

Using tablet PCs to quickly assess students' problem-solving performance in an engineering dynamics classroom

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ABSTRACT: The vast majority of published literature on tablet PCs focuses on the benefits of their introduction and providing best practice tips. This article presents two representative examples of how to use tablet PCs to assess quickly students' in-class problem-solving capacity in a foundational engineering dynamics course. During lectures, the instructor digitally sent a set of dynamics problems to each student. Students worked on their tablet PCs and, then, submitted step-by-step solutions to the instructor. This enabled the instructor to detect quickly the errors that students made in problem-solving and to provide immediate feedback. An attitudinal survey that included four Likert-type items and one open-ended item was administered at the end of the semester. The survey results show that students thought tablet PCs helped their learning due to the instructor's immediate feedback. Compared to clickers (i.e. classroom response systems), students preferred tablet PCs, because tablet PCs increased instructor-student interactions and enabled the instructor to assess the process, rather than just the final results of students' problem-solving.

INTRODUCTION

Engineering Dynamics

Engineering dynamics is a foundational core course that most students in mechanical, aerospace, civil, biological and biomedical engineering programmes are required to take in the second year of their undergraduate study. Student learning outcomes in this course impact highly on many subsequent courses, for example, advanced dynamics, structures and design, and machine dynamics and control [1].

However, dynamics is also widely regarded as *...one of the most difficult courses that engineering students encounter during their undergraduate study* [2]. The course covers a broad spectrum of foundational concepts and principles, and requires students to have a solid understanding of both conceptual and procedural knowledge of dynamics, i.e. to have strong problem-solving skills such as analytical and mathematical modelling skills [1][2]. Lack of strong problem-solving skills is one of the major reasons why many students fail dynamics [3]. On the Fundamentals of Engineering examination in 2009, the national average score for the engineering dynamics examination was only 53% [4].

Tablet PCs

Due to the rapid development of computers, the Internet and wireless technologies in recent years, tablet PCs are increasingly used for applications in the science, technology, engineering and mathematics (STEM) education community. They enable users to write *digital ink* directly on the computer screen and have been employed in a variety of STEM courses, for example, physics, food chemistry, electric circuits, digital signal processing, engineering statics and fluid mechanics [5][7]. Originally, tablet PCs were sold at a high price and, therefore, were only employed by course instructors to deliver course lectures [7]. As prices have fallen, tablet PCs are now employed by both instructors and students as a real-time, interactive learning tool to increase student participation, as well as instructor-student and student-student interactions in either a physical bricks-and-mortar or an on-line classroom [8][9].

Lord and Perry described numerous attractive features of the tablet PC offered for faculty (academic staff), such as the ability to capture content for instructor review, the ability to incorporate multimedia features (e.g. simulations, Web sites or images), and the ability of the instructor to face students and be mobile during a lecture [10]. They compared five methods employed by faculty of delivering lectures and presentations: blackboard/whiteboard, transparencies, PowerPoint on laptop, PowerPoint on tablet PC and Classroom Presenter on tablet PC [10]. They concluded that *...the tablet PC course preparation may take more time initially but the updates and reuse far outweigh the initial investment*. In addition, a tablet PC can *...serve as a useful tool for our current students who are comfortable with technology and expect it to be part of their daily lives* [10].

Based on classroom observations, surveys and interviews, Koile and Singer investigated the benefits of using tablet PCs [11]. They concluded that the appropriate use of tablet PCs in the classroom could: 1) increase student focus and attentiveness in class; 2) provide immediate feedback to both students and instructors about student misunderstandings; 3) enable the instructor to adjust course material in real time based on student answers to in-class exercises; and 4) increase student satisfaction and self-perceptions.

The Present Study

The results of a literature review show that the vast majority of published literature on tablet PCs focuses on the benefits of introducing tablet PCs (from faculty and student perspectives) and providing best practice tips. For example, a significant amount of the literature reported that tablet PCs increase student engagement in learning through increased faculty-student interactions [5-11]. The study of how to use tablet PCs to quickly assess students' in-class problem-solving performances is still limited. Solid problem-solving skills have long been regarded as an essential requirement for STEM graduates [12].

This article reports the author's efforts to use tablet PCs to assess students' in-class problem-solving performances in an engineering dynamics course. The course was taught in a recent summer semester with a total of 16 students enrolled. The article provides two representative examples of how to assess students' in-class problem-solving performances quickly. These examples will particularly benefit instructors who plan to use tablet PCs to assess student problem-solving in their classes. The article also describes an attitudinal survey that was administered at the end of the semester. The survey included four Likert-type items and one open-ended item asking for students' attitude and experiences with tablet PCs that students used in the class. The limitations of the present study and the future work are also discussed, followed by conclusions.

REPRESENTATIVE EXAMPLES: QUICK ASSESSMENT OF STUDENTS' PROBLEM-SOLVING

Each student in the class was provided with a *tablet PC*. To minimise costs, it was a laptop computer equipped with a VT PenPad 7.7-inch graphic pen tablet, so students could write *digital ink* on the pen pad and the *digital ink* would simultaneously show on the computer screen. DyKnow Vision ™, a computer software package specifically designed for interactive learning, was employed to facilitate the commutations between the instructor's tablet PC and students' tablet PCs [13]. DyKnow Vision ™ allows the instructor to share and record content, assess understanding and interact with students in many different ways [13]. In the present study, the interaction between the instructor and the students in the class was conducted in the way described below.

During lectures, a set of dynamics problems was sent to each student in the class. Students were asked to work on their tablet PCs in class and submit to the instructor step-by-step solutions. Students' digital submissions included detailed free-body and kinetic diagrams that they drew, and all associated mathematical equations. Therefore, the instructor could quickly detect the errors that students made in solving particular dynamics problems and could provide immediate feedback.

After teaching a particular learning topic, such as *Planar Kinetics of a Rigid Body: Force and Acceleration*, the instructor used DyKnow Vision ™ to send a related dynamics problem for the students to solve in class. The process of problem-solving was divided into several steps. For example:

Step 1: draw a free-body diagram and a kinetic diagram;
Step 2: use Newton's second law to set up mathematical equations;
Step 3: determine if more equations are needed to solve unknown variable;
Step 4: solve the mathematical equations created in Steps 2 and 3.

To assess students' problem-solving performances, the instructor required the students to submit, via DyKnow Vision ™, their solutions to each step. The instructor provided immediate feedback on students' submissions. In cases in which the instructor detected a common mistake by students, the common mistake was highlighted on the instructor's tablet PC and then shared with all the students on their tablet PCs. Therefore, all the students in the class could learn from the common mistake. The following paragraphs describe two representative examples to demonstrate how the instructor employed tablet PCs to provide quick assessments of students' problem-solving performances.

Representative Example No. 1

Figure 1 shows a dynamics problem employed in the class [1]. The problem statement is described below. The disk has a mass of 20 kg and is originally spinning at the end of the strut with an angular velocity of $\omega = 60$ rad/s. If it is then placed against the wall, where the coefficient of kinetic friction is $\mu_k = 0.3$, determine the time required for the motion to stop. What is the force in strut BC during this time?

In Step 1, all students were required to submit a free-body diagram and a kinetic diagram for this dynamics problem.

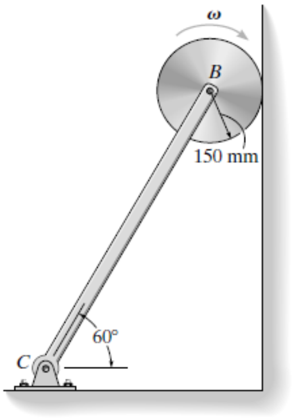
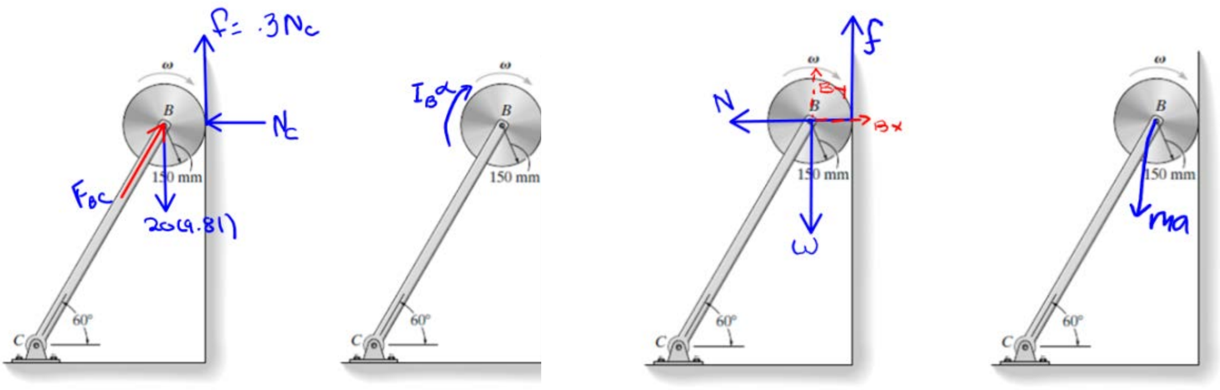


Figure 1: Example dynamics problem No. 1: a rod and a strut.

Figure 2 shows submissions from two students. The student who submitted Figure 2a correctly drew both free-body and kinetic diagrams. However, the student who submitted Figure 2b did not draw the kinetic diagram correctly. The latter student mistakenly used *ma* to replace $I_b\alpha$ on the kinetic diagram, which revealed that he did not understand the fundamental differences between rotational motion and translational motion. In fact, the disk B does not have translational motion in this case. Both Figures 2a and 2b were shared with, and explained, to all the students in the class, so students could compare correct and incorrect solutions and, then, learn how to develop correct solutions.

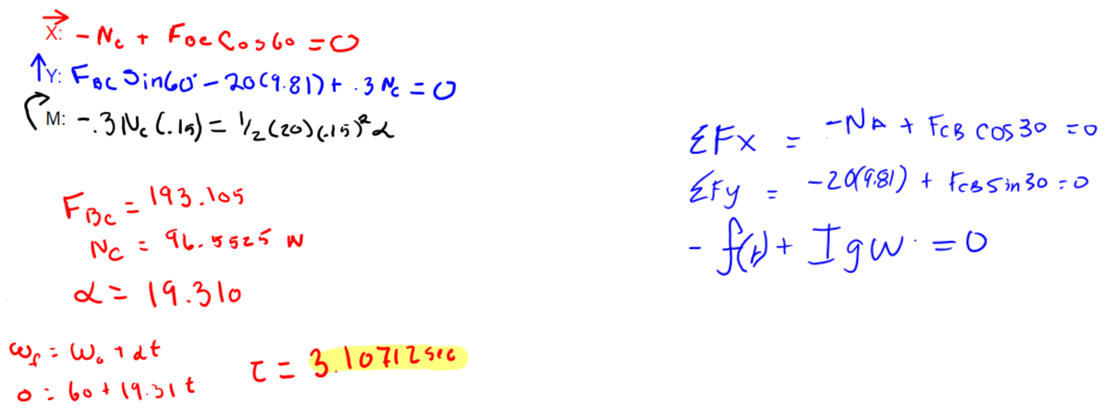


a)

b)

Figure 2: Free-body diagram and kinetic diagram: a) correct and b) incorrect.

Then in Step 2, students were required to submit the mathematical equations that they had set up. Figure 3 shows submissions from two students. Figure 3a shows correct equations. Figure 3b shows incorrect and incomplete equations. Figure 3b reveals that the student did not consider all the force or force components in either x- or y- directions; and the student could not correctly determine the moment generated by a force. The instructor provided immediate feedback to the student who submitted Figure 3b.



a)

b)

Figure 3: Mathematical equations that students set up: a) correct and b) incorrect.

Representative Example No. 2

Figure 4 shows another dynamics problem employed in the class [1]. The problem statement is described as follows: The cord is wrapped around the inner core of the spool. If a 5-lb block B is suspended from the cord and released from rest, determine the spool's angular velocity when t = 3 s. Neglect the mass of the cord. The spool has a weight of 180 lb and the radius of gyration about the axle A is k_A= 1.25 ft.

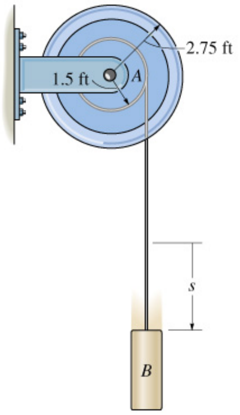


Figure 4: Example dynamics problem No. 2: a spool and a block.

The students were required to submit the free-body diagram and a kinetic diagram that they had drawn for this dynamics problem. Figure 5 shows a submission from one student, where the kinetic diagram is correct, but the free-body diagram is incorrect.

On the free-body diagram, the student did not include the force generated by the pin, which reflected either that the student overlooked it or did not have the knowledge. Furthermore, the student mistakenly thought the tension force T was equal to the weight of the block, which meant the student did not understand the difference between statics and dynamics. The instructor provided immediate feedback to the student and Figure 5 was also shared anonymously with all the students in the class.

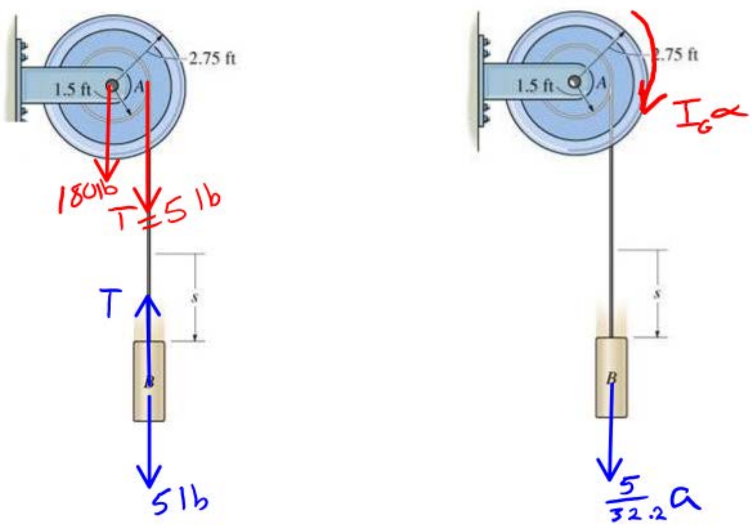


Figure 5: Free-body diagram (incorrect) and kinetic diagram (correct).

ATTITUDINAL SURVEY

At the end of the semester, students were asked to complete an attitudinal survey that included four Likert-type items and one open-ended item. Table 1 shows the four survey items and student responses. Figures 6 and 7 show the detailed student responses to each survey item.

As seen from Table 1 and Figures 6-9, overall, students had positive experiences with tablet PCs, particularly with survey items No. 2 and No. 4. Student responses to survey item No. 2 (*using tablet PCs improves my learning due to the instructor's immediate feedback*) had the second largest average rating (3.92) and the lowest standard deviation (0.64). For survey item No. 4 (*compared to clickers, I like tablet PCs better*), students gave the highest average rating 4 among the four survey items. Student responses to survey item No. 4 were not a surprise because the clicker technique (also called the classroom response system) only allows the instructor to assess the final results of students' problem-solving, but does not enable the instructor to assess the *process* of students' problem-solving [14][15].

Table 1: Survey items and student responses.

Survey items		Rating *					Average rating	Standard deviation
		1	2	3	4	5		
No.1:	Using tablet PCs increases my participation in the class.						3.69	0.95
No.2:	Using tablet PCs improves my learning due to the instructor's immediate feedback.						3.92	0.64
No.3:	Tablet PCs can fundamentally transform the way in which we learn engineering.						3.85	0.69
No.4:	Compared to clickers, I like tablet PCs better.						4.00	1.29

*1- highly disagree; 2 - disagree; 3 - neutral; 4 - agree; 5 - highly agree

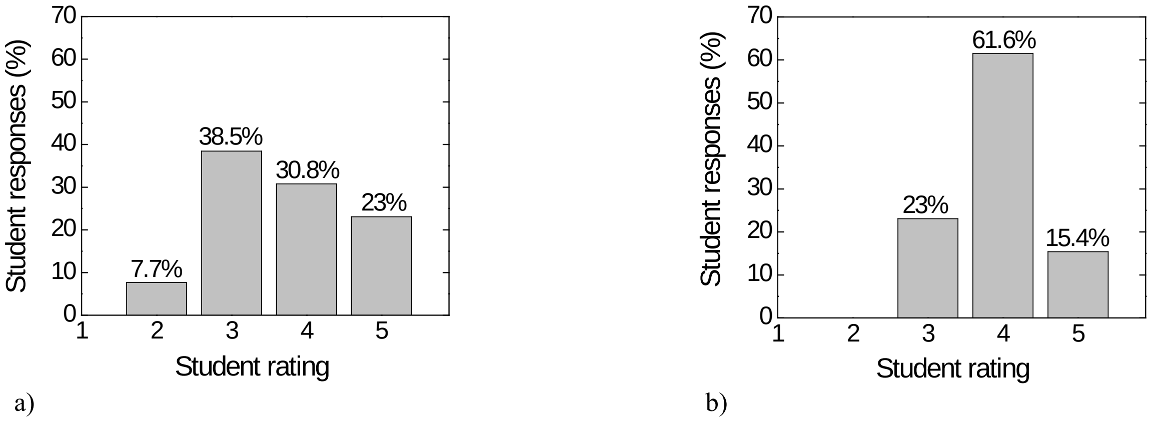


Figure 6: Student responses to a) survey item No. 1; and b) survey item No. 2.

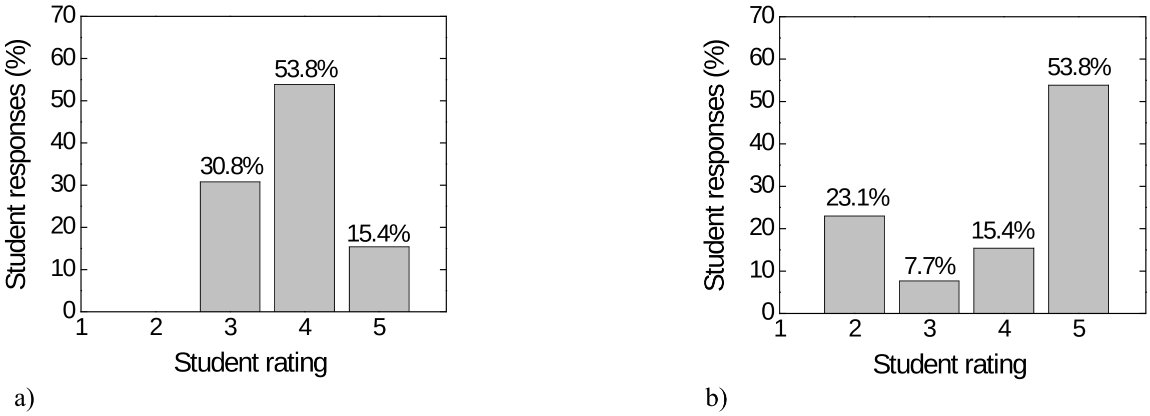


Figure 7: Student responses to a) survey item No. 3; and b) survey item No. 4.

Students' positive experiences with tablet PCs are also reflected in their responses to the open-ended survey item - *Describe your experiences, either positive or negative, with tablet PCs*. In their written responses to this open-ended item, students frequently employed the following words and phrases: *fast feedback*, *immediate feedback*, *quick feedback*, *instant response* and *more interactive*.

Representative student comments are:

- *Instructor feedback is good, and so is seeing other students' work.*
- *Class-wide participation and input and teamwork.*
- *I feel like tablet PCs are good for enabling more interaction with the class.*
- *Quick feedback and seeing many other good examples.*
- *All information, attempts, and notes are stored in an easy-to-find place and it is harder to lose notes.*

LIMITATIONS OF THE PRESENT STUDY AND FUTURE WORK

The present study has two limitations. First, the sample size of the study was small. Only 16 students registered for this summer engineering dynamics course. Second, the study included no control group, alternatively called a comparison group. From the results of the present study, it can be concluded that tablet PCs enable the instructor to assess students' problem-solving performance in dynamics quickly and provide students with immediate feedback. However, the present study cannot answer the research question: To what extent do tablet PCs improve student learning in engineering dynamics?

To answer the above research question, both a control group and an experimental group (also called a treatment group) must be included. Therefore, future work will include conducting a comparative research study that includes both control and experimental groups. In order to increase sample size, future study will also be conducted during a regular semester (spring or fall) when there are more students (typically between 80 and 120) registering for the dynamics course.

CONCLUSIONS

Students' problem-solving skills play a significant role in engineering dynamics. This article has reported the author's efforts to use tablet PCs to assess students' in-class problem-solving performance in engineering dynamics. Two representative examples have been provided to illustrate how the instructor could quickly detect the errors that students made in solving particular dynamics problems and, then, was able to provide immediate feedback to students.

The results of the attitudinal survey show that students thought tablet PCs helped their learning due to the instructor's immediate feedback. Students preferred tablet PCs over clickers because tablet PCs increased instructor-student interactions and enabled the instructor to assess the process, rather than just the final results, of students' problem-solving. Future work will include both a control group and an experimental group to determine the extent to which tablet PCs improve student learning in engineering dynamics.

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