of homework include better design of homework assignment by the instructor so that different levels of difficulty and learning are higher incorporated, more interesting assignments, and higher grade motivation. Those suggestions are not only inspired by the students' responses to the surveys, but are also founded in modern learning theories.

In order to generalize the findings of this study, additional data collection and analysis is required. The small class size (less than 15 students) inherent to the institution where the study was made presents some challenge. One way to circumvent this difficulty is to extend the study to the full student population (i.e. the fall and the spring course offering) and use that opportunity to neutralize the effect of the instructor (different instructors teach the course under study in the two semesters). Additionally, we suggest that such a future study would focus on Experimental Homework Intervention 2 and/or 3. Compared to the first intervention, the second intervention is selected because it is as good or better at maximizing learning according to the survey results.

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Appendix A: Student Motivation Survey (along with the results of the survey)

Student Motivation Survey
Fall Semester 2010
Dynamics, MENG 0314

To what extent do you agree with the following statements?

		Strongly disagree	disagree	neutral	agree	Strongly agree
1	In general, homework is an effective tool for learning the Dynamics course material	0%	0%	0%	33% (4/12)	67% (8/12)
2	I see the relevance of the Dynamics course to my future engineering career	0%	8% (1/12)	17% (2/12)	25% (3/12)	50% (6/12)
3	To fully grasp the concepts of Dynamics, it is essential that the homework be completed thoroughly	0%	0%	17% (2/12)	25% (3/12)	58% (7/12)
4	On average, Dynamics homework is more difficult to complete than homework in other courses	0%	8% (1/12)	8% (1/12)	50% (6/12)	33% (4/12)
5	On average, Dynamics homework is more time consuming to complete than homework in other courses	0%	0%	36% (4/11)	18% (2/11)	45% (5/11)
6	I see the relevance of the Dynamics course to my success in later courses in my degree program	0%	0%	17% (2/12)	33% (4/12)	50% (6/12)

7 If you do not normally complete Dynamics homework thoroughly, what best describes the main reason for that?

a) I won't learn much from doing it	8% (1/12)
b) It is not likely to affect my final grade	8% (1/12)
c) I am not willing to spend the time and effort it takes	8% (1/12)
d) I get frustrated with the difficulty and quit	83% (10/12)
e) Other: (briefly describe)	8% (1/12)*

*Response	More effort on my part need to be done when completing homework

8 What can best motivate you to complete Dynamics homework thoroughly in spite of its difficulty and time requirement?

a) Homework carries a significant portion of the total grade	25% (3/12)
b) My homework grade is going to be based on a quiz rather than on an assignment submitted for grading	50% (6/12)
c) The homework is easy and not overly challenging	17% (2/12)
d) The homework is more interesting.	25% (3/12)

Briefly explain your answer:

Response 1	In this class, it's worth a quiz grade. Also if you do not complete the HW, you definitely will not understand the course
Response 2	It helps me understand the concepts, if I can, and it is a grade that I need
Response 3	The homework that is too hard I do not do well
Response 4	The homework helps prepare me for the test

9 I consider my motivation to succeed in Dynamics as:

a) Very low	0%
b) Low	8% (1/12)
c) Moderate	8% (1/12)
d) High	50% (6/12)
e) Very high	33% (4/12)

10 In doing Dynamics homework, I typically:

a) Do not complete what is assigned	8% (1/12)
b) Complete only what was assigned	92% (11/12)
c) Complete more problems that assigned.	8% (1/12)

Appendix B: Student Learning Survey (along with the results of the survey)

Student Learning Survey
Fall Semester 2010
Dynamics, MENG 0314

To what extent do you agree with the following statements?

		Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	Having to earn my homework grade through an oral quiz instead of just turning in the assignment did help me learn the course material better	9% (1/11)	9% (1/11)	0%	27% (3/11)	55% (6/11)
2	Having to earn my homework grade through an oral quiz while still turning in the assignment did help me learn the course material even better	0%	9% (1/11)	9% (1/11)	36% (4/11)	45% (5/11)
3	Having a different homework assignment for each student group (group made of two to three students) did help me learn the course material even better	0%	0%	27% (3/11)	36% (4/11)	36% (4/11)
4	I think that maximum learning will occur if each student is assigned different set of problems to work on individually	0%	18% (2/11)	27% (3/11)	27% (3/11)	27% (3/11)
5	Working in a group helped me learn better	0%	9% (1/11)	18% (2/11)	18% (2/11)	55% (6/11)
6	Overall, the non-traditional approaches to homework used in my Dynamics course has helped me learn the material better	0%	9% (1/11)	9% (1/11)	55% (6/11)	27% (3/11)

7. Explain any other factors that affect your motivation to learn Dynamic course material.

Response 1	The oral quizzes where a really good idea and helped me learn the material a lot better
Response 2	Extra class periods to help outside of class shows professor actually cares that the students learn
Response 3	Knowing that I would have to get up and talk about the problem made me want to understand it more
Response 4	My main motivation was to do well in the course. Even though sometimes my grades were not the best, I truly did receive somewhat an understanding of the course.
Response 5	Some quick little hands on activities will help as well.