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Use of Video Technology to Improve Student Learning

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ABSTRACT_ This paper discusses the initial results obtained from the use of two video lectures developed for two engineering courses: Introduction to Engineering, a freshman course, and Introduction to Control Systems, a senior level course. We propose the use of video lectures to modify the classroom T/P (Theory to Problem Solving or Theory to Practice) ratio and provide more problem solving time in class for student populations who favor "learning by doing" or "learning through practice", thus improving student learning. One of the videos was shown in class as part of the lecture. The other was made available to students online, to view and study at their own convenience for time, place and general environment. The students were asked to view the video prior to the lecture on the subject and to solve a relatively simple problem as an incentive for viewing the video on their own time. In class, student questions on the video lecture were solicited by the instructor; then more complex problems were discussed and solved. Students were later surveyed about their learning experiences using the video lecture approach proposed here in comparison to the standard lecture approach. The use of video lectures is expected to provide more interactive class time between the instructors and students for learning the complex processes of open-ended problem solving. Analysis of the surveys indicates that students prefer increasing the class time used for problem solving interactively with the instructor, prefer watching the video to reading their textbook and think they learn better with this approach of more problem solving and video lecture for theory. A well-controlled study of the proposed approach is needed to show the extent to which student learning may increase in engineering at Historically Black College and Universities (HBCU) and other institutions.

1. Introduction

One of the main goals of engineering education is student learning, particularly in such areas as engineering design, open-ended problem solving, laboratory work, etc. As the learning styles of students can vary considerably [1-7], achieving this goal can be very challenging even when other variables which impact student learning are taken into account. Various teaching methods such as case studies, projects based learning, contexts based learning, computer based learning, etc, address the learning styles of different student populations [2], [8-11]. In this paper, we concentrate on student populations who favor "learning by doing" [3], [6]. We will use the term "learning by doing" to refer to the approach of learning by solving many individual problems or through practice as opposed to studying the theory with which the problems are solved.

The instructor of a course has a limited amount of class time, in which direct student-teacher interaction (DSTI) occurs, to work toward the goal of student learning. In many colleges and universities, the proportion of this limited time given to lecturing students on theory versus the time given to open-ended problem solving favors the former. The percentage of time spent on lecturing on theory versus problem-solving or theory versus practice (T/P) may be as high as 80% to 20% (or 4/1) for a number of core engineering courses. In other words, the instructor may discuss abstract considerations, concepts and methods during most of the classroom time and then provide an example problem as time permits to illustrate these abstract concepts and methods. Students are usually given homework problems to solve on their own and seek help from a teaching assistant if they have questions about the homework. Thus, most of the specific problem solving activity is done by the student, possibly with peer interaction, but with only a small amount of direct student-teacher interaction.

The question that immediately arises is: Given the course learning objectives, what is the optimal T/P ratio for student learning? Stated more precisely, for a class of students who favor "learning by doing", what is the proportion of lecturing on theory versus problem solving (i.e., the optimal T/P ratio) which would maximize student learning? Furthermore, if we wanted to change the current T/P ratio for an engineering course, how would we achieve the new ratio without simultaneously reducing student learning in other areas? Finally, given the advances in educational technologies and the trend toward the use of more online educational material, how can we best make use of current technology to implement the new T/P ratio?

2. Approach

In this paper, we propose the use of video technology, in particular video lectures on theory, as an approach to modify the T/P ratio and improve student learning in certain student populations and some engineering courses. In the current context, by a lecture on theory we mean the discussion of abstract concepts and methods which address a large class of problems, rather than the discussion of a particular concept or method used to solve a specific (even if typical) individual problem using specific physical systems or components. The approach proposed here is an outgrowth of the idea of showing a real-time video recording of a lecture in a classroom setting, instead of having an actual lecture on the same subject given by an instructor (see Acknowledgements).

The popularity and some of the obvious advantages of online education has encouraged the consideration of using video technology in engineering education as well, despite some of its important deficiencies for the case of engineering disciplines. In an apparent attempt to experiment with the use of video technology, many universities have placed a video recording of an actual classroom lecture on their web sites for students to view. In most cases, engineering students still have to do homework and submit their work on campus; also students usually continue to have access to a teaching assistant during weekly problem sessions and to the instructor during office hours. Various flipped classroom strategies are also under investigation in engineering courses [12].

The use of video technology in the manner described above makes lectures available to students online; however, it does not provide more problem-solving time with direct student-teacher interaction (DSTI). The advantage is that students don't have to miss the contents of a lecture if they are not physically in class and can watch the lecture at their convenience. It is not clear whether students are supposed to physically attend the classroom lectures most of the time or whether the intent is to watch the video without attending the classroom lectures. One characteristic of this way of using video technology is that the video takes as long as the actual lecture in the classroom. Whether adoption of this approach of using video lectures for theory without increasing the amount of direct student-teacher interaction (DSTI) would increase or decrease student learning is not clear and would require some investigation.

The approach of using video technology proposed in this paper differs from the one described above in several respects. In particular, rather than simply recording an actual lecture in a class, we propose making the video lecture using software that allows the editing and merging of video clips with a slide presentation, clip art, sound effects and any other editing techniques that would improve student engagement. Such software packages with powerful editing capabilities are currently available in the software market. The use of such software modifies the video lecture in several positive ways.

First, the video lecture is not a real time recording of a classroom lecture. The video does not take the same amount of time as a lecture in class might. The video lecture proposed here usually takes significantly less time than one given by an instructor in a classroom. In part, this can be achieved by simply editing out pauses, repetitions and superfluous statements that normally occur in unrehearsed speech. Simple editing can make the video lecture move at a faster, less boring speed without the loss of any information. In most cases, we can hear and understand speech spoken faster just as well as we would comprehend speech spoken at a normal speed. In fact, by moving the lecture at a faster clip, we can maintain the interest of the student in the video and improve student learning. Note that the student can always pause the video and review a portion of the video that moved too quickly for him to follow. Thus, the video lectures proposed here usually would take less time than an actual real time lecture would without any loss of information conveyed and with the potential of greater student learning by maintaining the student's attention on the subject.

Second, it forces the instructor making the video to plan the lecture from the perspective of not only including all the necessary technical material, but also for keeping the student's attention on the subject matter longer, enhancing the student's enthusiasm on the subject being studied, etc. using new tools that are not always available in a classroom environment. Because the video is not a real time recording, the instructor can modify and improve it as many times as desired until all the points have been made with sufficient clarity, the concepts explained thoroughly and the methods have been clarified in a way that enhances student learning. It allows the teacher more creativity to educate in a new medium by using new tools not always available in the classroom. A new style of lecture is possible in this medium when properly used. The main disadvantage is that it takes more time for the instructor to make and edit the video in comparison to a real-time recording of an actual lecture, which does not place new time demands on the instructor giving the lecture.

Finally, the way we propose to use the video lectures is different. The main purpose of using a video lecture of the theory is to make more time for problem solving in class where more direct student-teacher interaction (DSTI) is possible. Thus, amount of class time spent on discussion of theory is reduced in favor of increasing the amount of class time spent on problem solving which is increased. Accordingly, the T/P ratio is reduced in favor of DSTI time given to problem solving.

A typical scenario of a course may be as follows. The videos are made available to students online. Students are to watch the videos before coming to class. Now, a potential problem is that some students may not watch the video. After all, instructors usually ask students to read the sections of the textbook before coming to class. While we hope that that the video lectures will be more interesting and alluring to watch than reading a textbook, this cannot be assumed. One approach is to ask students to solve a relatively simple problem as a quiz or homework at the end of the video. Usually, students pay more attention to and are likely to do work that is graded and will make a difference to their final grade.

In class, the instructor collects the homework and solicits any questions about the theory in the video and the homework problem. After answering any questions on theory, which presumably will require less time than a whole lecture on the subject, the instructor brings up interesting open-ended problems possibly involving design and analysis of real world problems. This part of the classroom time is meant to be interactive between students and teacher, investigating problems that are not formulaic, but may require subjective trade-offs to which no single answer is possible, but a choice or compromise is required.

3. Implementation

In an initial attempt to evaluate how students might respond to the use of video technology in the manner proposed in this paper, two student surveys were conducted. The surveys asked students questions about their experiences with the videos they had watched. The student responses are described in greater detail in the following.

Two video lectures were developed using video editing software. One was a lecture on "Engineering Communication" which was part of a freshman "Introduction to Engineering" course. The class size for "Introduction to Engineering" is usually 20 students. The second video was a lecture on the "Design of Proportional plus Derivative (PD) Controllers" in a senior level "Introduction to Control Systems" course. And there are typically 15 students in "Introduction to Control Systems". The "Introduction to Engineering" lecture was shown to students at the beginning of the class. Even though the video lecture covered the same slides containing the same information which was presented in a normal lecture on this subject, the video lecture took less time to view, allowing time for a Q&A session and comments from students.

For the second video lecture, students were given a copy of the video to view at their convenience, at a time and place of their own choosing and in a setting of their own choosing, such as viewing with peers in the same class or alone in a dorm room. Students were asked to view the video prior to coming to class. In class, students were able to ask questions about any portion of the video they wanted. After questions on the video lecture were exhausted, the instructor was able to present and show a solution to a design problem using a PD controller with direct student-teacher interaction.

Prior to this second video lecture, we made a first attempt to distribute the videos to students as follows. A video lecture on a different control system design technique was developed and made available to students on YouTube. Students were able to go online to YouTube and view the video lecture. Unfortunately, the resolution of the video on YouTube turned out to be insufficient to view the detailed simulation plots in the video. Students were unable to follow the discussion and in some cases were unable to read some of the text and equations which were in smaller print. Accordingly, this method of distribution was unsuccessful and we decided to make the videos available on the department's web site in the future.

The choice of a freshman level course "Introduction to Engineering" and a senior level course "Introduction to Control Systems" was in part to see if students in different stages of their programs would respond differently to the use of video technology. Another reason for this selection was to see if the content or the level of the material in the lecture would make a difference in the use of a video. For example, the control lecture included a significant amount of mathematics and abstract concepts, but also involved the design of a control system, an open-ended problem more appropriate for a more mature student. The engineering communication lecture involved no mathematics, but discussed written and oral communication principles, also an open-ended problem whose solution is not unique. We were also interested to see if both topics could be handled by the medium of video.

4. Student Survey Results

Both groups of students were asked to complete a survey about their experiences in a later class. The questions and results of the surveys are discussed below. In the surveys, students were asked to respond to statements relating to their experiences with the video lecture they had recently viewed. The surveys were anonymous to avoid personal influences. Students were able to respond by indicating the extent to which they agreed or disagreed with a statement about the video lecture. Given a statement about the video lecture, students were asked to circle one of the responses shown below.

Strongly agree	Agree	Neutral (don't care)	Disagree	Strongly disagree
1	2	3	4	5

a) Discussion of Student Survey in "Introduction to Engineering" Course

This survey was taken by 20 students in a section of this freshman course. The video lecture discussed "engineering communication". The video was viewed by students during the regular lecture period and was followed by a Q&A period adding to a total of 50 minutes. For each statement, the mean and standard deviation of the student responses were computed. A verbal assessment of the student responses was developed as shown by the table below. Since a response above 5 or below 1 is not possible, a response that exceeds "agree" is selected to mean "strongly agree" and conversely.

Verbal Assessment of Student Responses	**Numerical Range of Mean Value**
Strongly agree	$1.00 \leq \text{mean} < 1.75$
Agree	$1.75 \leq \text{mean} < 2.25$
Mildly agree	$2.25 \leq \text{mean} < 2.75$
Neutral	$2.75 \leq \text{mean} < 3.25$
Mildly disagree	$3.25 \leq \text{mean} < 3.75$

Disagree	3.75 ≤ mean < 4.25
Strongly disagree	4.25 ≤ mean < 5.00

The survey statements are shown below followed by the (mean, standard deviation) of the student responses, then followed by the verbal assessment of the responses to the statement.

Q1 I would watch the video at my convenient time online rather than in class; e.g., watching it at home: (2.5, 1.32) **mildly agree**
Q2 I would watch the video more than one time to make sure I learn all: (2.15, 1.01) **agree**
Q3 I would rather watch the video than listen to the lecture in class: (3.00, 1.14) **neutral**
Q4 I would watch the video as a review for exams: (2.30, 1.00) **mildly agree**
Q5 Video is an effective teaching and learning tool: (1.95, .74) **agree**
Q6 I learned a lot from the video: (2.50, .87) **mildly agree**

Overall, the freshmen agree, sometimes only mildly, that they would watch the video in more circumstances than would be possible from attending a classroom lecture. The first four statements or questions above explore whether students would watch the video more than once in order to learn more, due to its convenience of time and to study for exams. They are neutral about watching the video versus listening to the lecture. On the other hand, in the last two statements above, they seem to agree that video technology produces a good learning tool and that they have actually learned from it.

One comment made by several students was that the material in the lecture was already familiar to them from high school. It is possible that this fact may have influenced their reaction and response to the video. Also, this was the first video we made using software editing and may not have been as effective as the second video due to our learning curve in making such videos.

b) Discussion of Student Survey in "Introduction to Control Systems" Course

This survey was taken by 12 students in the senior level control system course. The video lecture discussed the method and some of the considerations for designing a PD controller. Unlike the freshman video lecture, this video was viewed by the students prior to coming to class. In class, students asked questions about the theory discussed in the video. In the remaining class time, the instructor discussed a design problem with direct student-teacher interaction.

The teaching process implemented with the senior students more closely follows the scenario for using video technology proposed in this paper. Accordingly, this survey explores student reaction to having more time for interactive problem solving. The implementation did provide more time for problem solving in class interactively with the professor teaching the course. The response of the students to this process is discussed below.

Q1 I like that I can watch the video at my discretion whenever, wherever I want: (1.83, .39) **agree**

Q2 I like that I can use the video to study for exams: (2.25, 1.22) **agree**
Q3 I like that I don't have to take notes when watching the video: (3.08, .76) **neutral**
Q4 I'd rather watch the video than read the textbook: (2.08, .67) **agree**
Q5 I'd rather watch the video than listen to a lecture in class: (2.92, .79) **neutral**
Q6 When problem solving in class, I like that I can ask a question and get an immediate answer: (1.58, .51) **strongly agree**
Q7 I prefer solving a problem in class rather than solving it at home: (1.75, .62) **agree**
Q8 I like having more time for problem solving in class: (1.83, .72) **agree**
Q9 I think I learn better by solving problems in class: (1.67, .78) **strongly agree**

The first two statements confirm that seniors, as well as freshmen, agree that the convenience/availability of video technology is a desirable quality. Seniors are neutral about not having to take notes, possibly because they have developed study habits involving notes or because they value note taking as a technique for learning. Further study may clarify the reasons.

The fourth statement addresses an important issue for the approach proposed in this paper. Usually, instructors stress that students read and study the sections in the textbook which will be discussed in the next classroom lecture. Our experience, at least in our institution, has been that students rarely comply and study the textbook prior to the corresponding lecture. So, will students watch the video lecture prior to coming to class?

The fourth statement shows that students prefer the medium of video lectures to reading the textbook. A second incentive for students to watch the video prior to class is to include a (possibly simple) homework problem at the end of the lecture. This homework must be part of the final grade for the course. A third incentive is that the student knows a full-length classroom lecture on the subject will not be given; only a Q&A session is done in class. Of course, the video lecture is not intended or expected to replace the textbook. These issues must be studied further in future investigations of the proposed approach.

On the other hand, students seem to be neutral about their preference of the video versus a classroom lecture. On this point, freshmen and seniors are in agreement. This neutral response points out that a well-prepared video lecture may be an acceptable substitute to a classroom lecture. Of course, we further propose that after the video is viewed and studied by the student at their convenience and that any remaining questions be brought to class for interactive clarification and discussion.

The last four statements explore the impact of the proposed approach on interactive problem solving in the classroom environment. The seniors strongly agree that problem solving in class interactively with the course instructor is desirable. They also agree that problem solving in class (with DSTI) is preferable to solving a problem at home. Also, they agree with increasing the time spent problem solving in class; i.e., increasing the P/T ratio or reducing T/P. Finally, the seniors strongly agree that they actually learn better by problem solving in class, which is the main point of the proposed approach.

P-Value Analysis of the Surveys

To assess the statistical significance of the survey data, a p-value analysis of the data was done for the senior and the freshman courses. As a survey was not done prior to the intervention, we assumed that the null hypothesis consisted of a mean value of 3, corresponding to the neutral response in the survey. The Control Systems course survey had only 12 students. Since the prior standard deviation is not known, Student's *t* distribution was used to find the p value. The hypothesis we are testing is to see if the mean value of the survey questions (or statements) have statistical significance relative to a neutral mean value. Thus, the p value is the probability of the true mean for a question (or statement) being lower than the one shown in the table below (except for Q3), given that the null hypothesis is true. The results indicate that except for Q3 and Q5, the intervention actually had an impact on the students' perceptions. Thus, the intervention had a significant impact on students' perceptions on Q1, Q4, Q6-Q9 at a level of 0.01 (i.e., 1%) in the Control course. An alternative interpretation of the p values would be: the probability that the average value of 12 students' responses will be lower (higher for Q3) than the mean shown in the table when the true mean of these responses (not the pre-survey response mean) is 3 or neutral.

Control Course: the number of students is 12

	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q8**	**Q7**	**Q9**
mean	1.83	2.25	3.08	2.08	2.91	1.58	1.75	1.83	1.67
Stdev.	0.39	1.22	0.79	0.67	0.79	0.51	0.62	0.72	0.78
P value	0.000*	0.028**	0.362	0.000*	0.362	0.000*	0.000*	0.000*	0.000*

EGR 101 Introduction to Engineering Course: the number of students is 24

	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**
mean	3.13	2.58	2.5	2.29	2.13	2.04
Stdev.	1.12	0.88	1.31	1.08	1.03	0.81
P value	0.294	0.015**	0.038**	0.002*	0.000*	0.000*

*significance level of 0.01
** significance level of 0.05
*** significance level of 0.1

Also the intervention has significant impact on students' perceptions on Q4-Q6 at a level of 0.01, on Q2 at a level of 0.05 and on Q3 at a level of 0.1 in Introduction to Engineering course. Note the results might be biased because of our assumption that the average perceptions without (or prior to) the intervention are neutral. Future work will include the analysis of the pre-survey before the intervention is conducted.

5. Conclusions

In this paper, we propose the use of video lectures on theory, as an approach to modify the T/P (Theory/Practice or Theory/Problem Solving) ratio and improve student learning in certain student populations and some engineering courses. The hypothesis is that the proposed approach may improve learning in student populations that have a preference for "learning through practice" or "learning by doing". While the present study was done at a HBCU, the approach may be applicable at other institutions as well.

The goal is to improve student learning by reducing the amount of classroom time spent on theory and increasing the amount of time spent on practice through problem solving interactively in class. We propose to achieve this change in the classroom T/P (Theory/Practice) ratio by using video lectures on theory which students view online at their convenience, and using the class time thus gained for problem solving in an interactive mode between students and instructor. Conversely, students spend more time problem solving interactively in class rather than by doing homework on their own.

In the proposed approach, the video lectures are developed using editing software to take advantage of the capabilities of the medium. These video lectures usually take significantly less time than a real-time recording of an actual lecture given in class. While instructors making the video can use their creativity to develop the most effective videos to increase student engagement, a disadvantage of this process is that the instructor spends more time in developing the video.

To obtain an initial understanding of student response to this approach, two videos were made for two engineering courses: a freshman "Introduction to Engineering" course and a senior level "Introduction to Control Systems" course. Students were surveyed after viewing the videos to obtain an initial response to this approach. The survey of responses seems to indicate that students have a preference for increasing problem solving in class and would watch the videos at their own convenience on line. A well-controlled investigation of the proposed approach is needed to evaluate the approach proposed.

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