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Prototyping an Interactive Application to Support Collaborative Open-Ended Problem Solving for Precollege Students

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PROTOTYPING AN INTERACTIVE APPLICATION TO SUPPORT COLLABORATIVE OPEN-ENDED PROBLEM SOLVING FOR PRECOLLEGE STUDENTS

Abstract

The purpose of this paper is to showcase the design and implementation of a prototype of an interactive software application to support Model-Eliciting Activities (MEAs) for precollege students. MEAs were developed by mathematics education researchers to better understand and encourage problem solving. An MEA is an activity that is "thought-revealing and model-eliciting" [1] and has been adapted for other areas such as engineering from college to precollege. MEAs are realistic open-ended problem solving activities designed to encourage students to collaboratively create and improve mathematical models or algorithm. The instructional frame also provides a mean for educators to better understand students' thinking. MEAs involve students in communicating, working in team, critical thinking and problem solving, which are all necessary skills in engineering education.

A number of student team responses were analyzed to design the application in order to accommodate possible solution processes that may be employed by students so students do not feel restricted into pursuing a specific process to solve the problem. Students would collaboratively develop the first draft of their solution. Then they enter the solution into the application. The application executes each step and students see the results. Application provides immediate feedback for each step, which enables students to reflect on their solution and revise it. The prototype was tested with schoolteachers. The preliminary analysis shows overall positive reaction to the software with a number of suggestions. In addition, teams showed more collaboration on a big screen interactive boards compared to tablets.

Introduction

The interest to improve Science, Technology, Engineering, and Mathematics (STEM) education in pre-college educational systems has increased among government organizations and higher education institutes [2]. Despite this support there is no formal presence of engineering education at the U.S. precollege level [3]. In addition, the American Society for Engineering Education reports indicate that teachers believe studying engineering at college is more difficult than many other disciplines [3]. This perception passes from teachers to students. These may be some of the reasons that precollege students show no interest in engineering careers [4, 5].

Model-Eliciting Activities

One way to engage precollege students in developing interest and skills in STEM education is via Model-Eliciting Activities (MEAs). MEAs were developed by mathematics education researchers [6] to better understand and encourage problem solving. An MEA is an activity that is "thought-revealing and model-eliciting" [1] and has been adapted for other areas such as engineering [7]. MEAs are realistic open-ended problem solving activities (with a client) designed to encourage students to collaboratively create and improve mathematical models or algorithm. The product is the process for solving the problem. The end product is a mathematical model (or procedure) that the client can use. Figure 1 illustrates the process of designing the mathematical model. The instructional frame also provides a mean for educators

to better understand students' thinking. Research on MEAs reveals that these activities by providing a context for precollege students to explain thinking and justify conclusions, highlight the aspects of literacy that lead to students success; MEAs also help to identify specific areas that need attention in instruction [8].

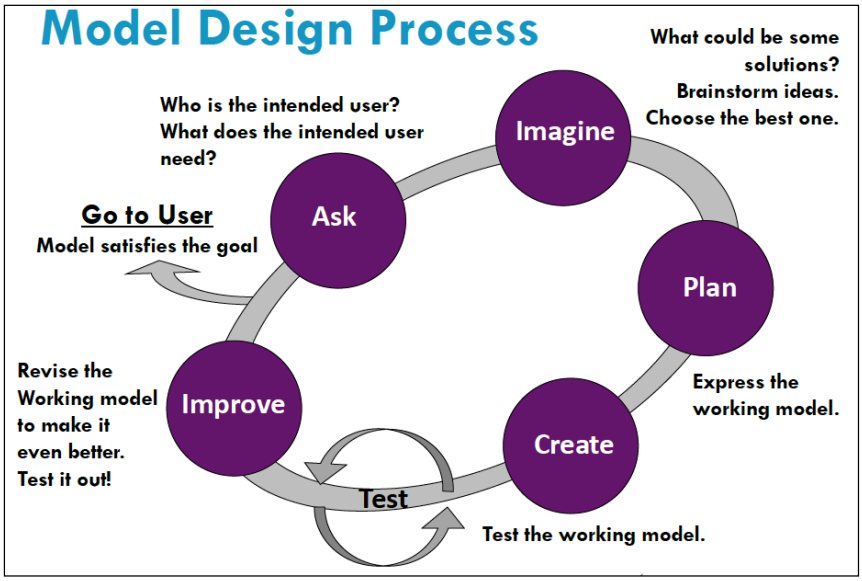


Fig 1 – MEA model design process.

MEAs involve students in communication, teamwork, critical thinking and problem solving, which are all necessary skills in engineering education [9, 10]. Mousoulides and English [11] argue that "engineering model eliciting activities in elementary school mathematics curricula can engage students in creative and innovative real-world problem solving and can increase their awareness of the different aspects of mathematical problem solving in engineering".

MEA's are based on six principles [1]:

1. Model Construction principle: The design of the problems must allow creating a model including elements, relationships between these elements, and patterns and rules governing these relationships.
2. The Reality Principle: Problems must be meaningful and relevant to the students.
3. Self-assessment principle: Students must be able to self-assess their solutions.
4. Construct documentation principle: Students must be able to reveal and document their thinking processes within their solution.
5. Construct share-ability and reusability principle: Solutions created by students should be easily adapted to other situations.
6. Effective Prototype principle: Others should easily be able to understand the solutions.

Interactive Devices in Education

With the emergence of the new technologies, the popularity of interactive devices has increased. Prior research has demonstrated interactive devices can promote learning [12, 13, 14, 15] and encourage participation and collaboration [16]. These devices are also enjoyable to use [17] and promote playfulness [18, 19, 20]. Because of these reasons, designing interactive software for MEAs may result in higher engagement of precollege students on these activities.

Research Purpose

The purpose of this paper is to showcase the design and implementation of a prototype of an interactive touch-screen application to support MEAs for precollege students.

Toothpaste MEA

The prototype has been designed and developed for Toothpaste MEA. In this activity, the president of Toothpastes "R" Us company, B. R. Ushing, asks student to help with the process of ranking recipes from best to worst. Table 1 illustrates the letter B. R. Ushing has sent to the students. Students are asked to develop a solution to rank different versions of toothpaste based on performance, safety, cost, and taste. The datasets that are provided with this MEA are designed in a way that there is no one correct answer and students have to decide which factors are more important (see table 2).

Table 1 – Letter of the president of the toothpaste company to the students

Toothpastes "R" Us
32 Permanent Teeth St.
Smiley, TX 91011

Dear Students,

Toothpastes "R" Us is a new dental care supply company that wants to get into the toothpaste business. We are trying to decide which recipe to manufacture on a large scale. We need your team's help! In order to come to a decision, we need you to rank the recipes from best to worst.

Here are some things your team should know. Our company has researched five toothpaste recipes and has evaluated them on four criteria: performance, safety, taste and cost. We have provided you with a copy of these ratings. Look over these data and then develop a procedure for ranking the toothpaste recipes.

Please write us back and tell us the order in which you ranked the recipes and why. Also, provide us with a clear and detailed procedure for how your team ranked the toothpaste recipes from best to worst. Make sure that your team's procedure will work even if we decide to research and collect additional data on other toothpaste recipes.

Thank you for your help!

Sincerely,

B. R. Ushing
President, Toothpastes "R" Us

Table 2 – A sample dataset for toothpaste MEA, there is no one correct answer

Recipe (the version of the recipe that was rated)	**Performance** (how well the toothpaste cleans teeth)	**Safety** (how safe the ingredient in the toothpaste are if swallowed)	**Taste** (how pleasant the flavor of the toothpaste is while brushing)	**Cost** (how much it costs to manufacture it)
Version A	☺	☺	☺	☹
Version B	☹	☺	☺	😐
Version C	☺	☺	☹	☺
Version D	☺	😐	😐	☺
Version E	😐	☺	☺	😐

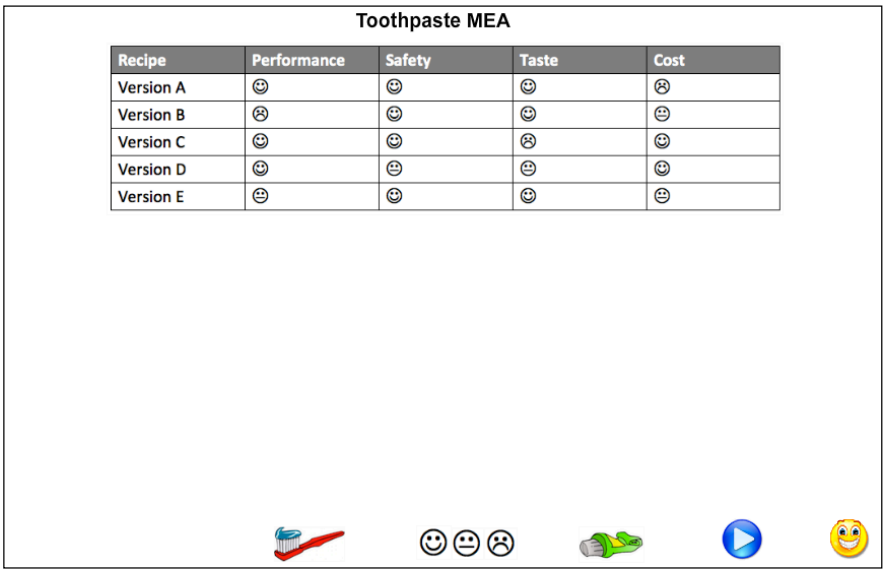
Designing the Prototype

One of the main challenges of designing software for an open-ended problem solving task is to accommodate, if not all, as many as possible different solutions students may develop. In order to do so, a number of student team responses were analyzed to design the application in order to accommodate all possible solution processes that may be employed by students so students do not feel restricted into pursuing a specific process to solve the problem. This analysis revealed that students typically use two main strategies to develop their procedure: elimination or mathematical strategy. In the elimination strategy, students simply decide to delete some versions based on the low rank in a criterion (e.g. remove all toothpastes with frowny face in safety). In this strategy, they keep removing the toothpastes until there is only one toothpaste left. In the mathematical strategy, students may assign values to each face, assign weight to each criterion and calculate a total point for each version, then rank them.

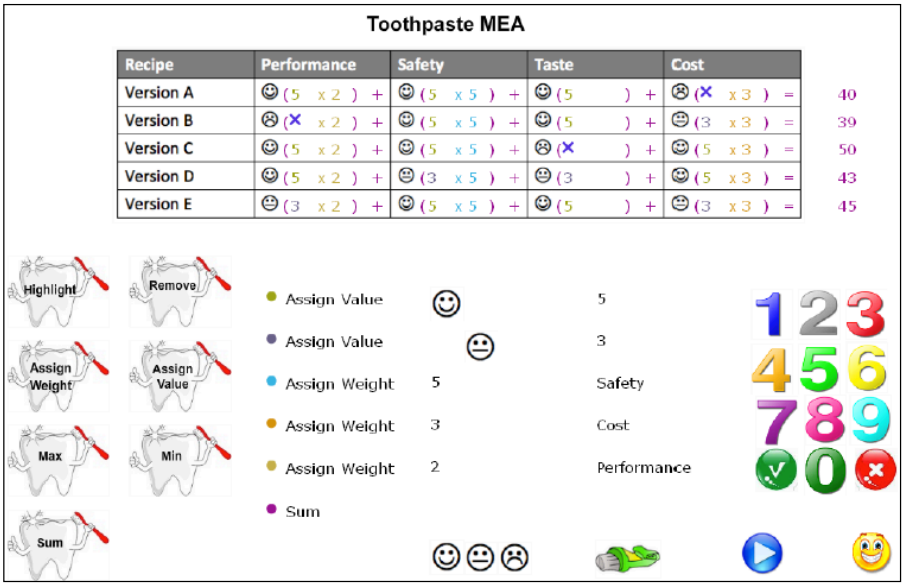
The first prototype was designed for a touch-screen interactive board. Figure 2a illustrates this prototype (at the beginning of the problem solving process). The screen has been divided into three main sections. The main interaction buttons are located at the lowest part of the screen, which is more accessible by children when interacting with a board. The top part of the screen is the data table, in which students can see the results of applying their procedure to the dataset. And the middle part of the screen, displays the steps that have been executed. Figure 2b illustrates the software with some steps executed.

Each step starts with an action. Thus a toothbrush button, resembling an action, was used. By clicking on the toothbrush (or action) button, students can select an action from all possible actions. The next steps are defined based on the action that the student wanted to apply. For most of the implemented actions, the student needs to select a face (e.g. assign a value to a face, remove a face) and/or a criterion in the table (e.g. assign a weight to a criterion). To select a face, they simply click on the face they want to apply the action on. To select a criterion for the toothpaste they click on the toothpaste button then they will be able to select their criterion. At the end of each step by clicking on the play button, the step executes and the students can see the immediate result of their actions on the table. This method of displaying the results of executing steps is very similar to what students were doing in class and applying their solution manually to the table on the paper. The actions are also color-coded. Thus students can easily keep track of the result of each action and they do not need to mentally keep track of that. This may lower the students' cognitive load and allow them to

focus on providing a solution. A refresh button designed to clear all the steps and students can try a new solution.



(a)



(b)

Fig 2 – Prototype designed for a touch-screen interactive board, (a) at the beginning of the problem solving process, (b) after executing a few steps.

Using the Prototype

Students will be assigned to teams of 3-4 and will be asked to collaboratively solve the Toothpaste MEA. Students collaboratively develop the first draft of their solution. Then they enter the solution into the application. The application executes each step and students see the results. Application provides immediate feedback for each step, which enables students to collaboratively reflect on their solution, discuss the results, revise the solution and try again.

Testing the Prototype

The prototype was tested in two phases. In phase one the prototype was showed to the MEA writing and research teams for a primary evaluation. In the second phase, the prototype was tested with schoolteachers. In a professional development program, schoolteachers interacted with the software via two different touch-screen devices, tablet and interactive board. They were asked to solve the toothpaste MEA using the software. At the end of this activity, they were asked to fill in a comment card and provide feedback, suggestions, questions or comments. Ten schoolteachers filled in the comment card.

Results and Discussion

The overall reaction of the teachers to the software was positive. One of the teachers commented, "This process elicits deep/broad (critical) thinking in participants." Another teacher commented, "I like the problem solving conversations these projects would evoke."

The teachers as well as the MEA writing and research teams suggested adding the following functionalities to the software to make it more useful for students:

- *Undo button*: the ability to undo an individual step
- *Print function*: printing the developed procedure
- *Save/Load*: software being able to save a procedure and then load it again at a later time.
- *Editing a numerical value*: the ability to edit an assigned value to a face or criterion.
- *Labeling the buttons (icons)*: participants suggested putting word besides the labels is beneficial from both usability and educational perspectives.
- *Special version for colorblind students*: since the actions are color coded, it was suggested to take into account colorblind students.

In addition, observations of schoolteachers collaborating with each other showed more collaboration on the big screen interactive boards compared to tablets. Since students are asked to solve the problem and create a solution in teams, using the software on a touch-screen interactive board might facilitate the collaboration among student team members. This is particularly important for elementary students to develop team-working skills.

Conclusion

This paper was the first attempt in designing software to support model-eliciting activities in precollege education. As mentioned earlier the overall reaction to the software was positive. However, there were some suggestions that can make the software more effective to be used by students. In the next step, we will design and implement these suggestions and test the software with the students.

Acknowledgements

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