



Self-Assessment of Learning Using Intelligent Interactive Worksheets

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Self-Assessment of Learning Using Intelligent Interactive Worksheets

Introducing new technologies in the classroom experience for students has been rapidly increasing. Tools that are functional and available on demand for students are even more essential. The focus of this paper is to determine the effectiveness of an intelligent interactive self-assessment worksheet to help students in a sophomore-level engineering course learn material. Often, when students are assigned classroom readings to be completed outside of class, they are not always able to adequately assess if the information read was retained or completely understood. The self-assessment worksheets developed can be used as an aid for the students to check their understanding of the reading and learn how to appropriately conduct problems that correspond to the selected reading. These worksheets not only help the student grasp the main concepts needed to obtain an understanding of the material but also serve as a way for the students to come to class prepared and ready to ask further thought provoking questions pertaining to the reading. With the Maple platform, the worksheets are developed to provide intelligent feedback to students based on the input they provide instead of simply generating a statement detailing if the answer was correct or incorrect or providing a long list of common errors. The worksheet tutorials are created with an aesthetically pleasing layout and provide the students with help buttons and self-check assessment reasoning.

This approach to learning engineering material can be useful to all levels of students, from students who are new to the material to students using the worksheets as quick reviews before exams for example. The main goal of an interactive self-assessment worksheet is to assist students in following along with pre-class reading and providing a useful aid in learning the material to help them come to class prepared. The paper will detail the testing used in creating the worksheets as well as the evaluation performed by students completing the sophomore-level engineering course and the impact of the worksheets on their learning.

Introduction

The motivation for creating and implementing intelligent interactive worksheets is to provide students a way that reinforces concepts taught in a course, in this case a sophomore-level engineering statics course. The authors identified a core, required, sophomore-level engineering science course to incorporate the worksheets because the course serves as a direct prerequisite for a large number of follow-on courses in many engineering curricula and therefore contains key engineering concepts that will be used in future courses. It is vital that students fully grasp the concepts to ensure a solid foundation for upcoming courses and future as an engineer. The importance of this course in an engineering curriculum was conveyed by Danielson and Danielson¹ who determined, "Success in latter courses is directly correlated to success in statics." By creating these tutorials, it provides students with an aid to properly self-assess their learning of the fundamentals and gauge their understanding of the material.

The goal behind these intelligent interactive worksheets is to create a tutorial that will allow the students to immediately validate their answers and receive instant, personalized feedback based

on their input. These tutorials are meant to provide students with hints to help solve the problems as well as guide them in the right direction if they answer incorrectly.

The structure of the worksheets is fairly simple. These tutorials fall into four categories: level zero, level one, level two, and level three. The category corresponds to the level of knowledge the student has at the point of completing the tutorial. For example, when a professor assigns reading to be completed before class in order to familiarize the student with the upcoming topic, the student might find a more guided approach helpful as they assess their knowledge of the topic. This would correspond to a level one type of problem as opposed to needing a quick refresher of a topic before a final exam, which might constitute a level three. This paper will describe the construction and implementation of the intelligent interactive worksheets and provide specific details on each level.

Background

An activity where the user provides input through the use of an interactive tool is not uncommon. In fact, interactive activities related to mathematics seem to be the most universal^{2,3}. Students who participate in these types of activities have been found to have an increased motivation to learn, and their performance shows an increase in understanding of the course material⁴. The research by Chandler and Mayer even discovered that students had a deeper learning outcome with an interactive learning environment⁵. Most of the interactive tools available simply assess the input provided by the user to see if the answer provided is correct or incorrect.

An ideal situation is one that mimics the situation created where “a student and teacher would have an extended conversation in which the teacher sets activities for the student, observes the student responses to the activity, and then adjusts the explanations and activities accordingly⁶.” Research related to this type of work has been conducted in Australia through the use of Adaptive Tutorials^{6,7}. Prusty, Ho and Ho⁷ conducted a study on Adaptive Tutorials using eLearning Platform for mechanics course in engineering. The tutorials are adapted to the user where difficulty, feedback, and sequence of the activities presented to the user are adjusted based on input received. Their research showed that students found the tutorials valuable, and the tutorials allowed for a better understanding of the fundamentals⁷. While the overall feedback from the students was positive, there was an emphasis on the importance of when the tutorials were released. They found that the “the release dates of the tutorials are very important and the best time for release is when the students have just completed the topics in class⁷.” This reiterates the significance of timing that each level of worksheets needs to be released in the current study.

In another study, Prusty and Russell⁶ worked on engaging students in learning threshold concepts in engineering mechanics. The student feedback from these interactive tutorials was encouraging. One student stated that the tutorials were “good for continued learning and to help with understanding – i.e. getting more feedback than possible with general hand in assignments⁶.” Another student stated that they “highly recommend this tutorial. It has a very appealing practical approach yet at the same time helps me in improving my conceptual understand of the topic at hand⁶.” These results confirmed that the goal of the tutorials were met and considered a success.

Using additional on-line tools to help further the students' understanding may not always be positively reciprocated. Morin, Keckskemety, Harper and Clingan's study⁸ on an inverted classroom approach evaluated the use of items, such as videos, tutorials, and quizzes. One activity implemented in their work was assigning a quiz before class. The authors were pleasantly surprised at the students' feedback as not all of the tools evaluated were well received by the students. Some students claimed that the quizzes assigned to them before class "helped give them motivation to complete the other components of the preparation, and allowed them to focus on the important topics⁸." While the use of quizzes in the work by Morin allowed students to only receive information on whether the answer was correct or incorrect, the work is similar to the intelligent interactive worksheets proposed in this paper where students assess their knowledge of the concept prior to coming to class.

As shown by the preceding review, there have been extensive efforts to incorporating interactive activities and increasing the overall understanding of the material by students. The feedback provided to the students from the interactive worksheets, the pre-assigned quizzes, and the timing of when the tutorials were released all factor into the successful outcome for the interactive tutorial worksheets conducted in this study. The results from previous works gave excellent insight as to what needs to be addressed in the current study.

Methods

The intelligent interactive worksheets developed are intended as an aid for students to check their understanding of a pre-class reading or assess their knowledge of a given concept. The authors identified a core, required, sophomore-level engineering science course to incorporate the worksheets because the foundational skills covered in this course apply to many of the follow-on courses in the curriculum. The worksheets are intended as supplemental assessment for the student and are not intended to be scored for a grade.

Worksheet Platform

When designing these tutorials, the first decision was to determine the platform on which to implement the worksheets. A variety of platforms were researched, but it was quickly decided that the Maple program would be the most appropriate option. While there may be other applicable programs such as Maple T.A., Maple provided the best fit for the tutorials and the Department of Aerospace Engineering at Texas A&M University for a variety of reasons. First, the University already owns licenses for the program; therefore, all students have access to it on campus. Another benefit to using Maple is that the program is utilized in multiple courses in the curriculum, so as the students advance in their coursework they will already be familiar with the program. In addition, programming in Maple has a quick learning curve and does not require extensive expertise to generate the tutorials. The Maple program also allows for a variety of ways to present a question. For example, it has the capability to require input in the form of multiple choice, true or false, or fill in the blank. The method used for the worksheets developed in this study was fill in the blank to allow the user the freedom to input what was felt to be the correct answer. Although fill in the blank may allow more room for error, it gives the user a chance to test his/her knowledge and not be limited to a select few answer choices.

Problem Structure

The interactive worksheets fall into four categories, level zero through level three. The difference between the levels is dictated by how much intermediary assistance is requested by the user in obtaining a final answer. Level zero contains knowledge typically learned in a prerequisite course. It is a foundational piece to the problem being covered. Level one breaks the solution set into step-by-step pieces allowing the user to assess knowledge throughout the process. Using level one type problems to help assess knowledge learned in a pre-reading before the topic is covered in class would be an ideal situation. Level two problems offer fewer step-by-step simplified pieces but still provide guidance in solving the problem. Evaluating knowledge retained after a topic is covered in class would be appropriate for level two type worksheets. Level three problems only solicit the final answer and would be helpful as an exam study guide. The purpose of each level is to offer assistance based on the amount of knowledge the student has at that point. The problems specifically developed for these worksheets were selected from noticeably challenging problems students encountered in the past. Before the students are given the worksheets, a tutorial is distributed to familiarize the students with the overall structure of the worksheets. The tutorial explains the notation used throughout the worksheets, proper methods to input data, utilization of the hint buttons, and how to read the feedback provided when checking their answers. A portion of the tutorial is shown in Figure 1. In this example, the problem statement has already been introduced, and the use of bold faced letters for vectors has been explained.

Find the x and y scalar components of \mathbf{F} :

- This is where the specific task should be completed.
- Input your answer for each question in the individual box associated with each variable.
- For additional help you may click the 'Hint' button. You MUST input all answers before clicking 'Submit'.
- Note that if an answer is in terms of $\cos(\)$ and $\sin(\)$, you will input: $\cos(\text{theta})$ and/or $\sin(\text{theta})$.

$F_x =$

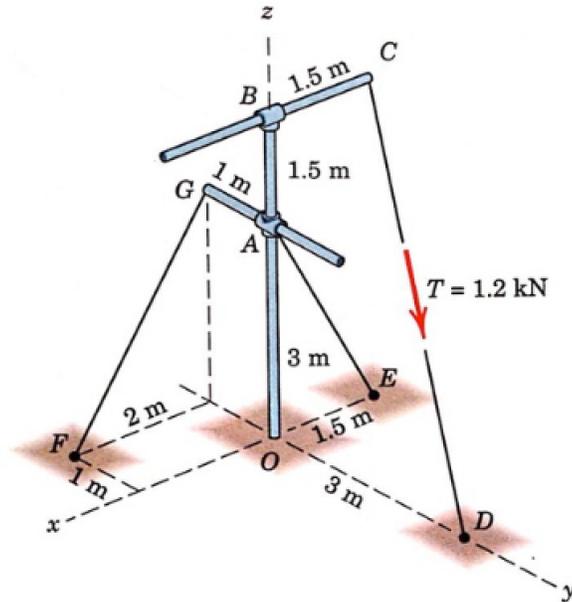
$F_y =$

Hint

Figure 1. Portion of the overview Maple tutorial worksheet.

Level zero, shown in Figure 2, consists of relatively simple concepts to reiterate what is taught in a prerequisite course. Previous observations in the particular sophomore-level statics course used in this study concluded that a majority of students struggled with three-dimensional analysis when solving for the tension in a rigid pole and cross-arm assembly, for example. Many times, it is the notion of finding the coordinates of the members in three dimensions that causes an issue, as opposed to actually determining the unit vector or solving the appropriate equations. In this situation, the level zero interactive worksheet focuses on the concept of locating the various coordinates in a three-dimensional figure, which is taught in the prerequisite mathematics course. Once the student inputs his/her answer, the worksheet checks the solution input. If incorrect, instant feedback will be given to the student stating why he/she may have missed the answer. For example, if a student inputs the correct value but misses a negative sign, the feedback will

instruct the student to recheck signs. Although the intent is for the different level worksheets to be distributed at certain times throughout the course, the level zero tutorials are accessible throughout the semester for reference on foundational concepts.



State the coordinates of each point labeled on the figure above:

	x	y	z
A =	0	0	3
B =	0	0	4.5
C =	-1.5	0	4.5
D =	0	3	0
E =	-1.5	0	0
F =	2	-1	0
G =	0	-1	3
O =	0	0	0

Check Answer

Figure 2. Overview of a level zero worksheet⁹.

The question posed in the level one worksheet, shown in Figure 3, is then broken down into step-by-step questions for the student. In this example, students are asked to find the tension in a three-dimensional vector. Here, students are asked to first input the solution for the coordinates in three dimensions of the points, the components of vector AB, the magnitude of AB, and then the components of the unit vector for AB. Students would be stepped through the process and provided feedback along the way to then finally find the force vector T in their last answer. If students stumbled in finding the components of the vector AB, they would be referred to the level zero worksheet on this topic. The design and continual checks of understanding make the level one worksheet excellent for assessing knowledge gained from a pre-assigned reading for

example. This allows the student to monitor his/her progress by working the problem and automatically checking the answer. If incorrect, the instant feedback aids the student by returning useful hints. Additionally, a hint button is present to guide the student towards a helpful page in the textbook for reference. By using this self-assessment worksheet, students can ensure they understand the reading and see if the material covered has been retained.

A turnbuckle at B is tightened until it induces a tension \mathbf{T} in AB of 2.4 kN. Express \mathbf{T} as a vector.

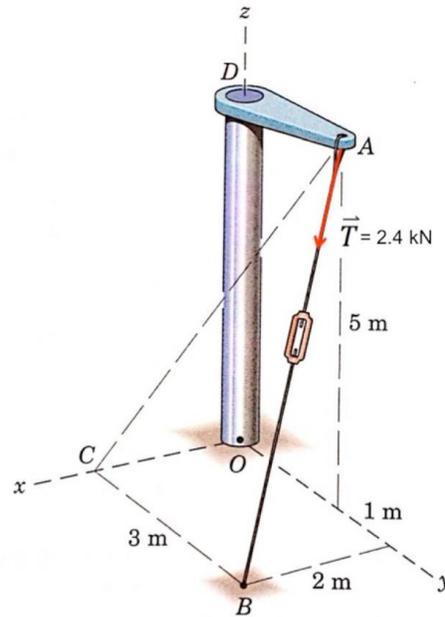
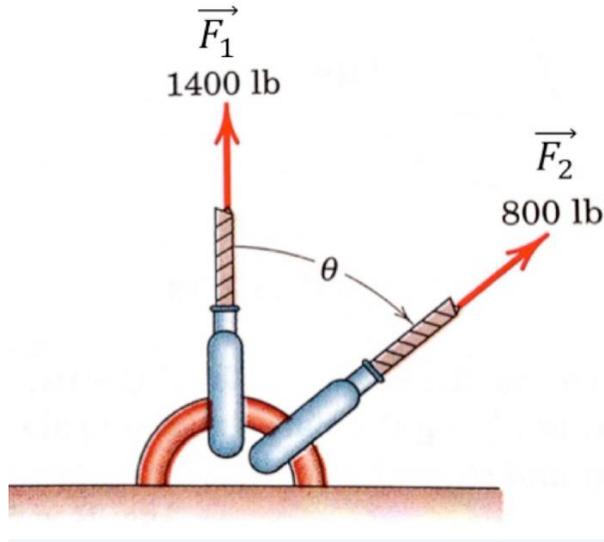


Figure 3. Question posed in the level one worksheet⁹.

The purpose of level two worksheet is to reiterate material covered in class with an ideal distribution being after the class in which the material for the worksheet was presented. A portion of the level two tutorial, shown in Figure 4, shows early guidance through the problem; however, responses for each step are not specified as in the level one problem. This allows for students to work through the problems without stepping through each simplified step. For example, the first step in this level two worksheet asks the student to input the vectors F_1 and F_2 instead of walking the student through this process. The student is then stepped through the pieces needed for solving the angle requested. Hint buttons are still embedded within the worksheets to advise students of examples problems on a specific page of the textbook.

At what angle θ must the 800 lb force be applied in order for the resultant \mathbf{R} of the two forces to have a magnitude of 2000 lb?



Find the vector \mathbf{F}_1 and \mathbf{F}_2 in terms of the unit vectors \mathbf{i} and \mathbf{j} :

$$\mathbf{F}_1 = \boxed{0} \mathbf{i} + \boxed{1400} \mathbf{j}$$

$$\mathbf{F}_2 = \boxed{800 \cdot \sin(\theta)} \mathbf{i} + \boxed{800 \cdot \cos(\theta)} \mathbf{j}$$

Figure 4. Portion of a level two worksheet⁹.

Level three tutorials were created to give students the tools necessary to work the problems and instantaneously check their answer to obtain adequate feedback. These problems do not contain any additional steps beyond a check of the final answer. Certain problems may contain a main hint button located beside the problem statement but not necessarily for every step. Intelligent feedback based on the answer received is still provided as applicable. Students can use these worksheets as aids for reviewing the chapter or as a study guide before an exam since they would be expected to work through the problem on their own instead of being guided by the tutorial.

Results and Discussion

Alpha Version

After the worksheets were created, it was important that students found the functionality and aesthetics acceptable. For this portion, three different students tested the tutorials in the presence of the worksheet developer, so that feedback on the process and solutions could be viewed and gathered. The first student had not yet taken the sophomore-level statics course but would be enrolled the following semester. The second and third students had previously taken the course but were unique in their approach to using the worksheets. One of the students was a meticulous direction follower whereas the other one but did not typically read directions, so his verbal input

and questions would be helpful. The three unique users were important because it allowed for a variety of items to be tested on the worksheets.

First, having a student who had not yet taken the course allowed for the clarity of the problems, the hint buttons embedded within, and the flow of the problems to be analyzed. Since he was not familiar with how to solve each of the problems fully, he was able to provide feedback that the other two users may not have noticed because they had both formerly completed the course.

The second user had successfully completed the course and was meticulous in following directions. This feedback provided the developer additional help on how to improve the tutorial and add more specifics to the conceptual parts of the worksheet.

The third user continuously asked questions verbally to the developer about the problems while working through them. This allowed the developer to see his thought process and ensure the adequate details had been included to guide a student autonomously through the process. When advised to read the directions, the questions by the student had been effectively answered on the worksheet.

Overall, the three users gave positive feedback along with suggested ideas for improvement. No major changes to the worksheets were needed; however, there were a few minor improvements changed, such as the format of questions and layout of the overall tutorials.

Beta Version

After the tutorials were modified, the researchers then assessed the interactive tutorial worksheets by implementing the beta version in a sophomore-level engineering statics course. The worksheets were implemented during Fall 2013 in a course with 76 students enrolled. The worksheets contained concepts taught during the first couple of weeks of class. Due to timing within the course and in completing final details on the worksheets, the process was changed from the researchers' goal of assigning worksheets in their respective order. Instead, they were given all at once at the end of the semester to serve as exam review guides. While this did not allow the researchers to properly assess the impact of the different levels of the worksheets, it did provide useful overall feedback on the intelligent interactive self-assessment worksheets. A small portion (3%) of the course grade was determined based on providing feedback on the worksheets. The grade received by students was based on whether or not input was provided in an on-line survey comprised of 36 questions requesting details on items from assessment of their knowledge of resolving vectors prior to using the tutorials to how they felt the worksheets could best be used as a resource to specific instances where feedback was not helpful. Overall, 66% ($n = 50$) of the students provided feedback through the on-line survey. Currently, there is no way to track how many students use the worksheets or how often the worksheets might have been employed. Overall, the students found the intelligent interactive tutorials helpful. As shown in Figure 5, 61% of students responded they liked the format of the interactive tutorials. Only 6% did not agree with this statement. Regarding the usefulness of the tutorials, 69% agreed that the worksheets were useful while 14% did not find them useful. Then, 64% of students found if they answered a problem incorrectly that hints provided were helpful to their learning with 19% of students disagreeing with this statement. Results related to additional information being needed

that was not provided were closer split with 43% disagreeing with this statement and 35% agreeing.

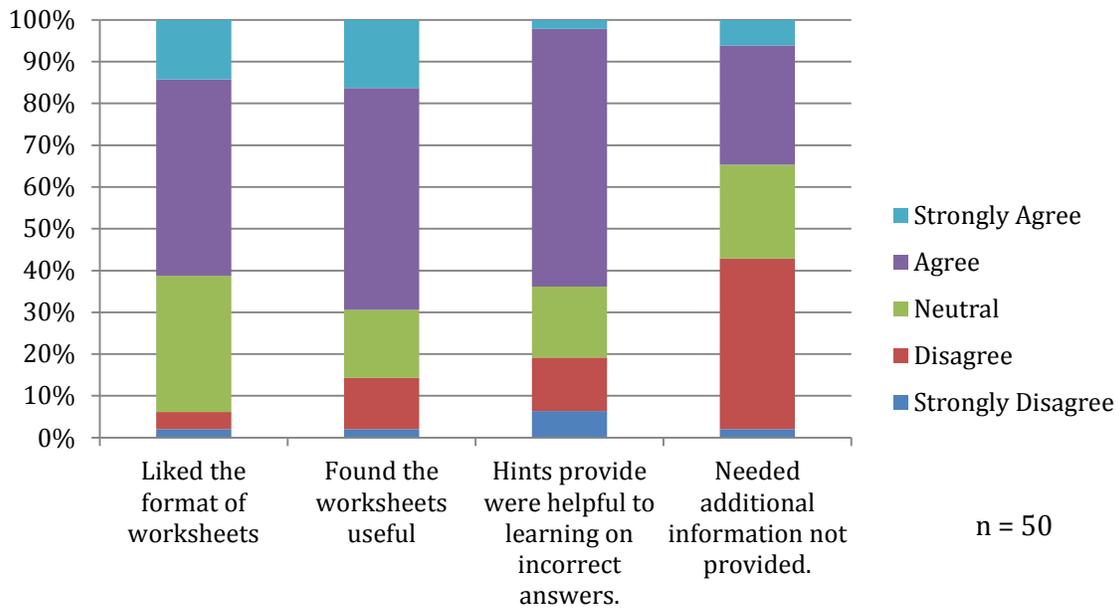


Figure 5. Feedback from Fall 2013 participants using the intelligent interactive tutorials.

The researchers felt the results shown in Figure 5 were promising. The majority of students liked the format of the worksheets, found them useful, and felt that hints provided were helpful to learning. Work needs to continue on providing adequate useful information in the personalized feedback, but this will be refined based on feedback received in the beta version.

As shown in Figure 6, overall students felt the experience of using intelligent interactive tutorial worksheets was positive with 63% of students agreeing with the statement. Then, 65% of students responded they would recommend these worksheets for someone learning the material. Finally, 67% of students would like to see similar interactive worksheets used in other courses as well.

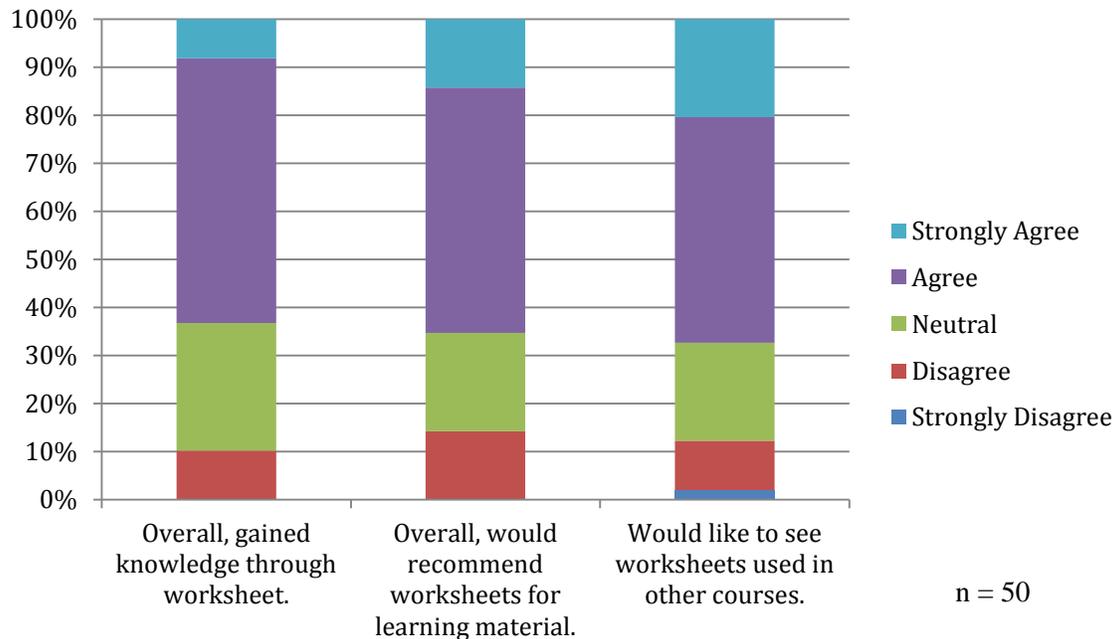


Figure 6. Feedback from Fall 2013 participants using the intelligent interactive tutorials.

Since the students received access to all four worksheets at one time, they were asked to compare and contrast their experience in going through a level one and then a level two worksheet. The students were not provided any information on what level the researchers had categorized each of the problems or what signified a level one from a level two. Even though they were already familiar with the subject matter from being taught earlier in the semester, they seemed to prefer the way the level one worksheet provided more feedback along the process. Students felt the level one worksheet was a lot easier to understand. This could be due to the fact the worksheets covered material they had not seen directly in several weeks, so having the tutorial step them through the solution was helpful.

Students did not find issue with using Maple for the platform for the worksheets. In fact, one student commented, “This was my first experience using maple and I found it easy to use and understand. It was extremely helpful.”. The only real issue with using Maple was that it was only available on-campus, so many students who work from home did not have access to it. Student computer labs are open 24/7, so this would not be seen as a limiting factor in the future.

In the next implementation of the worksheets, timing will be critical to assess. Comments, such as the following, reiterate this importance.

“I feel that these tutorials were very helpful in refreshing the concepts that we have previously learned. I think that they would be very beneficial when learning the material and checking to make sure it is understood. I really hope that classes use this resource in the future!”

“I like the idea of these tutorials, but I think usage throughout the course in its entirety would've been more beneficial than a single set just prior to the final.”

“I feel that if we were exposed to this interactive tutorial source all semester long, it would've prove to be helpful for the homeworks and exams.”

“Would have been more useful earlier in the year.”

The researchers found these comments useful to the importance students placed on helping them use the tutorials for learning.

Conclusion

Overall, the researchers found students considered the intelligent interactive tutorial worksheets to positively affect their learning. Students were able to identify areas they may not have understood correctly and target their learning to have a better foundational knowledge. With student comments, such as “I found the immediate feedback and the correct answer to be very helpful in the tutorials”, “I would like to see more of these throughout the course”, and “Overall I am pleased with the effectiveness of the tutorials. They served their purpose as good review problems and breaking down each problem into step-by-step solutions”, researchers are encouraged to continue to refine the current tutorials and develop new ones.

The next version of the worksheets will provide additional links within the tutorials to direct students to external sources on the Internet. Many students commented on resources they use to impact their learning in addition to the textbook for the course. Incorporating additional resources into the tutorials will also address the use of these worksheets for different learning styles of students. Relevant videos or tools already accessible online may help the visual or aural learner further their understanding of the material. One student alluded to this with the comment, “I do not directly benefit from maple tutorials such as the ones offered to help study for the final. However I do know of people who do benefit, so I think it is a good thing to offer in a class to better cater to every learning style.” Researchers plan to create a library of tutorials to be distributed throughout the course rather than the few that are currently available for topics covered early in the semester. This will also allow for future implementation in subsequent courses in the curriculum. In addition, the researchers plan to automatically document student use of worksheets instead of having them self-report time spent and then track the performance of students in the class based on this usage. These will be important parameters to gauge success of the project.

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