Assessing the effectiveness of Tablet PC-based instruction

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Abstract

Engineering professors in a number of universities have begun using Tablet PCs in the classroom. A literature search shows that there are a number of articles describing methods and tools for Tablet PC use in the classroom, but that there is very little literature on objective assessment of the effectiveness of the Tablet PC as a teaching and learning tool. This paper describes the mode of Tablet PC use in teaching an electric circuits class. It also compares course delivery metrics between an instructor who used a Tablet PC to teach the circuits class and an instructor who did not use a Tablet PC. Student achievement data from the cohorts of students associated with the two instructors are presented and analyzed. Some of the variability between the populations in the two cohorts is removed by using student grades in the prerequisite calculus class as a basis for comparison. The study shows that Tablet PC use by the instructor as described in the paper leads to savings in class time that can be devoted to additional problem solving and testing opportunities for students. It also shows that such Tablet PC use resulted in significant improvement in the performance (measured by the overall numeric course score) of above average students.

Introduction

There are a lot of recent articles in the literature describing the use of Tablet PCs for instruction. Anderson et al.[1] discuss the use of Classroom Presenter (a presentation system that allows for ink annotation on electronic slides) in the engineering classroom. The benefits of digital ink annotation are described by Hulls[2] and contrasted with other teaching methods. Wise et al.[3] present responses to student surveys that indicate that Tablet PC use by instructors can help improve student learning. The above-mentioned papers use subjective instruments (such as student surveys) to identify benefits of using the Tablet PC for instruction. The authors have been able to find very little in the literature that objectively assesses the impact of Tablet PC use on student learning.

This paper describes efforts to objectively assess the effect of Tablet PC use on the classroom teaching and learning environment and on student learning. It does this by comparing student performance and other data from an electric circuits course that was taught by two different instructors. Instructor A did not use a Tablet PC, while Instructor B used a Tablet PC to teach the course. The performance of students of the two instructors (based on their final numeric course grade) was used as one of the comparison metrics. Variation in the quality of students between the two populations was accounted for by using student grades in the prerequisite

Calculus class as a baseline for establishing student quality. The results show that Tablet PC-based instruction significantly improved the performance of higher achieving students (in the A and B grade range).

One of the advantages of Tablet PC based instruction in conjunction with skeleton notes as described in this paper is that it can significantly reduce the amount of time needed to effectively teach a concept. The time saved can be used for group problem solving and other active learning opportunities in the classroom, as well as for additional student testing opportunities in the form of quizzes. Instructor A used three examinations to evaluate student performance and assign course grades. The time saved in the classroom using Tablet PCs allowed Instructor B to give students 11 quizzes in addition to three examinations. It could well be that the higher student performance in the Tablet PC group is due in part to the incentive to keep up with the course provided by the regular quizzes.

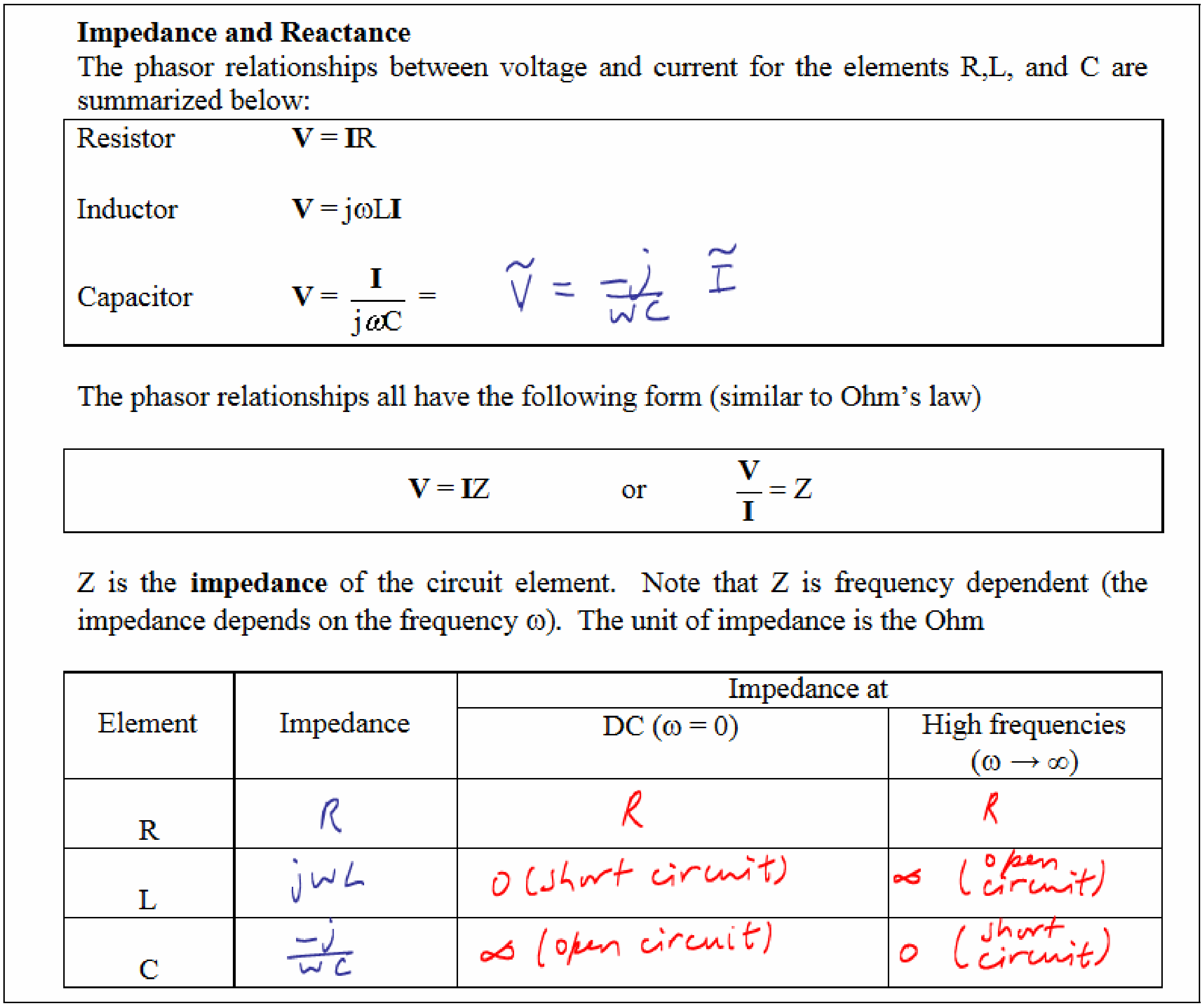
The paper now proceeds to describe the teaching methods of Instructors A and B, objectively compare the course content and testing instruments of the two instructors, objectively compare the performance of students of the two instructors, and draw conclusions from the studies.

Teaching methods of the two instructors

Instructor A uses overhead transparencies to teach the circuits course. The transparencies are blank at the beginning of the class period, and the instructor uses a marker to write on the transparencies. This method of course delivery is similar to using a chalkboard or a whiteboard. Instructor A is known for his engaging style of lecturing, is generally highly rated by his students, and has received several teaching awards.

Instructor B uses a Tablet PC to teach the circuits class. About 160 pages of skeleton notes are provided to students at the beginning of the semester. The skeleton notes contain theorem and problem statements, figures, partially completed tables, etc. The skeleton notes serve as the backbone for course delivery. In class, the instructor talks through the preprinted material on the skeleton notes and works out problems and fills in other blanks in the notes using digital ink annotation on the Tablet PC. The availability of the skeleton notes frees students from having to spend all their class time taking notes. They can instead concentrate on trying to understand the material. Students are kept engaged, nevertheless, and have to participate in class by filling in the gaps in the notes. The notes are designed to contain background text and figures; the gaps are strategically placed and correspond to points where key concepts or problems will be worked out in class.

Figure 1 depicts a sample section of a skeleton note in which the concept of impedance is summarized. The “skeleton” consists of the printed text and tables. All of the handwritten (color) annotations were made using digital ink via the Tablet PC. The background text and tables allow the instructor to teach the concept quickly without having to write much. The instructor keeps the students engaged by open discussion on the relevant equations and by having to complete the notes by filling them in. The skeleton note concept is thus quite different from a canned PowerPoint presentation which can leave the students un-engaged and easily distracted. The pre-printed content in the handouts enable an instructor to cover a concept quickly (relative to having to write everything down on a chalkboard). This leaves extra time in the class period during which the class can participate in group problem solving. Extra time for active participation and problem solving by students helps them get a better handle on the material during the class period. This can be beneficial in a climate in which engineering students seem to be spending less time studying than is necessary.



Impedance and Reactance

The phasor relationships between voltage and current for the elements R,L, and C are summarized below:

Resistor	$\mathbf{V} = \mathbf{I}R$
Inductor	$\mathbf{V} = j\omega L\mathbf{I}$
Capacitor	$\mathbf{V} = \frac{\mathbf{I}}{j\omega C} =$ $\tilde{V} = \frac{-j}{\omega C}\tilde{I}$

The phasor relationships all have the following form (similar to Ohm's law)

$$\mathbf{V} = \mathbf{I}Z \qquad \text{or} \qquad \frac{\mathbf{V}}{\mathbf{I}} = Z$$

Z is the **impedance** of the circuit element. Note that Z is frequency dependent (the impedance depends on the frequency ω). The unit of impedance is the Ohm

Element	Impedance	Impedance at	
		DC ($\omega = 0$)	High frequencies ($\omega \to \infty$)
R	R	R	R
L	$j\omega L$	0 (short circuit)	∞ (open circuit)
C	$\frac{-j}{\omega C}$	∞ (open circuit)	0 (short circuit)

Figure 1. A sample skeleton note with digital ink annotations.

Comparison of the courses as taught by the two instructors

The testing instruments used by the two instructors were studied to give an objective comparison of the topics covered by the two instructors. This comparison was chosen because it had the potential to shed light on differences in course coverage and level of testing and thus reveal quantifiable differences in the courses due to the "extra class time" claimed to be made available by the time savings generated by the Tablet PC and skeleton notes. Table 1 lists the topics covered in the circuits course and the number of examination questions on each topic for

Instructors A and B. Instructor B administered quizzes (on a close to weekly basis) in addition to examinations, whereas Instructor A did not. The last column of the table lists the number of quiz questions on each topic for Instructor B.

Topic	Instructor A exam questions	Instructor B exam questions	Instructor A quiz questions
Current, voltage, power, passive sign convention	2	1	2
Ohm's and Kirchoff's laws, voltage and current division	2	3	4
Node voltage method	1	1	1
Mesh current method	2	1	1
Thevenin equivalent circuits, max. power transfer theorem	3	4	1
Analysis of op-amp circuits		2	1
Inductors, capacitors, and their properties	1	3	1
First order circuits: natural and step response	4	4	2
Second order circuits: natural and step response	3	4	1
Sinusoidal steady state analysis of linear circuits	2	3	3
RMS value calculations		1	
Sinusoidal steady state power calculations	2	2	

Table 1. Comparison of the testing instruments of the two instructors.

Comparison of the first two columns of data in Table 1 shows that Instructor A had no questions on operational amplifier circuits and RMS value calculations. Besides these two topics, the exam questions of both instructors are relatively balanced. Follow up conversations showed that Instructor A had not covered operational amplifier circuits in class and had not spent much class time on evaluating the RMS value of arbitrary periodic signals. Instructor B covered both these topics and spent about three class periods on these topics.

The third data column of Table 1 shows that Instructor B had quiz questions on all topics except those covered close to the end of the semester. Instructor B had a total of 11 quizzes over the semester. Each quiz occupied about 20 minutes of class time; the total time spent by Instructor B on quizzes thus amounted to about four class periods of 50 minutes each.

The additional topics covered and the quizzes administered by Instructor B thus amount to about seven class periods. The number of class periods in a typical semester is about 43. Instructor B thus had 7/43 or 16.3% more class time available than Instructor A. The combination of the Tablet PC and skeleton notes thus provided time savings of about 16.3%. This time saved was used by Instructor B to cover additional topics and introduce student testing on an almost weekly basis. This regular testing provides an incentive for students to keep up with the class, and not just begin studying when an examination is around the corner.

Comparison of student performance

The grades of students taught by Instructors A and B were compared to see if any effect of Tablet PC-based instruction could be detected. Trying to detect the effect of Tablet-PC based instruction on student performance is not easy. Student grades are affected by a number of other variables such as differences in the quality of students in the two groups, differences in the level of difficulty of examinations, and differences in the grading style of the two instructors. The following approach was used to remove some of these variables. Calculus 2 is a prerequisite course to electric circuits, and must be passed with a grade of C- or better. The Calculus 2 grades of students of Instructor A (referred to as Cohort 1) and of students of Instructor B (referred to as Cohort 2) were obtained. Each Cohort was then divided into three bins based on the letter grades earned in Calculus 2 (the three grade bins are A, B, and C). Comparisons were then made between Cohort 1 and Cohort 2 for each of the three grade bins. This approach removes the quality of the student as a variable when comparing the performance of students taught by Instructor A (without the Tablet PC) with those taught by Instructor B (with the Tablet PC).

Cohort 1 consisted of 19 students, and Cohort 2 consisted of 13 students. Table 2 presents the overall numeric Circuits course grades of students in Cohorts 1 and 2 across the three Calculus 2 grade bins. As an example of how to read the table, the Circuits scores of the students of Instructor A who scored in the A range in Calculus 2 range from 92 down to 49. The bottom half of Table 2 gives the average Circuits score of students in each of the three grade bins.

Circuits score for students of	**Calculus 2 grade bin**		
	A	**B**	**C**
Instructor A (Cohort 1)	92 91 84 82 79 72 64 49	99 57 50	91 76 70 70 52 49 48 43
Instructor B (Cohort 2)	88 87 79 79 70	83 78 70 67	70 69 55 48
	Average score in each of the three grade bins		
Instructor A (Cohort 1)	76	69	62
Instructor B (Cohort 2)	80	74	61

Table 2. Circuits scores of students in Cohorts 1 and 2 in the three Calculus 2 grade bins.

Examining the average scores yields some useful insights. The average Circuits score of students who had a C grade in Calculus 2 was roughly the same in both cohorts (averages of 62 and 61). Average students (who scored a C in Calculus 2) thus performed roughly the same in the electric circuits course whether taught by Instructor A or B. This leads to the conclusion that the level of difficulty of exams of Instructors A and B and the grading style of Instructors A and B are roughly the same. Other differences between Cohorts 1 and 2 are attributed to whether the corresponding instructor used a Tablet PC or not.

Now looking at students who had an A grade in Calculus 2, we see that students in Cohort 2 scored 4 points more on average than students in Cohort 1 (the average scores for Cohorts 1 and 2 are 76 and 80, respectively). Similarly, looking at students who had a B grade in Calculus 2, we see that students in Cohort 2 scored 5 points more on average than students in Cohort 1 (the average scores for Cohorts 1 and 2 are 69 and 74, respectively). In summary, average students in both cohorts performed roughly the same. However, higher performing students (with A and B grades in Calculus 2) did significantly better in Cohort 2 than in Cohort 1. The 4 to 5 point average score difference between the two cohorts in the A and B grade bins is significant (a point difference of this magnitude often results in a half letter improvement in course grade).

The following conclusions can now be drawn: Average students (those with C grades in Calculus 2) perform the same whether a Tablet PC is used for instruction or not. However, above average students perform significantly better (with a 4 to 5 point average score difference) when a Tablet PC and skeleton notes are used as described above. The mean of the entire population (of Cohorts 1 and 2) is 71 and the standard deviation is 15.3. A 5 point score difference between Cohorts 1 and 2 corresponds to about a third of a standard deviation.

Conclusions

An objective study has been undertaken to examine whether students taught by an instructor using a Tablet PC perform any better than students taught by an instructor who did not use a Tablet PC. The study, based on a limited population of 32 students in an electric circuits course shows that (1) The instructor using a Tablet PC and well crafted skeleton notes was able to offer significantly more testing opportunities and was able to cover more material than the instructor who did not use a Tablet PC. (2) Numeric course scores show that above average students (in the A and B grade range) are able to perform significantly better when taught with a Tablet PC. Students in the Tablet PC group scored about a third of a standard deviation above the mean relative to the non-Tablet PC group. The above conclusions are interesting but are drawn based on limited data. To make more definitive conclusions, further studies with larger student population groups are planned.

References

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