Int. J. Engng Ed. Vol. 24, No. 3, pp. 616–624, 2008
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Using Handheld Computers for Instantaneous Feedback to Enhance Student Learning and Promote Interaction*

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In this project our goal is to improve student learning in engineering mechanics courses. Our hypothesis is that learning is improved by providing rapid feedback to students of their understanding of key concepts and skills being taught. This hypothesis was tested through experiments in which student performance on quizzes was measured after classes in which they were provided rapid feedback. The feedback system acts as a catalyst to encourage students, working in pairs, to assist each other in correcting misconceptions or deepening each other's understanding of the concept or skill at hand. Furthermore, the system allows the professor to assess the students' level of comprehension or misconception in a just-in-time fashion, and thus guide the pace of covering the material. The feedback is enabled through wireless-networked handheld computers or color-coded flashcards, and this study focused on the differences in results between these two rapid feedback methods. In the first two years of the study, this study was implemented in two sections of a lower-level, core-engineering course, Statics, as well as in follow-on courses of Dynamics and Solid Mechanics. Our results show that there was no statistically significant difference in knowledge gained between the two feedback methods, as measured by student performance on quizzes. The students' perception, however, was that the handheld computers were more useful to them. The students showed a good retention of Statics concepts and skills in follow-on courses.

Keywords: Concepts learning; mechanics; personal digital assistants; rapid feedback; statics; handheld computers

INTRODUCTION

CORE ENGINEERING COURSES, such as Statics, comprise key concepts and skills that students need to master in order to succeed in follow-on courses. Students must comprehend these concepts at sufficient depth (as opposed to rote memorization of procedure) and transfer this understanding to other courses and contexts. In our multiyear project, the hypothesis is that such learning is facilitated in an active, peer-assisted environment in which the students are provided frequent and rapid feedback of their state of learning.

Providing feedback to students of their current level of understanding of concepts is critical for effective learning. It is also important for the professor. This feedback is typically realized through homework sets, quizzes and tests. All of these techniques, however, suffer the faults of being too slow, too late, and too tedious to apply frequently. Freeman and McKenzie [1] discuss several issues that inhibit better student learning in higher education. For students, there is a lack of individual feedback on learning, few opportunities for dialogue to improve learning and a feeling that the subject is impersonal. From the faculty members' perspective, the difficulties lie in knowing what students are really learning, providing individualized feedback, addressing students' specific misconceptions, attending to diverse learning styles and engaging students in learning.

Bransford *et al.* [2] state: 'Learners are most successful if they are mindful of themselves as learners and thinkers. In order for learners to gain insight into their learning and their understanding, frequent feedback is critical: Students need to monitor their learning and actively evaluate their strategies and their current levels of understanding.' Freeman and McKenzie [1] support this idea, noting that 'Feedback is fundamental to learning . . . Students may receive grades on tests and essays, but these are summative assessments . . . What are needed are formative assessments, which provide students with opportunities to revise and improve the quality of their thinking and understanding. If the goal is to enhance understanding and applicability of knowledge, it is not sufficient to provide assessments that focus primarily on memory for facts and formulas.'

Our project addresses these issues by providing students with timely feedback and opportunities to improve learning. Our goal is to combine rapid feedback with conceptual learning and skills development and to evaluate our methods through rigorous experimental design and data analysis.

* Accepted 31 May 2006.

PROJECT DESIGN AND IMPLEMENTATION

Course description

At Rowan University, Statics is a required course for sophomores in three of the four engineering disciplines (Civil & Environmental, Electrical & Computer, and Mechanical Engineering). The course content is similar to that of most engineering programs in the US, although the pace and length of the course is unusual. Rowan students take Statics in a compressed, half-semester (7.5 weeks) format, with classes meeting for three 75-minute periods each week. Students receive two semester-hour credits upon passing the course. The format dictates a faster-than-usual pace of coverage of the material with little time spent in reviewing course material from previous lectures. Statics is delivered in the first half of the Fall semester, followed in the second half-semester by Dynamics. In the first half of the Spring semester, Civil & Environmental and Mechanical Engineering students continue in the engineering mechanics sequence by taking Solid Mechanics (also known as Mechanics of Materials).

In Fall 2003, we began this study with one of the authors teaching two sections of this course. In that year, we collected some data to practice for what we might expect in the following year and focused on the details of implementing this project. Essentially, we treated the year as a 'trial run'. For example, we acquired all the personal digital assistants (PDAs) that were to be used for this study, set up, tested and practiced with the software used to collect data, and developed most of the quizzes for which rapid feedback would be provided to students. In Fall 2004, we repeated what was implemented in the previous year except that data were taken for subsequent analysis. All of the reported results in this paper are from Fall 2004.

As mentioned previously, one of the authors taught two sections of Statics in Fall 2004. This was done in order to minimize any differences in teaching style or content between the two sections. Having a single professor also ensured that the two sections maintained the same pace through the course from day to day. At the start of any class, the students in each section are provided with one of two means of receiving rapid feedback: a PDA or a flashcard. With the PDAs, students are paired up and share a single PDA, whereas with the flashcards, each student in the section is provided one. Details about the feedback methods are described later.

The in-class portion of this study is conducted in a similar manner to that described by Mazur [3]. The professor presents a new topic or concept for no more than 10–15 minutes, using traditional lecture, demonstration, or sample problem solution. Thereafter, he poses a 'concept question' or a 'skill quiz' to gauge the students' understanding. If the student responses from the feedback system (PDAs or flashcards) show that a high percentage of students do not understand the concept or have not mastered the skill, the professor elaborates on or further explains the topic. If the responses show that a reasonable fraction of students understands (a distribution of answers, but a plurality with the correct answer), the professor directs the students to take time and explain the concept or skill to each other. Thereafter, the students are asked to either respond again to the same question or a different question on the same topic. The final scenario occurs when the student response shows a high percentage of correct answers, indicating that students understand the topic. In this case, the professor simply continues to the next topic.

In addition to assigned homework sets, which were completed by students in two-person teams, quizzes and tests were used for student evaluation and data analyses for this study. In the 7.5-week period of the course, nine homework sets were assigned, and eight quizzes and two non-cumulative examinations were given. Identical homework sets were assigned to the two sections. Whenever a homework set was submitted by the students, a brief quiz was given which covered some concept covered in the homework. Quizzes were designed to be similar, but not identical, between the two sections. The scores on the quizzes were analyzed, as described later, to assess for differences between the two feedback methods.

A crossover design of experiment is used in this study [4]. The method is intended to eliminate potential confounding factors that cannot be controlled for using a standard analysis of variance model. For example, students may not be randomly assigned to each of the two Statics sections (one section may have mostly electrical engineering students, who have a different motivation level from the other section, which might be populated mainly with mechanical engineering students), or the time at which each section is held may affect student performance. Without the crossover a potential treatment effect would have been indistinguishable from a section effect.

In a crossover design, one of two study groups (course sections in this case) will be randomly chosen to receive rapid feedback with the PDA-enabled system (the 'treatment' group) while the other group will use the flashcard system (the 'control') for a fixed period of time. For the next 'treatment period,' the two sections simply swap the feedback method, and this continues for the duration of the course. In this manner, each student acts as his or her own control to eliminate the non-correctible confounders. This design has the additional advantages of eliminating any bias that may be introduced by the professor in course delivery in the two sections, and minimizing any attitude bias that may be displayed by students of either section due to receiving a single method of feedback for the entire course if swapping did not occur. The treatment periods generally lasted from two to five class meetings, as was determined to be logical based on the skills or concepts being covered during the period. In Fall 2004, one section of the course had 19 students and the other had 16 students. Our statistical analyses of the demographic data and various academic performance measures (e.g. current GPA, prior grades in Calculus and Physics) showed that there was no statistically significant difference between the two student populations.

Rapid feedback methods

The flashcard method for providing feedback to students was developed by Mehta [5]. In short, double-sided and color-coded cards were used by students to display their answer to a question posed by the professor. Each card was used to display one of six possible responses. The cards provided a quick means for the professor to scan the class's response and qualitatively determine the distribution of answers.

A fleet of 18 PDAs was used for the PDA-enabled feedback method. Half of the PDAs were Palm-OS-based and half were PocketPC-based. All of the PDAs had wireless networking capabilities (802.11b or WiFi) and communicated with the professor's Windows XP Tablet PC using a peer-to-peer networking mode. The software that was used to manage the inter-computer communications and to record and display student responses from the PDAs was a pre-beta version of OptionFinder VP, which was being developed by Option Technologies Interactive (www.option-technologies.com).

Regardless of the feedback method used each time, the concept question or skill quiz was posed by the professor through his Tablet PC and projected to the front of the class, along with the solution choices. The correct solution was embedded with incorrect answers, which were derived from common student mistakes or misunderstanding. Students were given time to reflect on the question posed, discuss it with their peers, and then they had to select from the possible solutions. The major differences between the two feedback methods were that the PDA/software-based method allowed for 1) quantitative and permanent recording of the student responses for future review and 2) a display of the tallied student responses, which was projected up on the screen nearly instantaneously after the students responded. An example of a concept quiz is shown in Appendix A at the end of this paper.

Data analysis

This project comprises three major components: 1) the development of a suite of concept questions and skills quizzes for the course, 2) the use of rapid feedback and peer-assisted learning in the classroom, and, for Fall 2004, 3) a comparison between the two methods of providing rapid feedback to students. The third component required the bulk of the statistical analysis. The goal of this analysis was to see if the method of implementing the rapid-feedback, using PDAs (the 'treatment') vs. flashcards (the 'control'), had an effect on the students' learning. The response variable tested is the score on a quiz for the corresponding period of instruction where one section had the treatment and the other the control (or vice versa). This would be done while controlling for factors (or variables) other than the treatment factor which might affect the scores.

To analyze the treatment factor (PDA vs. flashcard) while controlling for the other 'nuisance' factors that could affect scores but are not attributable to the treatment, we employed the following general linear model using the DataDesk statistical package:

$$y_{mijkl} = \mu + \beta_1 x_{1,m} + \beta_2 x_{2,m} + \beta_3 x_{3,m} + \beta_4 x_{4,m} + \alpha_i + \gamma(\alpha)_{j(i)} + \delta_k + \tau_l + \varepsilon_m \quad (1)$$

where

$y =$ the score on the quiz,
$\mu =$ the grand mean (average score with no factors taken in to account),
$x_1 =$ the student's Freshman-year GPA (which includes x_2, x_3 and x_4.),
$x_2 =$ the student's Calculus I grade,
$x_3 =$ the student's Calculus II grade,
$x_4 =$ the student's Physics I grade,
$\alpha =$ the Section (Section 01 (8 am class meeting) or Section 02 (10:50 am class meeting)),
$\gamma =$ the student nested in section, or Student-in-section,
$\delta =$ the Period (or quiz or topic),
$\tau =$ the Treatment (PDA = 'treatment' and flashcard = 'control'),
$\varepsilon =$ random error.

The Freshman-year GPA and the Calculus I, Calculus II and Physics I grades were treated as continuous covariates. The Section factor was discrete, and the Student factor was discrete, and nested in section (student 1 in Section 01 is not the same as student 1 in Section 02). The Period (or quiz) factor was discrete and included because some quiz topics may be intrinsically more difficult than others. The Treatment factor was discrete as well. For various reasons, only five of the eight quizzes were judged to be valid (for example, one quiz inadvertently included more than one concept, and a student's score was not broken down to distinguish an error on either or both concepts) and were included in the analysis. Although the quiz scores were skewed towards zero (i.e. most were bunched at the high end of the scoring scale), the residuals were nearly normal, and no transformation of the data was needed.

RESULTS

When the model above was analyzed, Calculus II, Physics I and Student-in-section factors were

Table 1. Significance of terms in the model given by (1)

Covariates	Factors				Interactions
1, 2, 3*, 4**	Section	Student-in-Section***	Period	Treatment ($p = 0.2735$)	
1, 2, 3*, 4**	Section	Student-in-Section***	Period	Treatment ($p = 0.3238$)	Section/Period
1, 2, 3*, 4**	Section	Student-in-Section***	Period	Treatment ($p = 0.4439$)	Period/Treatment
1, 2, 3, 4**	Section	Student-in-Section**	Period	Treatment ($p = 0.3080$)	Student-in-section/ Treatment
1, 2, 3, 4**	Section	Student-in-Section**	Period	Treatment ($p = 0.2925$)	Section/Period & Student-in-section/Treatment

For each model the factors marked with '*' were significant at $\alpha = 0.05$ (5%), with '**' at $\alpha = 0.01$ (1%), and with '***' at $\alpha = 0.001$ (0.1%). Underlined factors were 'significant' at $\alpha = 0.10$ (or 10%). Note that covariate 1 = Freshman GPA, 2 = Calculus I, 3 = Calculus II and 4 = Physics I

significant at $\alpha = 0.05$. We will address the terms in their order in the model. Recall that factors other than the Treatment are in the model to account for likely sources of variability in the quiz scores. That way, any variability due to the Treatment is not masked by the other factors and we can detect the Treatment effect. Table I gives a more detailed look at the significance of each term.

Because Freshman-year GPA was derived in part from the grades for Calculus I, Calculus II and Physics I, it is not surprising that with these included in the model, and the latter two significant, Freshman-year GPA was not significant. That Calculus I was not significant might be because the most important calculus techniques used in Statics come from Calculus II, though we could not be certain of this reasoning. It was not surprising that Calculus II and Physics I were significant (p-values = 0.0448 and 0.0018, respectively), because each course contains skills and concepts important to Statics and both courses were completed by most students in the semester immediately preceding the one in which Statics was taken. Section was not significant (p-value =.0912), which reinforced preliminary results from Fall 2003. That it was only marginally not significant justified its inclusion in the model to account for some of the variation that might mask a treatment effect. Student-in-section was significant (p-value = 0.0003), which should be expected, as scores should always depend on the individual student. That Period (quiz) was not significant may or may not be surprising. The fact that the scores for different quizzes were essentially the same indicates that the quizzes inherently adjusted for the difficulty of the material, or that the periods of instruction were constructed so that no period or topic was inherently more difficult. Finally, and most importantly, the Treatment (PDA or flashcard use) was not significant (p-value = 0.2735). This result suggested that using PDAs or the flashcards to provide feedback to the students had little effect on their score. In other words, it did not matter *how* one provides rapid feedback. Although we had thought that the 'coolness' of the PDA might affect a student's learning, it really would only affect their interest during the physical activity in class of reporting their answers. In the end their scores would be affected by outside work (such as studying!) and inherent interest or motivation in the material, neither of which would be greatly influenced by the fact that a PDA was used in class.

Although we had a large number of observations, the nature of the crossover design and the fact that the students were nested in the sections meant that there were only four two-way interactions that could be added to the model, and these generally one-at-a-time. When the Section-by-Period interaction was added, it was not significant, with all of the other factors in model (1) significant or not as before. The Period-by-Treatment interaction showed similar results. When we added the Student-in-section-by-Treatment interaction, only the Physics I and Student-in-section factors were significant at $\alpha = 0.05$ (though the Calculus II factor was only marginally non-significant with a p-value of 0.0505). When we added the pair of two-way interactions, Section-by-Period and Student-in-Section-by-Treatment, only the Physics I and Student-in-section factors were significant at $\alpha = 0.05$ (though the Calculus II factor was only marginally non-significant with a p-value of 0.0558). Hence, adding any of the relevant interactions, singly or in the one pair, made virtually no change in the significance of any of the factors in model (1), nor were the interactions themselves significant.

A second set of results obtained was from two surveys administered to the cohort, one approximately halfway through the course, and the other on the final day of the course. Each survey (midcourse and final), along with the combined responses from both sections, is shown in Tables 2 and 3, respectively. The responses for both surveys were originally broken down into the two sections, but chi-square tests of the questions (with some necessary combining of categories) showed no differences between the sections, which justified our combining the responses.

Table 2. Results from the midcourse survey administered to the Fall 2004 sections of Statics

Question	Response	Response Count	Percentage
Before this class, have you used a PDA?	Yes, I have one.	3	8.8
	Yes, but it was someone else's	10	29.4
	No.	21	61.8
Rate your familiarity with PDA's	No experience	17	50.0
	Beginner	10	29.4
	Somewhat familiar	5	14.7
	Expert	2	5.9
How useful were the flashcards for your learning?	Very helpful	5	14.7
	Somewhat helpful	15	44.1
	No difference	9	26.5
	Somewhat hindered	4	11.8
	Very hindered	1	2.9
How useful were the PDAs for your learning?	Very helpful	11	32.4
	Somewhat helpful	14	41.2
	No difference	5	14.7
	Somewhat hindered	3	8.8
	Very hindered	1	2.9

Table 3. Results from the final survey administered to the Fall 2004 sections of Statics

Question	Response	Response Count	Percentage
How useful was rapid feedback (either method) to your learning?	Very helpful	16	45.7
	Somewhat helpful	19	54.3
	No difference	0	0
	Somewhat hindered	0	0
	Very hindered	0	0
How useful was using FLASHCARDS to your learning?	Very helpful	5	14.3
	Somewhat helpful	23	65.7
	No difference	5	14.3
	Somewhat hindered	2	5.7
	Very hindered	0	0
How useful was using the PDAs to your learning?	Very helpful	16	45.7
	Somewhat helpful	17	46.8
	No difference	1	2.9
	Somewhat hindered	1	2.9
	Very hindered	0	0
Do you think you would have done better or worse if this course was taught by the same professor, but in a more traditional method of teaching?	Much better	0	0
	A little better	0	0
	No difference	12	35.3
	A little worse	21	61.8
	Much worse	1	2.9

In general, the survey results show that students have relatively little familiarity with PDAs (based on the mid-course survey), but still an overwhelming majority in either survey found that the PDAs (and the associated rapid feedback method) were useful in their learning experience (74% and 93% in the midcourse and final survey, respectively). In both surveys, a majority of students found that rapid feedback with either the flashcards or the PDAs was at least 'somewhat helpful' to their learning (59 per cent and 80 per cent for flashcards, respectively in each survey), with a preference in both surveys for the PDAs. In fact, when questions two and three in the second survey were compared using a chi-square test of homogeneity (combining the 'no difference' responses with the two 'hindered' categories), the PDAs were considered by students to be more helpful than the flashcards ($p = 0.0089$). We attribute this finding to the immediate availability of the tallied responses that was provided to the students using the PDAs and software. Finally, in comparing the results between the two surveys, it is obvious that as the course progressed, the students' acceptance of rapid feedback using either method increased. This is seen in the results showing that the percentage of students who found either method to be at least 'somewhat useful' increased from 59 to 80 per cent for the flashcards and from 74 to 93 per cent for the PDAs.

Based on our statistical analysis of the quiz scores, the Treatment factor was not significant in any model we examined. At first this was disappointing, as this was the factor of interest for this part of the project. On reflection, however, this finding, along with our survey results, suggested that rapid feedback was useful and well accepted by students, and that it did not matter which of the two forms of feedback was used, so long as it was used. What was interesting was that the chi-square analysis implied that the students believed the PDAs were more helpful to their learning than the flashcards.

As a comparison between subjects, we measured the students' 'gain' in Statics through the application of a Statics Concept Inventory [6]. The reader is referred to the referenced work for details on this particular Concept Inventory and its use as a measure of student learning. In summary, the students from the Rowan Fall 2004 cohort scored an average gain of 35.9 per cent. We do not yet have sufficient data to make comparisons with other groups or to draw conclusions from this finding.

FINDINGS IN FOLLOW-ON COURSES

To assess the durability and transferability of the Statics concepts and skills, the rapid feedback methods, both flashcards and PDAs, were used in the subsequent mechanics courses of Dynamics and Solid Mechanics (Mechanics of Materials). Many of the concepts and skills that students learned in Statics were tested in the follow-on courses and student performance was tracked. The concepts and skills in Dynamics that students should be able to do are: draw free body diagrams (FBD), write and add vectors, decompose a vector into its components, carry out a cross-product to compute a moment or couple and compute and know when to use a unit vector. In Solid Mechanics, the students again must be able to do the above as well as write the equations of equilibrium.

Since one of the authors teaches only one section each of Dynamics and Solid Mechanics, no crossover experimental design was conducted. Instead the rapid feedback methods were used in one of two ways: 1) as a precursor to a topic in a follow-on course that was previously learned in Statics to detect retention and transferability, or 2) during the lecture as new concepts or skills were being taught, similar to the procedure that was used in Statics. When a topic such as determining the moment about a point due to an external force was needed to solve a problem in Dynamics, a question was posed to the students along with possible solutions before this concept was reviewed. Thus, the feedback results were tabulated to determine student retention of concepts previously learned in Statics. If a majority of students answered incorrectly, then they were asked to discuss and answer again before the instructor provided review. If a majority answered correctly, then no review was necessary. Further questions were posed to the students to provide rapid feedback to the instructor when teaching new concepts in Dynamics and Solid Mechanics. In both cases the correct solution was embedded with 'distractors' derived from common student mistakes or misconceptions as previously discussed.

In the first year of the study, students took Dynamics from one of the authors in the Spring of 2004. This was a trial run at using the system and students showed some retention of concepts—such as free body diagrams, cross products and moments—from Statics to Dynamics on the order of 50 per cent. The authors did not teach and thus were unable to implement the use of feedback in Solid Mechanics in the Fall of 2004.

In the second year of the study, 2004–2005, the same instructor as in the previous year taught both Dynamics and Solid Mechanics. In that year, Dynamics was moved to the second half of the Fall semester, which was the 7.5 weeks immediately after Statics, and Solid Mechanics was moved to the first half of the Spring semester. In Dynamics student retention of concepts such as moments and vector forces was high at over 80 per cent, which may be due to the fact that time between the Statics and Dynamics courses was short. The same author taught and used the feedback methods in Solid Mechanics. The author often asked skill and concept questions of the students to test their ability to draw free body diagrams, write equations of equilibrium and determine reaction forces and moments. For example, without reviewing, the author tested the students on free body diagrams and equilibrium for trusses to introduce axial forces. Retention was

Table 4. Concepts in follow-on courses in 2004–2005

Course	Statics skill or concept	Percentage correct
Dynamics	Determine the vector position from one point to another (used in the kinematic equations for rigid bodies)	70.6
Dynamics	Determine the vector cross product (used in the kinematic equations for rigid bodies)	82.4
Dynamics	Determine the unit vector that describes the direction of motion of a pin in a slot	70.6
Dynamics	Compute the moment of a force about a point	85.7
Solid Mechanics	Draw the correct FBD of a pin joint of a truss	50.0
Solid Mechanics	Given the correct FBD of a pin joint, decompose the vector forces into x-y components and write the equilibrium equations	92.6
Solid Mechanics	Draw the correct FBD of an axially loaded bar	80.0
Solid Mechanics	Draw the correct FBD of a simply-supported beam	58.3

50 per cent for the correct free body diagram and 90 per cent for decomposing forces into components and writing the equilibrium equations. Table 4 is a summary that lists the follow-on courses, concepts that were taught in Statics and tested without review in the follow-on courses, and the percentage of students who answered correctly. While these results are 'tainted' with data by students who did not learn Statics in one of the two experimental sections in the Fall semester (there were a total of three Statics sections), they still are interesting preliminary findings.

CONCLUSIONS

Based on our results from the second year of our study, we can conclude that student scores in a Statics course were significantly associated with their prior performance in Calculus II and Physics I (both from the second semester of the freshman year). Most importantly, we found no difference between the scores when the students were provided with rapid feedback facilitated by the use of flashcards versus PDAs and software, something we found mildly surprising. In other words, it did not matter *how* one provided rapid feedback, so long as it was provided. Although we had thought that the 'coolness' of the PDA might affect a student's learning, it really would only affect their interest during the physical activity in class of reporting their answers. In the end their scores were not influenced by whichever of the two feedback methods used. In 2005 and 2006, our project will continue with a crossover design between two sections in which the treatment (using the PDAs) will be contrasted with the control (using no feedback method).

The final survey results indicated that students overwhelmingly felt that having rapid feedback of their state of learning was somewhat or very helpful to them, with a significant preference for the PDAs over the flashcards. Hence, although the use of PDAs versus flashcards did not affect the actual learning (measured by the analyses of the quiz scores), the use of PDAs was *perceived* by students to be more helpful to their learning than the flashcards. Finally, 65 per cent of the students believed that they would have performed worse in a course in which rapid feedback was not provided, while the remainder believed they would have performed at the same level (see Table 3).

The rapid feedback also had impacts on the authors as instructors. Regardless of the feedback method, we had to be more organized for each class and to plan ahead in preparing skill and concept questions and placing them appropriately in the lecture period. We also found that posing the feedback question was useful to get students to refocus or review even if a question was created "on the spot" during class. We observed that students took the feedback quizzes quite seriously, trying hard to answer correctly even though no grade was involved. This was an additional benefit in that the students were forced to think about the concepts now rather than later (or perhaps much later) when they sat down to do homework. The results of the rapid feedback questions also allowed us to note what concepts were most difficult for students and thus improve future instruction. While technical difficulties with the PDAs and set-up time may be slightly cumbersome, the authors believe that the benefits for the students and the faculty far outweigh these negatives.

We also believe that rapid feedback use improved knowledge retention (durability) and knowledge application in a different environment (transferability) in subsequent courses of Dynamics and Solid Mechanics as shown by preliminary results in these courses. The next phase of this study will include comparisons of students who did or did not use the rapid feedback method of instruction in Statics.

Acknowledgments—The authors gratefully acknowledge the support of the National Science Foundation through grants DUE-0243227 and EIA-0312868.

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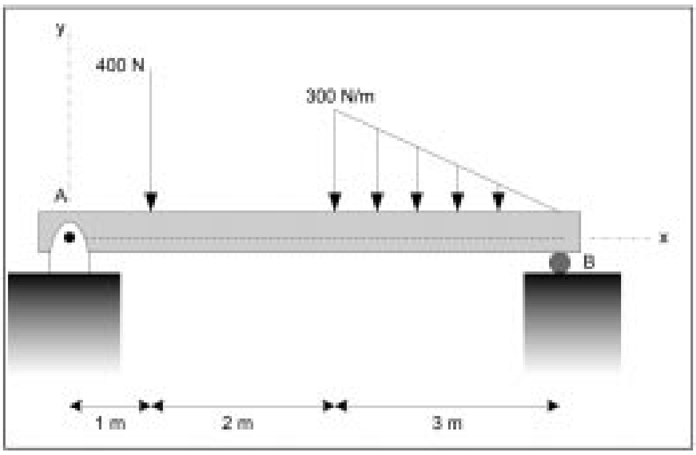
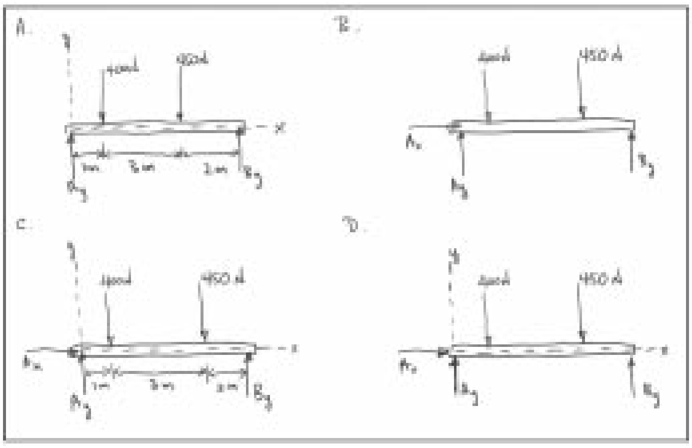
APPENDIX A

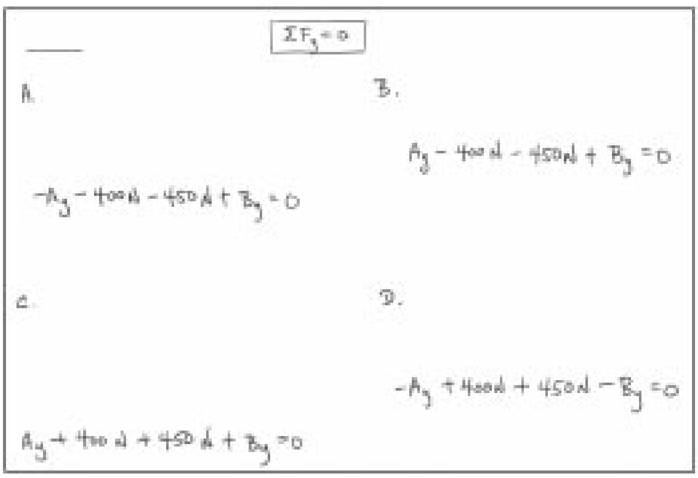
Example: A massless beam is loaded and supported as shown.



Choose the correct Free Body Diagram



Choose the correct equilibrium equation for the vertical direction



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