AC 2012-5110: USE OF SUPPLEMENTARY ONLINE LECTURE MATERIALS IN A HEAT TRANSFER COURSE

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Abstract

Students are often looking for internet resources to supplement college courses. Solutions manuals for course textbooks are readily (if illicitly) available and reduce the amount of time students spend outside of class actually learning to problem-solve. At the same time, the content for many courses is readily available online in many forms - some reliable, some not. There are currently valid concerns about both of these trends; related to the ability of students to solve problems independently and the quality of the information they may find online (due to poor information literacy).

Pencasts® provide a way to have students become familiar with course content outside of class, leaving more time in class for problem-solving exercises and discussion and explanation of lecture materials. A Pencast® consists of a video that displays the written work of the instructor with overlayed audio explanations; this is accomplished with a smartpen and a notebook with small, closely-spaced dots (dot paper). The smartpen records the audio and captures the pen movements as written on the dot paper. The resulting videos can be used for lecture content, example problems, demonstration of a process, or course announcements. Pencasts® allow quick production of schematics, equations, and sketches (with accompanying audio) which have been much more difficult to produce.

We have begun to implement the following strategy in a senior level course in heat transfer: use of Pencasts, including lecture and examples, as the "homework" outside of class and use of student problem-solving with immediate feedback in class. The results of the initial implementation of this strategy are reported, including results of the pre/post Heat Transfer Concept Inventory (HTCI).

Introduction

The availability of information for students, including worked problems in all engineering disciplines, is probably at an historic high. Although these are potentially useful resources they can clearly be abused or misused. In a Google search (search term: "*heat transfer solutions manual Incropera*") [1] to attempt to find a solutions manual for a popular heat transfer book by Incropera et al.[2] seven out of first ten non-sponsored hits are from peer-to-peer "torrent" sites, user-upload file hosting sites, or cramster.com (looking at the first 100 hits also yields similar statistics). Whether we want them to or not, students can and do get these manuals.

The author (Lemley) teaches a senior level course in Heat Transfer at the University of Central Oklahoma (UCO) for Engineering Physics-Mechanical Systems students. This paper describes an attempt *to have student's devote time outside of this class engaged in learning lecture material and problem-solving using "play-pause-rewind" (PPR) technology*. This approach was adopted to guide student's use of time outside of class and take advantage of a recent economical technology, which makes production of these PPR resources accessible to instructors at all levels. An additional factor in choosing to introduce new resources for the students in this course was the decline of mathematical skills and engineering problem-solving skills revealed by local surveys of senior students in the program, and additional resources could begin to address these issues.

Pause-Play-Rewind (PPR) Technology

PPR technology for instruction/lecture is not new, but new products do make it possible for a lone instructor to produce resources for students in their classes without a production studio or the help of the information technology office. The particular product that has been effective for the author (Lemley) is a Livescribe™ Echo™ smartpen[3]. The pen uses a camera to capture written notes on a special grid paper (the grid allows software in the pen to decode the pen tip location as a function of time). In addition to capturing these images, the pen also contains a microphone to capture audio. Software, LiveScribe Desktop with Livescribe Connect™ [4], then allows the user to transfer the "pencasts" to a computer or to one of several online locations, including Google Docs[5] and Evernote[6]. One possible format for the pen output is in Adobe's portable document format[7] (pdf). The newest version of the Adobe Reader supports multimedia. The saved pdf actually contains a movie that shows the recorded images of the pen that is matched to the recorded audio from the pen. The observer can control the playback of the pdf-movie – hence the pen and related software allows creation of PPR instructional media.

One example of the utility of PPR instructional media is that a student can gradually work through a difficult example problem, making sure they understand each step in the explanation. Left to attempt capture of the example in class or drill sessions by taking notes, students often miss key points of an explanation, or, even if everything said by the instructor is noted by the student, the later decoding of the notes by the student (if attempted), may also miss key points. Having access to the pencast allows the student to watch (and re-watch) the problem-solved as it was in class with all the sensory input of the classroom – except, potentially, visual contact with the instructor.

Pedagogical Considerations

Although the approach that was tried here has an online component, it is not a purely online class; this class was run primarily as a traditional class. Purely online classes in engineering are somewhat rare[8]. The most common term applied to this approach is "blended" learning[9]. For the most part, regular lectures were given in this class. The author's goal is to transition this class to an inverted classroom[10-11], where lecture-materials are primarily learned outside of the classroom and the classroom is used for other activities (such as problem-solving). This paper reports an initial attempt to move toward an inverted classroom in this class, and makes no claims that an inverted classroom that uses the PPR media described will be effective compared to other approaches.

One possible criticism of the approach that was adopted here is the somewhat "passive" learning that students do while watching the PPR media. It should be pointed out that in this class, in addition to the PPR media and in-class sessions, the students also worked homework problems, took quizzes and exams, and carried out a computational-based project. So a lot of hands-on problem-solving took place. But the "passive" nature of these technologies brings up an important question: what is the most effective way for students to learn to work heat transfer problems or other engineering problems? There has been much published regarding *active learning* and *discovery learning*, which derive mostly from the constructivist movement in psychology, see Phillips[12]. Entire curricula have been developed and certainly classroom instruction has been generally affected by this movement. More recently, *pure* discovery learning has been called into question[13-15]. It appears that guided learning certainly works best, and in novice learners, *observing worked examples actually works best*[15-16]. It may not be clear whether our students are novices or not, but providing students with PPR media, including worked examples and other content, along with their own problem-solving, should help students with a wide range of preparation.

Concept Inventories

The *concept inventory* was initially developed to assess gains made by beginning physics students in mechanics in the inventory called the *Force Concept Inventory*[17]. The use of concept inventories has now been extended into various engineering areas as seen on the *CiHub* housed at Purdue University[18]. The initial Heat Transfer Concept Inventory (HTCI) introduced by Jacobi et al.[19] was developed in 2003, and updated in 2006, and is now available to faculty through ciHub.org[20]. The HTCI contains 30 questions that cover basic concepts/energy balances (10%), steady-state conduction (40%), transient conduction (10%), convection (23%), and radiation (17%).

The HTCI was used as a pre-test and post-test in the class described in this paper. The pre-test was administered on the first day of class and the post-test was taken during a portion of the final exam time for the course. One way to look at the data is to calculate a G*ain*, *G*, from the pretest to the post-test as:

$$G = \frac{S_{post} - S_{pre}}{100\% - S_{pre}} \qquad (1)$$

Where S_{post} and S_{pre} are the post- and pre-test percentage scores, respectively.

Results

In the Fall 2011 offering of Heat Transfer at UCO, PPR media was created as supplemental material. The enrollment in this class was 13 undergraduate students. A total of about 320 minutes of PPR media was produced and made available to the students in the class. These PPR media primarily cover an overview of heat transfer and conduction heat transfer, although a small amount of PPR material on convection heat transfer was produced as well. The approximate breakdown of the media was: 14% basic concepts, 67% steady-state conduction, and 19% convection. A sample page of a document is shown in Figure One. Note this is a static image of the document and hence does not demonstrate the PPR features of this approach.

One issue that arose in producing the PPR media was the loss of the transfer cable required to upload the media to an online location. The replacement cable is non-standard and must be obtained from the pen manufacturer. Production of the media can be time consuming as well and despite not requiring a recording studio, should be done in a relatively quiet location.

For the most part the method of recording lecture notes and examples was performed in the author's (Lemley) office, but one other technique was tried in a few cases (and is currently being used by the author in other classes): using the smartpen directly during class-time. This was accomplished in a classroom equipped with a document camera that could be displayed on a screen as the author wrote and spoke. An advantage of this technique is the ability to quickly build a library of PPR media from each class meeting, as well as capturing the lecturer's enthusiasm while interacting with students in class (as opposed to somewhat dry presentations achieved in the office environment). Disadvantages of this technique are that the audio obtained in class is typically lower quality and despite the positive value of student questions and comments being recorded, issues of student permission to post the media can arise.

The overall gain of the 13 students that took the HTCI was 18% from the pre-test to the post-test as calculated with Eq. (1). It should be noted that the HTCI has not been used previously at UCO, so *unfortunately, it was not possible to use previous classes as a control group to attempt to ferret out the sole effects of using PPR media*. The author (Lemley) decided that given the access to the smartpen, rather than delaying a year to get HTCI results, that building a library of worked examples and lectures and giving students access to these took priority. Even though PPR was used in this instance, the class was run mostly in traditional mode, so the HTCI from this instance can be used to compare to future instances where the classroom is truly inverted and using PPR.

One other way to assess the effects of the course (including the PPR media) is to look at improvement by students as a function of test area. *This improvement was not calculated as a Gain*, but instead as the percent improvement of the class on average in each test subject area as:

$$PI_i = \frac{C_{i,post} - C_{i,pre}}{C_{i,pre}} 100\%$$

Where PI_i is the percent improvement for subject area i of the HTCI, $C_{i,pre}$ is the class average fraction correct on the HTCI pre-test for subject area i, and $C_{i,post}$ is the class average fraction correct on the HTCI post-test for subject area i. The students had the following PI_i values: basic concepts/energy balances: 31%, convection: 58%, radiation: -4%, steady-state conduction: 45%, and transient conduction: 36%. These improvements are cited without confidence intervals, due to the small numbers of students and of questions in each area.

The anonymous university instructional survey asks standard questions, which do not specifically address the PPR media discussed in this paper. However, of the seven out of thirteen students that made comments in addition to answering survey questions, two of the students made specific positive comments about the online resources created using the smartpen. Informally students indicated they had very positive attitudes about the availability of the PPR media. Even students in other classes who had heard about the materials watched them and informed the instructor how much they liked them. These are not concrete results, but the authors were satisfied that students actually spent more time on a class and reported positive attitudes about the process.

Conclusions

Pause-Play-Rewind lectures and examples were produced for a Heat Transfer class as a supplement to material covered in the class lectures. The technology used to create the PPR media was a simple, inexpensive *smartpen* that allows production without a recording studio and in most cases without the help of an information technology office.

A modest gain of 18% (Calculated using Eq. (1)) was observed from pre- to post-test administrations of the Heat Transfer Concept Inventory (HTCI). Viewed in light of the content of the PPR media only covering roughly 40% of the HTCI content, this gain cannot be attributed to introduction of PPR media. *In addition, the HTCI had not been used in this course in previous semesters at UCO, so it is difficult to even know if the gain is typical for students at our institution.* Future work will focus on observing the effects of an inverted classroom where data exists for a control class taught in a traditional fashion where there is Concept Inventory for our institution.

The improvements observed in several areas of the HTCI: the largest being 58% improvement in the seven convection heat transfer questions, and the lowest being a 4% drop in performance on the five radiation questions. *These results are potentially meaningful, but given the small number of students and questions asked in each area, no strong inferences should be drawn*. It can be noted that the 45% improvement in performance on steady-state conduction questions (40% of the HTCI) and the 217 minutes of PPR media (67%) of PPR media produced devoted to steady-state conduction may be correlated, but the authors do not make this claim. Instead, the authors will seek to implement a way to rigorously test the effects of these media in the context of an inverted classroom where the results can compared to a traditional course control.

Given that recent educational psychology research which incorporates controlled experiments, indicates that simple observation of worked examples is effective in learning problem solving in a discipline, production of PPR worked examples should proceed in that discipline to create a library of worked examples that students can watch.

The future related work of the authors will include additional administrations of the HTCI and the production of more PPR media for this class including more worked example problems for transient conduction, convection, and radiation heat transfer.

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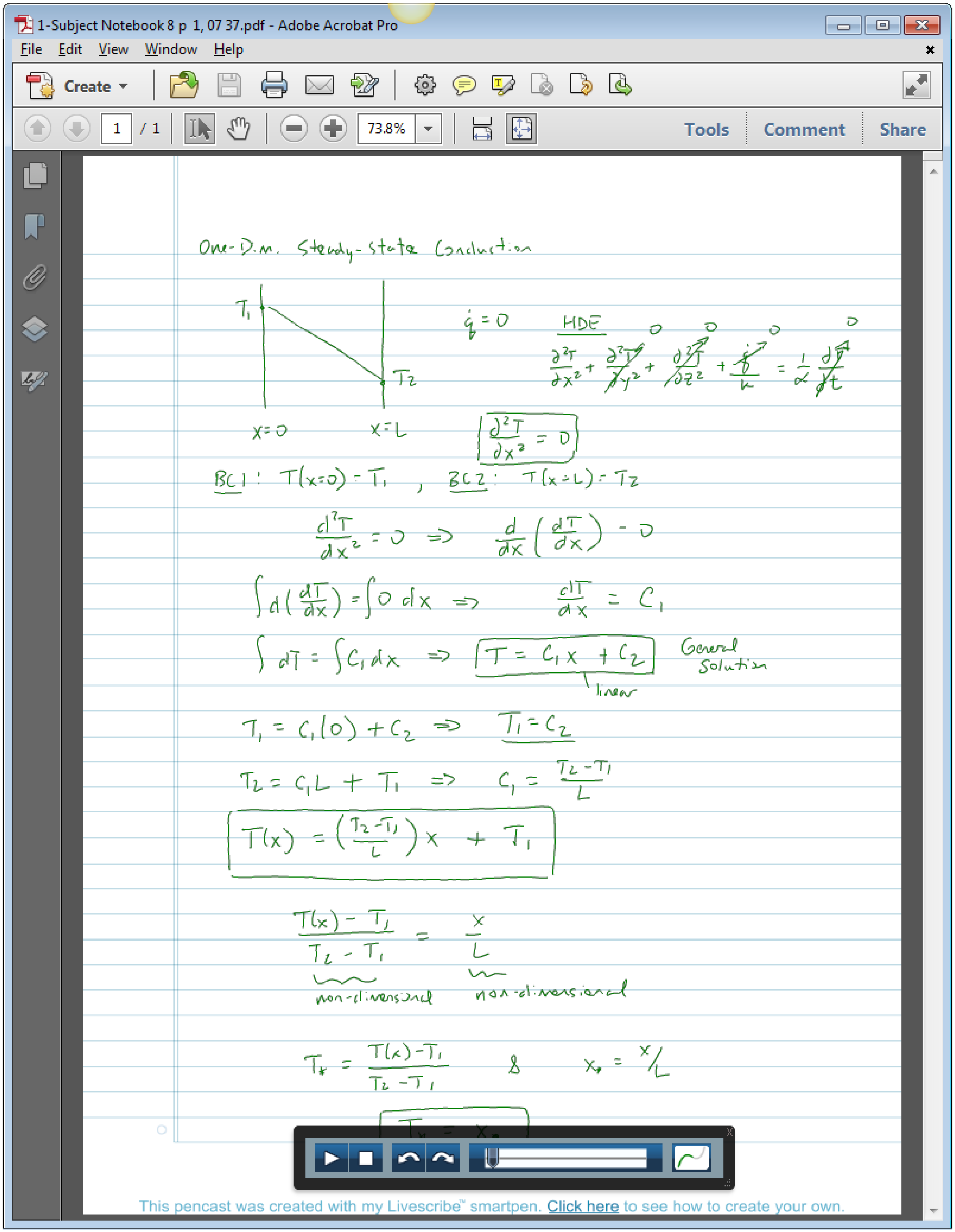

Figure 1 Sample *Pause-Play-Rewind – PPR* document.

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