Interactive Modern Physics Worksheets Methodology and Assessment

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Abstract
There are a variety of teaching tools available for use in introductory modern physics classrooms. Determining which teaching tool students support can help the teacher structure classroom instruction to include more effective teaching tools. Student participants were surveyed at the end of four separate semesters after using different teaching tools throughout the semester. They were asked to rate which teaching tools they found to be most effective in aiding their understanding of the course material and provide comment where necessary. Students on a "least effective" to "most effective" scale rated each teaching tool. This scale was transferred into a number scale with 1 being "least effective" and 5 being "most effective." Through use of the quantitative and qualitative analysis, it was determined that students strongly prefer the use of in-class worksheets. The normalized data shows that 68% of students strongly favored the worksheets over textbooks (29%) and homework (32%). Students gave positive comments that the in-class worksheets allowed for teacher-student interaction and guided learning.
Keywords: Interactive engagement, worksheets, tutorials, modern physics

Introduction

Active student-centered engagement has become the goal of the contemporary physics classroom (Hake, 1998; Redish, 1994). Physics education has proven it to be successful in learning and retaining qualitative and quantitative physics problems through a variety of active engagement tools (Fagen, 2003; Redish, 2003; Beichner et. al, 2007). Multiple-choice questions provide a quick real time assessment of performance such as peer instruction methods by Eric Mazur (1996) through either flash cards or clicker questions (Beatty et. al, 2006). Although these methods are favorable over the traditional passive lecture, these questions do not address specific student strengths and weaknesses. Some students may lack in problem solving skills or simply missed the general theme of the lessons.

Worksheets in the classroom would provide the versatility and one-on-one attention to problem solving needed in the classroom. Worksheets and tutorials have been made popular in the introductory classroom (McDermott et. al, 1998; Finkelstein, 2005) and proven to work with any class size (Leslie-Pelecky, 2000). These methods can be extended into physics courses beyond the introductory sequence, such as Modern Physics. Even though course content is more advanced at this stage, students have a large range of abilities and would benefit from activities that are at their own pace.

Efforts to improve Modern Physics instruction have recently been studied by physics education researchers. The creation of a Quantum Mechanical Conceptual Survey (QMCS) allows instructors of modern physics to perform pre and post test to measure standardize gains in knowledge in the modern physics classroom (McKagan et. al, 2010). This test yields higher scores with interactive engagement versus traditional lectures, although long term retention is still questionable (Deslauriers and Weiman, 2011). This survey was created after the already popularized and accepted introductory physics assessment tool the Force Concept Inventory (FCI) test (Hestenes et. al, 1992) as well as the Brief Electricity and Magnetism Assessment (BEMA) test (Ding et. al, 2006). Also, free online Java simulations are available in modern physics topics through the Physics Education, which have also aided instruction of Modern Physics in the classroom through live manipulation of physics concepts (Podolefsky et.al, 2010).

Methodology

Over the course of four years, Modern Physics utilized in-class worksheets as an instructional tool. Class met twice a week for seventy-five minute sessions that were divided into half lecture, half worksheet (variations in this depended on the length of each worksheet). Worksheets constituted 10% of their grade and were graded on a check plus, check, check minus system. Students were allowed to ask each other about content in the worksheet; however each individual must submit their own answers at the end of class. During each semester students were also assigned textbook readings and individual homework. The student body was comprised mostly of university sophomores with either a major or minor in physics. There were on average fourteen students in each class. When the semester concluded, students were asked to complete an anonymous survey that asked them to rate the helpfulness of each method of learning in understanding course content. Students on a "least effective" to "very effective" scale rated each method of learning. This scale was transferred into a number scale with 1 being "least effective" and 5 being "most effective." The data was normalized for each preferred qualification (1-5) by tallying the number of responses for each category (textbook, homework, worksheet) and dividing it by the total number of responses. Therefore the total responses for each preferred qualification is equal to one. Each box in table 1 represents the percentage of students who voted for each method. The average and standard deviation of all student responses were also calculated using standard statistical calculations with the results shown in table 1. A bar graph shows the distribution of student responses in figure 1.

Worksheet in Physics Education

Worksheets in Modern Physics emphasized both problem solving and conceptual understanding. Problem solving portions of worksheets vary in their approach from stepwise calculations leading to an overall result to a general problem given where the students have to figure out the necessary steps. The predominant goal of the worksheets is for students to not only demonstrate that they learned the day's lesson, but to advance the lesson beyond what was discussed in class. In some worksheets it is necessary to point out key steps so students do not rush to the conclusion without taking each step into consideration. One example of this technique is by solving the one-dimensional time independent Schrodinger's Equation for a free particle as a worksheet rather than a lecturer driven solution. The result is students that are able to think through each step of this example and apply the technique later on to more complicated examples.

As the class is working on these problems, the lecturer circles the room either validating those that are doing well or pointing out a key fact that a student is missing to solve the problem correctly. These questions are often instructor initiated; similar to what is found in the introductory physics classroom (Scherr *et. al.*, 2006). The lecturer also sporadically jumps to the board to provide hints or advice in how to tackle problems. Those students who are already finished with this section feel more confident with their approach while those struggling can get assistance and not feel guilty about their difficulties. As some of the higher achievers leave after completing the worksheet, it leaves those that really need the help behind. This allows the instructor utilize class time with those that really need it to help them in any area the students are struggling.

	Textbook	Homework	Worksheets
Strongly Disagree (1)	0.07	0.00	0.00
Disagree (2)	0.07	0.02	0.00
Neither (3)	0.34	0.15	0.06
Agree (4)	0.23	0.51	0.26
Strongly Agree (5)	0.29	0.32	0.68
Average (M)	3.61	4.13	4.62
St. Dev (Σ)	*1.90*	*2.03*	*2.15*

Table 1. *The normalized data for each learning method from the student evaluations*

* Fifty-three students were surveyed. Worksheets were preferred over traditional independent textbook reading/learning and homework problems assigned in class.

The normalized data in table 1 shows that of the three learning methods, worksheets were more preferred by the students. 94% of students agreed or strongly agree that the worksheets were beneficial to their learning experience. 83% of students agreed or strongly agreed that the homework was beneficial and only 52% of students agreed that the textbook was beneficial. No students claimed that the worksheets had no educational value whereas 2% of students claimed that the homework had no value and 14% claimed that the textbook had no value. Based on this study, students therefore appreciate the active engagement proven to enhance their learning experience in the classroom (Fagen, 2003; Redish, 2003; Beichner et. al, 2007).

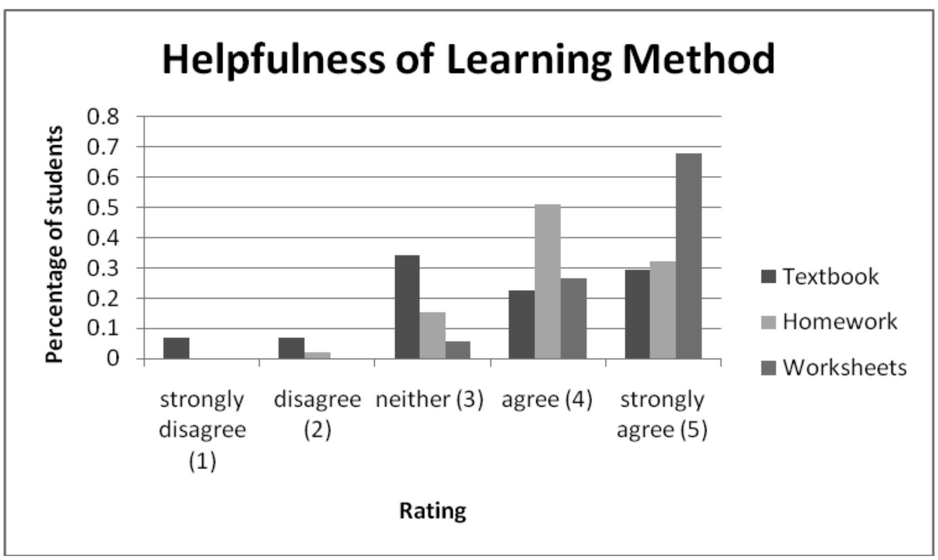

Figure 1*. The distribution of student responses for the usefulness of textbooks, homework, and lectures are shown based on the percentage of students responding to a survey*

** Overall, 53 students were surveyed. The majority of students surveyed about the worksheets believed that they were "very effective" while the majority of students surveyed about the homework thought it was "effective."

The above chart visually demonstrates the data in table 1. Here it is easy to see that worksheets dominate in the "strongly agree" column and are not present in either of the "disagree" columns. The textbook was given a neutral rating more often than either of the other learning methods but the majority (>50%) still agreed that the textbook was useful.

Most of the students who completed the evaluations agreed (a few had no opinion) that the worksheets were beneficial to their learning experience. The students were given comment sections within the evaluation and many students commented on how the worksheets helped to "understand what we were learning in lecture." In particular it was stated that the best learning experience was due to the worksheets being completed in the presence of the professor and in collaboration with other students. Only one student commented that the worksheets were "very difficult," however, this student still rated the worksheets as being beneficial.

Conclusion

Worksheets have been shown to be the most preferred method of learning by students in a Modern Physics course. Over two thirds of the class strongly agrees (rank of 5 out of 5) on a survey that worksheets are the preferred method of learning in the course while reading the textbook and solving homework problems have only one third of the class strongly agreeing that this is the preferred method of learning in the course. In the future, giving out both the Quantum Mechanical Conceptual Survey (QMCS) as well as the student driven survey would be beneficial to see if this standardized test survey correlates to the preferred method of instruction. When examining anticipated letter grades based on this survey, no correlations could be drawn. Therefore, worksheets were perceived to be beneficial for all students in the course.

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