AC 2011-2253: THE EFFECTIVENESS OF "PENCASTS" AS AN INSTRUCTIONAL MEDIUM

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The Effectiveness of “Pencasts” as an Instructional Medium

Abstract

A “pencast” is a type of video presentation in which recorded digital ink and audio are replayed in synchronization. To create a pencast, a Livescribe^{TM} “Smartpen” is used to record handwritten content with voice narration. An instructor can use a Smartpen to construct a pencast that replays the solution to a problem with synchronized explanation. Pencasts, are becoming a popular instructional tool, but their educational effectiveness has not been formally studied. Thus, we present a research study which compares the educational effectiveness of pencasts to that of traditional instructional media, specifically, electronic PDF documents. In each study session, students in a Statics course were given one of two tutorials. One tutorial was a pencast, the other was a PDF with identical content. Each session included a pre- and posttest to measure learning gains. The study comprised two sessions, one concerning belt friction problems, the other wedge friction problems. The study also included a survey of the students’ opinions about the two types of instructional media. While the two treatments provided equivalent and significant learning gains, there was a clear preference among students for the pencast tutorials.

Introduction

A “pencast” is a type of video presentation in which recorded digital ink and audio are replayed in synchronization. To create a pencast, a Livescribe^{TM} “Smartpen” is used to record handwritten content with voice narration. For example, an instructor can use a Smartpen to write the solution to a sample problem while explaining each step. When a student views the resulting pencast, the pen strokes and audio are replayed like a movie, with the explanation synchronized to the rendering of the strokes.

Several aspects of pencasts have led them to become a popular instructional tool. For example, in a pencast tutorial, the explanation is synchronized with the construction of the relevant graphical objects, whereas with printed instructional materials, the graphical objects and textual explanation must be interpreted separately and then integrated to provide a complete understanding. Additionally, because pencasts contain audio and animation, visual and auditory learners[1] may prefer them to traditional printed instructional materials.

Despite their popularity, the educational effectiveness of pencasts has not been formally studied. Thus, we present a research study aimed at comparing the educational effectiveness of pencasts to that of traditional instructional media, specifically, traditional electronic documents. In each study session, students were given one of two tutorials explaining the solution to a sample problem. In one treatment, the tutorial was a pencast containing a handwritten solution to the sample problem accompanied by spoken explanation. In the other treatment, the tutorial was an electronic PDF document. The content of the PDF and pencast tutorials were essentially identical — both covered the same solution steps, equations, and concepts. However, there were small differences in the presentation due to the inherent differences between spoken and written language. For example, in the pencast, the first step was introduced as “The first step is...”, while in the PDF, the steps were simply numbered.

Each session included a pre- and posttest to measure learning gains. The study comprised two sessions, the first employing belt friction problems, and the second wedge friction problems. The study also included a survey of the students’ opinions about the two types of instructional media.

An analysis of variance revealed significant learning gains from pre- to posttest for both pencasts and PDFs. However, the difference in gains between the two media was, for the most part, insignificant. The survey revealed that students clearly prefer pencasts to PDFs. Thus, in our study, the pencasts and PDFs performed equally well, but pencasts were preferred by students.

The next section places this work in the context of related work. This is followed by a description of the experimental design and our approach to assessing student performance. Next, our analysis of the data and the results are presented. Finally, conclusions are discussed.

Related Work

The use and effectiveness of pen-based tools for education are areas of active research. For example, several studies have investigated the use of tablet PCs in interactive learning environments. Tront[2] examined the usefulness of Classroom Presenter[3] in the context of a Computer Engineering course. This software, which runs on tablet PCs, enables students to: receive and view digital copies of the instructor’s lecture slides; annotate their own copies of those slides; and respond to in-class exercises, such as completing a multiple choice quiz or solving a sample problem. The instructor can anonymously present students’ solutions to these exercises to the class. This system enables the instructor to detect and address misconceptions. In this study, students kept journals detailing their experience with the tablet-based instruction. In general, student satisfaction with this learning environment was high, although the study did not measure learning gains of the interactive learning environment.

There have been several other studies examining the usefulness of tablet-based lecturing software.[4–7] These studies are usually conducted within a college level Computer Science or Engineering course. Surveys from these studies typically show that students are satisfied with the tablet-based instruction and prefer it over traditional lecture methods (i.e., lectures based on presentation slides or handouts in which students are encouraged to ask questions and solve example exercises). Only some of these studies measured learning gains. For example, Bravo[5] compared participants’ final grades to their entrance grade point averages (cumulative GPA prior to taking the course) for students who received tablet-based instruction and students who received traditional instruction. The variance of these measures was too high and the sample size too small to conclude whether tablet-based or traditional instruction provides greater learning gains. Enriquez[6] compared quiz, homework, and test scores of students in an Electric Circuits course who did receive tablet-based instruction to those who did not. In this study, there was significantly better performance by students who received tablet-based instruction.

The pencast tutorials studied in our current work differ from this type of tablet-based instruction. Pencasts provide a replayable presentation of handwritten solutions to problems along with spoken explanation. Students can control the replay and view the material at their own pace. By contrast, the tablet-based lecture software is intended for real-time interaction in the classroom.

Oviatt et al.[8] investigate the impact different digital pen-based interfaces have on a student's ability to solve geometry problems. The interfaces studied include an Anoto-based digital stylus and paper interface,[9] a pen tablet interface, and a graphical tablet interface. This work suggests that "as the interfaces departed more from familiar work practice..., students would experience greater cognitive load such that performance would deteriorate in speed, attentional focus, meta-cognitive control, correctness of problem solutions, and memory".[8] Note that in this study, these interfaces were used only to record student solutions, and unlike pencasts, did not present tutorial materials.

More recently, researchers have begun to create intelligent, pen-based tutoring systems. Newton's Pen[10] is a Statics tutoring system implemented using Smartpen technology similar to that used in our study. Newton's Pen scaffolds students in constructing free body diagrams and equilibrium equations for particle equilibrium problems. The system interprets a student's handwritten work and provides tutorial feedback in response to problem-solving errors. Similarly, Kirchhoff's Pen[11] is a tablet-based tutoring system used to teach Kirchhoff's Law. It also interprets a student's handwritten work and provides tutorial feedback in response to errors. The pencast tutorials we consider differ from these systems in that pencasts present prerecorded tutorial information, while these systems are interactive and provide feedback in response to student work.

Our work is most similar to research on the use of multimedia for instruction. Lieu[12] included an interactive multimedia CD as a supplement to the conventional course text book for an Engineering Graphics course. The contents of this CD helped students visualize graphical concepts covered in the class such as orthogonal projection. The CD presented concepts using a mixture of animation, audio, and interactive exercises. Responses to a survey at the end of the course typically showed that students found the CD to be more helpful than the textbook. Additionally, students claimed to spend 83% of their total weekly study time using the CD while only 10% of their study time was spent using their notes, and 3% was spent with their textbook. This study did not measure learning gains. Balci et al. [13] have developed web-based learning modules for eight different Computer Science topics. Each web module contains a number of interactive animations that are accessible over the internet. García et al.[14] developed a series of instructional animations using Macromedia Flash. These animations assist students in learning Descriptive Geometry, a branch of geometry focused on the representation of 3D objects on a plane. The animations were made to be interactive via pause, play, and rewind buttons. Survey results from this study show that the animated instruction is greatly preferred by students to traditional paper-based instructional materials, but no performance gains were reported. These animation-based instructional materials use complex graphical depictions, and include typeset text. These materials often resemble traditional lecture slides. Pencast tutorials, by contrast, contain natural handwritten solutions and spoken explanations.

Experimental Design

To compare the educational effectiveness of a pencast to that of a PDF, we conducted a study comparing learning gains achieved using tutorials presented in the two forms. The study included two sessions. A total of 62 students participated in the first study session, and 48 in the second. The participants were enrolled in an undergraduate Statics course at University of California, Riverside. This is a required course for Mechanical Engineering students and covers the usual topics: equilibrium in both 2D and 3D, trusses, frames and machines, distributed forces, and dry friction. The study was conducted during the ninth week of a ten week quarter.

Prior to the study, students had received a lecture on dry friction problems, but the application to wedges and belts had not been discussed. At the start of each session, students were given a brief, 10-minute lecture introducing the topic of that session via an example. For the belt friction study, this lecture introduced the belt slip equation and presented an example of a rope wrapped around a mandrel with a weight attached to each end. For the wedge friction study, the lecture example was a wedge used to split firewood. As the survey responses indicate, most students had not been exposed to wedge or belt friction prior to the study.

In each session, students were given one of two tutorials which explained the solution to a problem. In one treatment, the tutorial was a pencast containing a handwritten solution to the sample problem accompanied by a spoken explanation. In the other treatment, the tutorial was a static PDF with content identical to that of the pencast. The PDF contained text and precise images created with a graphics editor. Participants were each given their own computer to view the tutorial. Students viewing the pencast tutorial were also given headphones. A participant who received the pencast tutorial in the first session received the PDF tutorial in the second, and vice versa.

After the 10-minute lecture, and prior to viewing the tutorial, students completed a pretest problem. After viewing the tutorial, they completed a posttest problem. Within each treatment group, the problems used for pre- and posttest were alternated to control for order effects. Students were given as much time as they needed to complete the pre- and posttest problems, as we have found that students can typically complete such problems in under 10 to 15 minutes. Because of the limited time available for each study session, we did however, constrain viewing of the tutorials to 10 minutes. Students typically completed viewing the tutorials in less than the allocated time. Students were expected to complete the posttest problem without referencing the tutorials. Below, we describe the problems

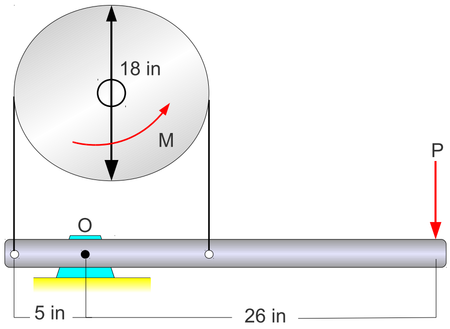

Figure 1: Belt friction tutorial problem. The student is asked to determine the force on the lever necessary to resist the moment applied to the flywheel.

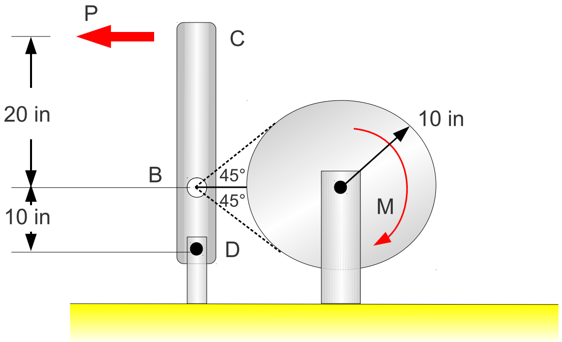

Figure 2: Belt friction problem A. The student is asked to determine the force on the lever necessary to resist the moment applied to the flywheel.

used for the tutorials and tests.

Belt Friction Problems

The belt friction tutorial problem, shown in Figure 1, concerns a band brake comprised of a lever, flywheel, and belt. The two ends of the belt are attached to the lever on either side of the pivot. The belt wraps around the flywheel with a wrap angle of 180°. Pressing on the lever engages the brake. The student is asked to determine the force on the lever necessary to resist the moment applied to the flywheel.

Belt friction problem A, shown in Figure 2, is another band brake and operates much like the one in the tutorial problem. In this case, however, both ends of the belt attach on the same side of the lever pivot and the belt ends attach at 45° angles rather than perpendicular to the lever. There is an additional superficial difference: the lever is vertical rather than horizontal as in the tutorial. Here again, the student is asked to determine the force on the lever necessary to resist the moment applied to the flywheel.

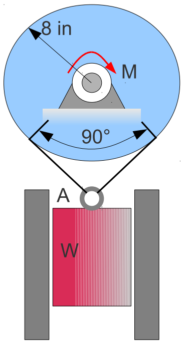

Figure 3: Belt friction problem B. The student is asked to determine the largest moment that can be applied to the flywheel without causing it to slip.

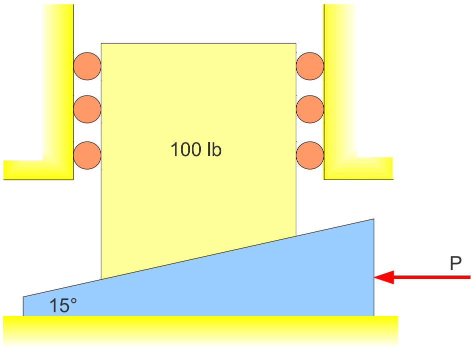

Figure 4: Wedge friction tutorial problem. The goal is to determine the minimum force P necessary to raise the block.

Belt friction problem B, shown in Figure 3, concerns a device comprised of a weight, two guides, a belt, and a flywheel. The two ends of the belt are attached to the weight at a single point. Similar to problem A, the ends attach at 45° angles. The frictionless guides constrain the weight to move vertically. In some sense, this problem is like problem A with the weight being equivalent to an infinite lever. The student is asked to determine the largest moment that can be applied to the flywheel without causing it to slip.

Wedge Friction Problems

The wedge friction tutorial problem, shown in Figure 4, involves a wedge used to lift a block. The wedge rests on a horizontal surface and has friction on both faces. The block is constrained to move vertically by frictionless rollers. The student is asked to determine the minimum force necessary to raise the block.

Wedge friction problem A, shown in Figure 5, can be thought of as a rotated version of the tutorial problem. It is comprised of a wedge, block, and spring. The spring pushes the block horizontally, which in turn presses the wedge against an incline. Both faces of the

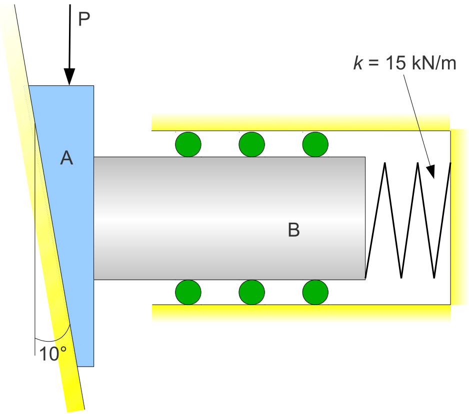

Figure 5: Wedge friction problem A. The student is asked to determine the minimum force P needed to push the wedge downward.

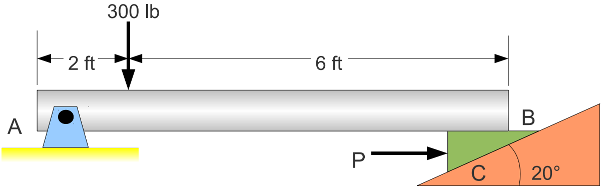

Figure 6: Wedge friction problem B. The student is asked to determine the minimum force P needed to move the wedge up the ramp.

wedge are subject to friction, while frictionless rollers constrain the block to move horizontally. Students were asked to determine the minimum downward force needed to overcome friction and move the wedge down.

Wedge friction problem B, shown in Figure 6, is comprised of a lever, wedge, and ramp. Again, there is friction on both faces of the wedge. Students were asked to find the minimum force needed to move the wedge up the ramp, thus raising the beam.

Assessing Student Performance

To evaluate the effectiveness of the pencast and PDF tutorials, we assessed each student's pre- and posttest performance. We evaluated performance in terms of the number of errors made. To that end, we first identified the major steps involved in solving the problems: constructing the free body diagrams (FBDs), creating the corresponding equilibrium equations, and applying the slip conditions. We then enumerated the major conceptual errors a student could make in each of these steps, such as omitting a force from an FBD, or constructing an equilibrium equation that is inconsistent with its referent FBD. Each error has a corresponding *error indicator*: a binary-valued measure which is marked 1 when a student makes such an error, and 0 otherwise.

For most elements, one indicator represents errors with the element, and a second represents the omission of the element. For example, there is one indicator for an incorrect tension force, and another for a missing tension force. If an element is missing, we record this as being both incorrect and missing.

A student who does not attempt a solution step demonstrates a lower level of understanding than a student who does attempt that step but makes errors. To ensure that the assessment method reflects this, all error indicators of a solution step are marked as incorrect if a student made no attempt at that step.

In the following section we describe the major problem-solving steps and corresponding error indicators for both the belt and wedge friction problems.

Belt Friction Error Indicators

Our assessment of performance on belt friction problems considers five major solution steps: constructing the flywheel FBD; constructing the equilibrium equation for the flywheel; constructing the lever or weight[*] FBD; constructing the equilibrium equation for the lever or weight; and applying the belt slip relation.

The complete list of error indicators for the belt friction problems is included in Table 1. The indicators for FBDs concern the presence and correctness of the required forces. Here we differentiate between tension, reaction and applied forces/moments. The indicators also consider forces erroneously included on the FBD. Here we also differentiate between forces that are internal to the FBD, and other erroneously included forces. Internal forces are those that occur inside the system, and thus should not appear on the FBD. The indicators for the equilibrium equations also concern the presence and correctness of the required forces, and the presence of extraneous forces. Additionally, there is an indicator concerning inconsistency of the equilibrium equation with its associated FBD.

The construction of FBDs and corresponding equilibrium equations relied on general Statics concepts which the students learned in the eight weeks leading up to this study, although the application of these concepts to belt and wedge friction problems was new. By contrast, the last solution step, applying the belt slip relation, involved a concept most students had only been introduced to in the 10-minute lecture at the start of the study session. The belt slip relation is expressed by the equation: $\frac{T_1}{T_2} = e^{\mu\beta}$, where T_1 and T_2 are the two tension forces on the belt ends, β is the belt wrap angle, and μ is the coefficient of static friction. This equation can be used to determine the maximum tension that can be applied to the belt before slip occurs. For this step, a single error indicator is used which measures whether the belt slip relation was correctly used or not.

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[*] Although, problem A has a lever whereas problem B has a weight, the solution steps are identical and thus we discuss them in tandem.

Solution Step	Errors
Constructing the flywheel FBD	Tension force incorrect Tension force missing Reaction force incorrect Reaction force missing Applied force or moment incorrect Applied force or moment missing Internal friction force included Extraneous force included
Constructing the flywheel equilibrium equation	Tension force incorrect Tension force missing Applied force or moment incorrect Applied force or moment missing Extraneous force or moment included Inconsistent with its associated FBD
Constructing the lever or weight FBD	Tension force incorrect Tension force missing Reaction force incorrect Reaction force missing Applied force or moment incorrect Applied force or moment missing Internal friction force included Extraneous force included
Constructing the lever or weight equilibrium equation	Tension force incorrect Tension force missing Applied force or moment incorrect Applied force or moment missing Extraneous force or moment included Inconsistent with its associated FBD
Applying the belt slip relation	Belt slip relation applied incorrectly

Table 1: Error indicators used to assess student performance on the belt friction problems.

Wedge Friction Error Indicators

Our assessment of the wedge friction problem solutions considers six major solution steps: constructing the beam or block[†] FBD; constructing the equilibrium equation for the beam or block; constructing the wedge FBD; constructing the X- and Y-force equilibrium equations for the wedge; and applying the slip relation.

The complete list of error indicators for the wedge friction problems is included in Table 2. The indicators for FBDs concern the presence and correctness of the required forces. Here we differentiate between friction, normal, and other forces. As students often modeled the beam or block as part of a composite system that included the wedge, we consider the erroneous presence of internal friction and normal forces. The error indicators also consider the erroneous presence of other extraneous forces. In creating the wedge FBD, students sometimes used the wrong angles for the forces. This is represented by the "wrong wedge angle" indicator. As before, the indicators for the equilibrium equations concern the presence and correctness of the required forces, and the presence of extraneous forces. Wedge friction problems typically contain multiple normal and friction forces. The error indicators explicitly consider the inclusion of normal and friction forces that should not appear in the equilibrium equation ("improperly included"). There is also an indicator concerning inconsistency of the equilibrium equation with its associated FBD.

The final solution step for the wedge problems concerns the application of the slip relation. This is expressed by: $F = \mu N$, where F is the maximum friction force, μ is the coefficient of static friction, and N is the normal force. This equation can be used to determine the maximum force that can be applied before slip occurs at the contact surfaces. Students had previously used this slip relation, but not in the context of wedge problems. For this solution step, a single error indicator is used, indicating if the slip relation was correctly used or not.

Results

In our analysis, we consider one between subjects variable, tutorial treatment — pencast vs. PDF, and one within subjects variable, pre- vs. posttest. For both the wedge and belt friction problems, we performed an analysis of variance (ANOVA) to determine whether these variables had a significant impact on student performance. Rather than considering the indicators separately, we compute the mean indicator value for each of the major problem-solving steps. For example, the performance on the lever or weight FBD for the belt problems is characterized by the mean of the values of its eight indicators. We refer to these means as the "mean error-indicator values".

[†] While problem A concerns a block and problem B concerns a beam, the solution steps for both are identical and thus we discuss them in tandem.

Solution Step	Errors
Constructing the beam or block FBD	Friction force incorrect Friction force missing Normal force incorrect Normal force missing Other forces incorrect Other forces missing Internal friction or normal force included Extraneous force included
Constructing the beam or block equilibrium equation	Friction force incorrect Friction force improperly included or missing Normal force incorrect Normal force improperly included or missing Other forces incorrect Other forces missing Extraneous force included Inconsistent with its associated FBD
Constructing the wedge FBD	Friction forces incorrect Friction forces missing Normal forces incorrect Normal forces missing Other forces incorrect Other forces missing Extraneous force included Wrong wedge angle
Constructing wedge X- or Y-force equilibrium equation	Friction force incorrect Friction force improperly included or missing Normal force incorrect Normal force improperly included or missing Other forces incorrect Other forces missing Extraneous force included Inconsistent with its associated FBD
Applying the slip relation	Slip relation applied incorrectly

Table 2: Error indicators used to assess student performance on the wedge friction problems.

Belt Problems

The pre- and posttest mean error-indicator values for the belt problems for each of the tutorial treatments are presented in Figure 7. Each graph in the figure shows the mean error-indicator values for one of the five major steps required to solve the belt friction problems.

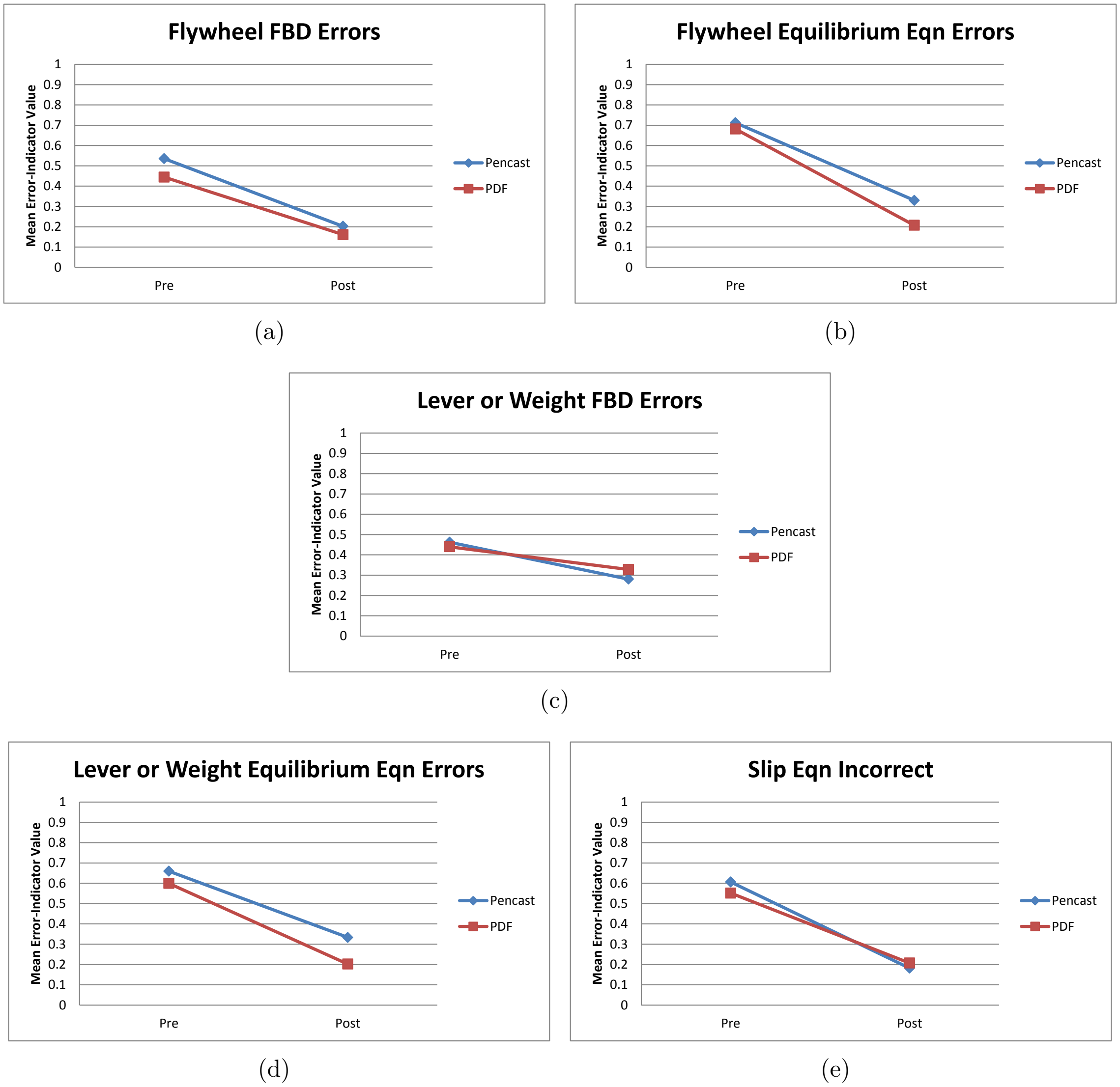
For both treatments, there were clear learning gains. For both the PDF and pencast treatments, there was a statistically significant reduction in the mean error-indicator values on the posttest compared to the pretest ($F = 106.06$, $p < 0.001$). Moreover, both treatments resulted in nearly equivalent learning gains — the slopes of the two traces in each plot are effectively the same. For both the FBD error indicators and the slip equation error indicators, the difference in learning gains between treatments was not significant. More specifically, the reduction in the FBD mean error-indicator values from pre- to posttest for one treatment was not significantly different from that of the other ($F < 1.0$, $p > 0.1$). Similarly, the reduction in the slip equation mean error-indicator values from pre- to posttest for one treatment was not significantly different from that of the other ($F < 1.0$, $p > 0.1$). However, the difference in the reduction in the equilibrium equation error indicators from pre- to posttest approached a significant difference ($F = 4.1$, $p < 0.1$), with the PDF having slightly larger gains.

Wedge Friction Problems

The pre- and posttest mean error indicator values for the wedge problems for each of the tutorial treatments are presented in Figure 8. Most graphs in the figure show the mean error values for one of the major steps required to solve the wedge problems. There is one exception, however. Because steps four and five (creation of the X- and Y-force equilibrium equations) have identical error indicators, we have combined them in our analysis by computing one mean error-indicator value for the set of indicators from the two steps (Figure 8.d).

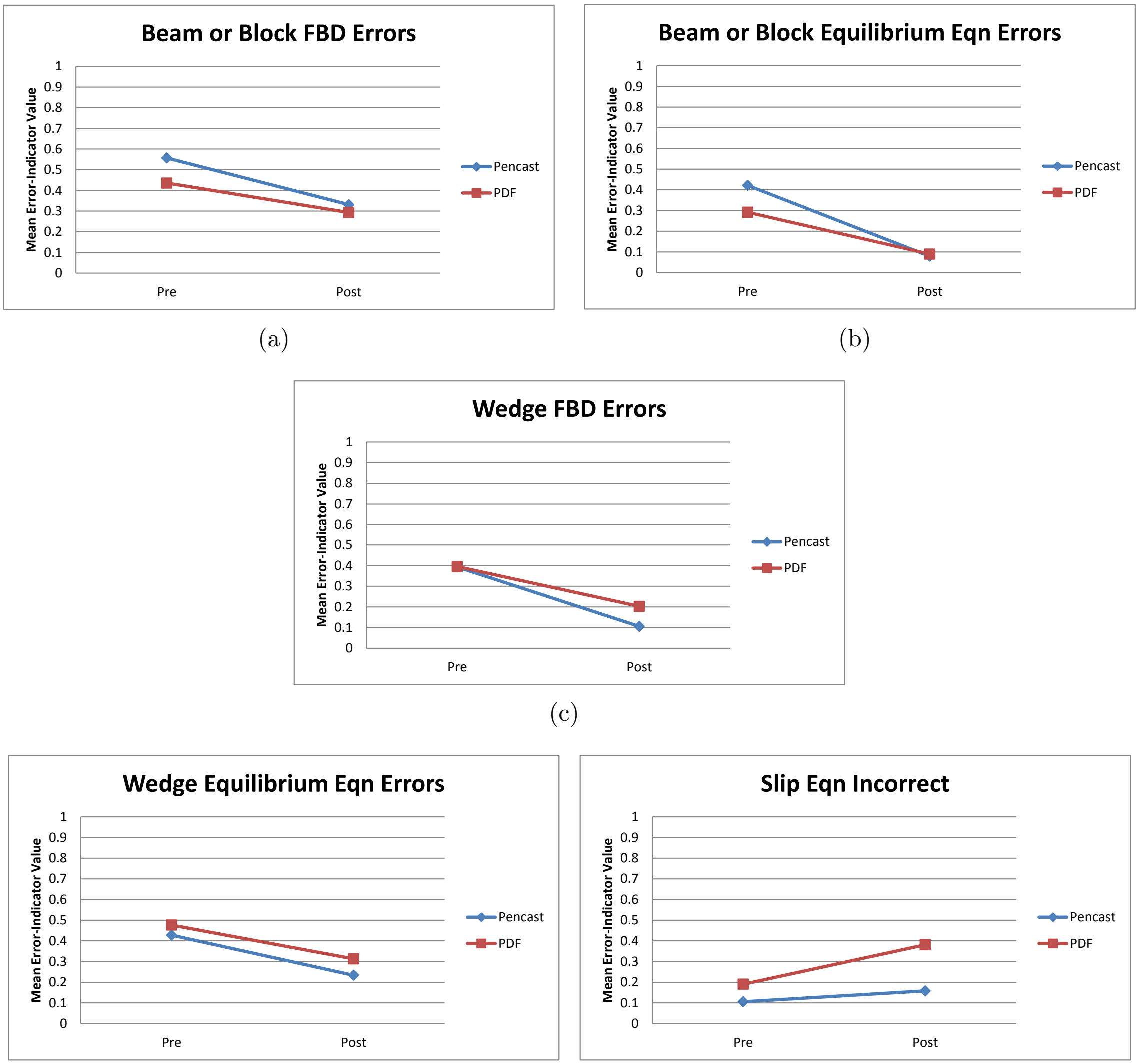
There were clear learning gains for both tutorial treatments for the FBD and equilibrium equation steps. More specifically, there was a statistically significant reduction in the mean error-indicator values from pre- to posttest for both the FBD ($F = 28.8$, $p < 0.001$) and equilibrium equation ($F = 35.2$, $p < 0.001$) steps. Interestingly, for both treatments there was an increase in slip equation errors from pre- to posttest. ANOVA revealed that this increase was not significant, thus it is difficult to draw conclusions from this observation.

For the wedge problems, both treatments resulted in nearly equivalent learning gains. For all mean error-indicators, the difference in learning gains between treatments was not significant ($F <1.0$, $p > 0.10$).



(a) (b) (c) (d) (e)

Figure 7: Mean error-indicator values from the pre- and posttest for each of the belt friction solution steps. (a) Flywheel FBD errors. (b) Flywheel equilibrium equation errors. (c) Lever or weight FBD errors. (d) Lever or weight equilibrium equation errors. (e) Slip equation errors. A decrease from Pre to Post indicates improvement in student performance. Equilibrium equation errors (b) and (d) are the only cases in which there is a statistically significant difference in the error reduction between the two treatments.



(a) (b) (c) (d) (e)

Figure 8: Mean error-indicator values from the pre- and posttest for each of the wedge friction solution steps. (a) Beam or block FBD errors. (b) Beam or block equilibrium equation errors. (c) Wedge FBD errors. (d) Wedge equilibrium equation errors. (e) Slip equation errors. A decrease from Pre to Post indicates improvement in student performance.

Survey Results

Each session included a survey of the students' preparation and opinions about the two types of instructional media. The questions and responses from both surveys have been combined in Table 3 in the Appendix. The first five questions concern the students' prior familiarity with the subject matter of the study. The remaining questions concern their tutorial treatment preference.

The responses to questions 1–5 indicate that, in general, students were not very familiar with wedge or belt friction problems prior to the start of the study session (i.e., prior to the 10-minute lecture). Furthermore, most students had not previously seen any of the problems used in the study.

Discussion

Figures 7 and 8 show that in all but one case (Figure 8.e), there is a reduction in the number of errors from the pre- to posttest for both tutorial treatments. This gives a strong indication that students did indeed gain a better understanding of the subject matter by viewing the tutorials. The slip equation step for the wedge problems is the odd exception to this trend, as there is a slight increase in the number of errors from the pre- to posttest. However, ANOVA suggests that this increase is not significant, and thus it is difficult to draw conclusions.

ANOVA revealed that for all but two solution steps — the equilibrium equation steps for the belt friction problems (Figures 7.b and 7.d) — there is no significant difference in the learning gains between students who viewed the pencast and PDF tutorials. For the two exceptions, the the PDF provides only a slightly greater reduction in errors than the pencast. Thus, this study provides evidence that the two media achieve equivalent educational effectiveness.

This finding belies our early intuition that pencasts with audio and animation would be more effective than PDFs for auditory and visual learners. It is possible that the limited time and scope of our study may be insufficient to reveal such an effect. A longitudinal study conducted over the complete duration of a Statics course and considering a wider range of Statics concepts may reveal a more appreciable difference in learning gains between the two media.

Survey responses indicate that a majority of students had not encountered either belt or wedge friction problems or concepts prior to the study. Thus, this study evaluates the usefulness of pencast and PDF tutorials in a context in which students have little familiarity with the subject.

Contrary to our experimental design, a few students in the pencast treatment group of the first study session continued to view the tutorial when they began the posttest. In particular, three students with posttest B, and four students with posttest A did this. After only a few minutes had elapsed, these students were informed that they should stop viewing the tutorial, and they completed the remainder of the posttest without it. Because only a few students did this, it should have a negligible effect on our results, and thus we included their data in our analysis. In the second session, no students viewed the tutorials during the posttest.

Responses to survey questions 7–9 demonstrate that students have a clear preference for the pencast tutorial over its PDF counterpart. While question 6 shows that in general students found both tutorials useful, there is a larger number of students who found the pencast very useful (14 students) compared to the PDF (3 students). While the survey clearly indicates that students prefer pencasts over the PDFs, it does not consider which properties of a pencasts, such as the audio or the animation, make them preferable.

Here, pencasts were compared with another self-study material, PDFs. What was not investigated, but is of equal interest, is the use of pencasts as a substitute for face-to-face instruction.

Conclusions

We have presented a research study comparing the educational effectiveness of pencasts to that of traditional instructional media, specifically an electronic PDF document. A pencast is a type of video presentation in which recorded digital ink and audio are replayed in synchronization. In each study session, students in a Statics course were given one of two tutorials, one in the form of a pencast, the other in the form of a PDF with identical content. Each session included a pre- and posttest to measure learning gains. The study comprised two sessions, one concerning belt friction problems, the other wedge friction problems. Student performance on the pre- and posttest problems was measured in terms of problem-solving errors related to the construction of free body diagrams and equilibrium equations, and the application of the slip relation. The study also included a survey of the students' opinions about the two types of instructional media.

The results of the study demonstrate significant learning gains for both tutorial modes. Furthermore, both modes achieved essentially equal learning gains. However, results of the survey revealed that students have a strong preference for the pencast over the PDF. Thus, while both media are effective instructional tools, students prefer pencasts.

Acknowledgements

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Appendix

Q1. How familiar were you with with wedge/belt friction problems prior to today's lecture?		Survey 1	Survey 2
Reponses	Very familiar	3	1
	Moderately familiar	16	19
	Unfamiliar	29	39
Q2. How comfortable were you with wedge friction problems after today's brief lecture?		Survey 1	Survey 2
Responses	Very comfortable	3	6
	Moderately comfortable	32	18
	Uncomfortable	13	35
Q3. How familiar were you with the pretest problem prior to today's class?		Survey 1	Survey 2
Responses	Previously solved it	1	0
	Previously saw solution	3	3
	Never saw it before	44	56
Q4. How familiar were you with the pretest problem prior to today's class?		Survey 1	Survey 2
Responses	Previously solved it	4	1
	Previously saw solution	5	4
	Never saw it before	39	54
Q5. How familiar were you with the posttest problem prior to today's class?		Survey 1	Survey 2
Responses	Previously solved it	3	2
	Previously saw solution	4	4
	Never saw it before	41	53
Q6. How useful was the tutorial problem in preparing you to solve the posttest?		Survey 1	Survey 2
PDF Responses	Very useful	3	9
	Moderately useful	18	17
	Not useful	2	1
Pencast Responses	Very useful	14	12
	Moderately useful	11	20
	Not useful	0	0
Q7. If you participated in session 1, which type of tutorial presentation do you prefer?		Survey 1	Survey 2
Responses	Strongly prefer traditional written document	N/A	2
	Moderately prefer traditional written document	N/A	6
	Have no preference	N/A	3
	Moderately prefer pencast	N/A	14
	Strongly prefer pencast	N/A	22
	Didn't participate in session 1	N/A	1
Q8. If you participated in session 1, would you prefer tutorial problems presented as:		Survey 1	Survey 2
Responses	Traditional written document	N/A	10
	Have no preference	N/A	6
	Pencast	N/A	29
	Didn't participate in session 1	N/A	3
Q9. If you participated in session 1, would you prefer homework solutions presented as:		Survey 1	Survey 2
Responses	Traditional written document	N/A	8
	Have no preference	N/A	5
	Pencast	N/A	28
	Didn't participate in session 1	N/A	0

Table 3: Survey questions and responses from both sessions. Questions 1–6 appeared in the surveys for both sessions, while questions 7–9 appeared only for the second session.