Enhancing Middle School Math with Alice Programming

Chitra Gadwal
Computer Science and Electrical Engineering
University of Maryland, Baltimore County
Baltimore, MD USA
cgadwa1@umbc.edu

Mentor:
Susan H. Rodger
Computer Science Department
Duke University
Durham, NC USA
rodger@cs.duke.edu

ABSTRACT

This paper describes how we integrated computing into middle school math using Alice, a 3D virtual programming environment [12]. We created math games in Alice that will assist teachers in teaching North Carolina's concept standards. We created step-by-step tutorials for students to rebuild the games or they can download the finished world and play the game. Either way, the students will get practice and gain a better understanding of math concepts and if they build the worlds they will also gain better understanding of programming. In this paper, we will give details of some of the worlds we created.

1. INTRODUCTION

Technology is constantly changing, generating a strong demand for jobs. However, there are not many students to fill those positions. Students in middle school are starting to think about careers. A lot of kids, especially girls see computer scientist as a non-social geek sitting at a computer. But the truth is computer science allows students to be creative and adventurous, especially with Alice.

Alice is a 3D programming environment [2] that allows users to create an interactive story or game, and export their game into a video. With its drag and drop interface, it allows students to get an easier introduction to object-oriented programming. Alice includes many 3-D objects of people, buildings, animals and vehicles. This programming tool also allows users to create their own 3D text objects and build their own person. Alice can be used by students and teachers in any discipline. It allows students to become more engaged in concepts teachers want them to learn.

2. PREVIOUS WORK

In the summer of 2008, the Adventures in Alice programming team ran a three-week Alice training course [1]. The first two weeks consisted of teaching middle/high school teachers key concepts in Alice [3].

In the summer of 2009, three one-week workshops were held for K-12 teachers [15]. There were 100 participants, almost half the teachers were high school (9-12), one third were middle school (6-8), and the rest taught at elementary schools (K-5). One interesting thing that was noted by Lana Dyck, [4] was

only 30% said teachers would allow students to do the programming. The teachers were from a variety of disciplines and they requested over 300 additional objects they wanted for Alice.

In the summer of 2010, there were two one-week workshops catered to 38 teachers from a variety of disciplines either in middle or high school [14]. The research assistants [5] presented their own Alice worlds to show teachers examples they could do in their own classroom. In addition to the two one-week workshops, there were two two-day workshops for returning teachers from previous summers. At the first two-day workshop most teachers wanted to learn more on how to create games. While the second two-day workshop had more of an interest in subject-specific worlds such as Math and Biology. Along with focusing on discipline-specific projects, the summer of 2010 focused on game and project examples for teachers.

3. Other Work

Calvin College's Imaginary Worlds Camp [6] was a one week day camp that used Alice for boys and girls ages 10-14. They reported by the end there was a positive shift in girl's attitude on computing.

Bloomsburg University ran a Math and Science Summer Experience program for middle school students. They advertise it for students interested in math and science but introduced Alice to see if the kids would be interested. By the end, 56 students out of 82 indicated they liked the Alice session the best, which is more than two-thirds of the camp. The kids came because they had a true interest in math and science, but these results show that students who like math and science enjoy computer programming as well.

Surprising Possibilities Imagined and Realized through Information Technology (SPIRIT) [7] was a three-year project funded by the National Science Foundation. This program helped high school teachers with integrating Alice into their classrooms. During the summer, they go through two-week training and during the school year they are required to meet with the SPIRIT team four times and report their progress.

Based on the teacher's testimonials, this program has proven to be successful. There is evidence that proves that when students apply concepts to real-life situations then they tend to learn better. One teacher who has a class that is diverse in the fact that some of students are gifted, average and low-performing stated that 100% of her students passed their assessments because of Alice. Another math teacher's class had a hard time understanding a specific word problem until the teacher represented it in Alice and the class understood it much better. The majority of this success was due to the teacher's excitement.

Jane Nawrocki, in collaboration with Alka Harriger from Purdue University created Alice Game templates [8] that can be used by all teachers of any discipline. According to Harriger, regular review and reinforcement will help students understand their school work. However, regular review and reinforcement is very tedious and boring so by integrating concepts into games students will get better with practice.

Some game templates include Vocabulary Jeopardy, Hollywood Squares, and Whack-A-Mole. Vocabulary Jeopardy can be used for all subjects where students need to memorize words and definitions. The game is similar to the TV Jeopardy except there are two players. Hollywood Squares can be used to represent true/false or multiple choice questions. Teachers add questions, and if they get it right then they get to an X or O. The goal is to get three X's or O's. Lastly Whack-A-Mole is used to represent four multiple choice answers. You have to whack the correct mole in order to get the question right. These templates are easy to follow, and allow teachers to input their questions and answers directly without building the entire world.

4. SUMMER OF 2011 WORKSHOP

This summer we held two workshops: one two-day workshop for returning teachers from previous summers and one two-week workshop for beginner teachers who had an interest in learning Alice.

The two-day follow up workshop was very informal and only had a few teachers. We mostly heard how teachers are using Alice, and some of them even shared some of their student's worlds. One of the teachers mentioned how she has only a short amount of time with the students, so she has created videos of her doing the tutorials we provide on our website [13]. She suggested that we should create videos of us doing the tutorials step by step. One of the teachers from Durham Technical Community College, demoed one of his student's worlds with a catapult shooting cats into hoops. In Section 5.3, we will go into detail on how we incorporated his student's idea in one of our worlds.

The two-week workshop was for 27 teachers with no programming experiences although there were about four who were familiar with Alice. The majority of the teachers taught at middle or high school and the subjects they focused on varied widely. The first week was spent going through step-by-step instruction using the tutorials from our online database. The hardest tutorial for the teachers was the four-part Princess and Dragon tutorial. At the end of the Princess and Dragon tutorial, the teachers were given an assignment as a follow up to the tutorial. The majority of the teachers showed their finished world.

By the second week, we noticed a lot of progress from the teachers. The second week had little instruction and mostly the teachers spent their time developing their own worlds and lesson plans. We also worked very closely with the teachers to get their worlds just right. Later on in the week they presented their worlds and lesson plans.

During the second week we got a chance to ask the math teachers what kinds of worlds they would like. One of the teachers said that many students have a hard time with operations involving negative numbers. She says that they were supposed to have learned it the previous years, but they either forgot or did not really grasp the concepts. She recommended going back and overview the basic operational concepts such as addition, subtraction, multiplication, and division involving negative numbers.

Another teacher shared with us website links that she frequently used. She told me that a lot of her kids do not get enough exercise, so she uses Math Middle School Energizers [9]. She even took one of the energizers, Sign me up, and recreated it in Alice. The way Sign me up works is the teacher gives the students a problem, and once they solve the problem they must do the physical activity associated with the sign of the answer for 15 seconds. If the sign is negative then they have to march in place for 15 seconds. If the sign is positive they hop up and down and if the answer is zero then they must jog in place. The teacher recreated this in Alice and had the numbers in the problems randomized. She had five people in her world who serve as the students and one person who serves as the teacher. Later on, in Section 5.5 we will describe the energizer that we recreated in Alice.

5. MATH WORLDS

This summer we mainly focused on integrating math into Alice. We looked up North Carolina's education standards [11], which are concept guidelines that all teachers must follow in North Carolina. Based on those standards we have created our worlds.

5.1 Ice Cream Functions

Danica McKeller writes books for girls to better understand math concepts. She uses examples that girls can relate to. One of the ideas we took from her book [10] and recreated in Alice was her functions factory. She describes it as putting a food product into a factory and it comes out differently. She relates this to how one would plug in x into an algebraic expression and get a different answer. We integrated this concept into this world, and used ice cream as the x value that goes into the factory or algebraic expression and comes out the factory with a different ice cream flavor.

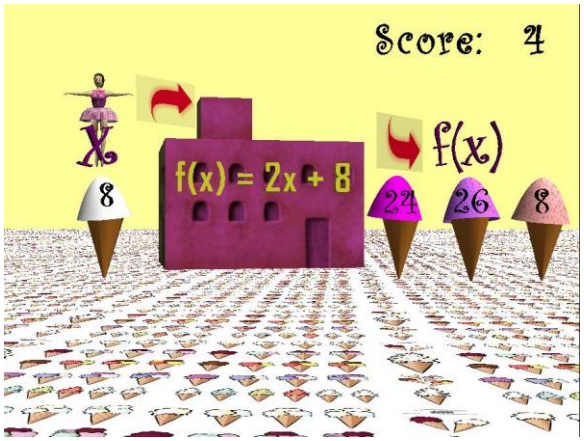

Figure 1: Screenshot of Ice cream tutorial

The world starts with the shop owner who is also a ballerina tells the player the rules, the player is only allowed to click on the ice cream scoop and not the cone. Then x value, coefficient, constant, and the wrong answer choices are generated randomly. The player must click on the choice that they think is correct. If they get it right, then the ballerina will say "Correct!" and the score goes up by 1. If they get it wrong, then the ballerina will move to the correct answer and the score does not increase. There is a loop that continues the process over again 9 more times. The goal is to get them all right so the reward is a life time supply of ice cream.

Teachers can modify the number of questions the player must answer and the amount of questions they need to get correct in order to receive the prize. Also, they can change the type of equation; instead of

doing algebraic expressions they could do something simpler. An exercise they could complete after they play and/or build the world is to add negative numbers to the world. Changing x-value, coefficient, and constant to generate random numbers that can be negative will make the world more difficult and once they play they can get practice working with negative numbers. According to the North Carolina Standard Course of Study [11] this tutorial fulfills grade 8 learning object 5.01 which includes developing and understanding the concept of a function.

5.2 Toy Story Discounts

Toy Story teaches students how to apply percentage discounts to whole numbers. In this world, there are about eight toys either on a table, hanging on the wall, or under the table. The guide was created using the *she builder* and has built-in methods such as happy and confused. One at a time each toy tells the player, what their original price is and what their percent discount is. The player must calculate the new price and enter it in when prompted to. Each toy's original price is randomly 10, 20, 30 or 40. The first toy's discount is 10% and as you continue to the next toy the discount is increased by 10%. So the last toy has a discount of 80%. If the player gets the question right then the score will increase by 1 and the guide's happy method will be called.

Figure 2: Guide's happy animation.

If the player gets the question wrong then the score will stay the same and the guide's confused method will be called.

Figure 3: Guide's confused animation.

Some assignments that can go along with this world include adding more toys, changing the percentages to something other than multiples of 10, changing the original prices to something other than 10, 20, 30, or 40. According to the North Carolina Standard Course of Study this tutorial fulfills grade 7 learning objective 1.01 which includes the use of ratios, proportions and percents.

5.3 LCD Catapult

As mentioned before, during the two-day workshop a teacher from Durham Tech presented one of his student's worlds that involved a catapult shooting cats into hoops. We incorporated this student's idea, but added a math twist to it. We included two fractions and asked the player to calculate the Least Common Denominator (LCD). The answer choices were displayed above the hoops and the player had to click on the hoop that they thought was the correct answer. If the player got it right then a 3D text object appears that says "Correct!" and if they got it wrong then another text object appears that says "Wrong" in big red letters.

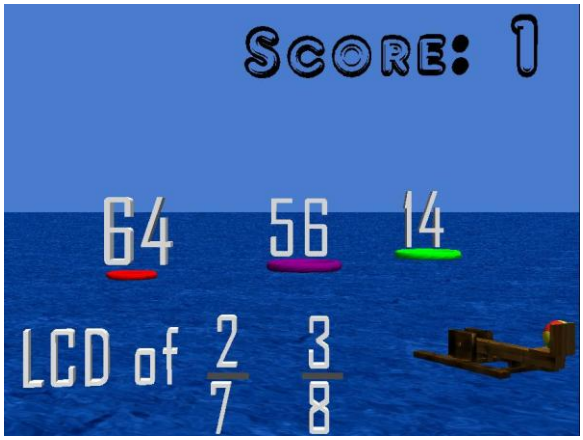

Figure 4: Screenshot of LCD Catapult

As an exercise after they create this tutorial they can add another fraction and find the LCD of all three denominators. Also they can randomize the positions of the hoops to make it more interactive. According to the North Carolina Standard Course of Study this tutorial fulfills grade 6 learning objective 1.05 which includes the use of factors and multiples.

5.4 Shark Attacks Probability

Shark Attacks Probability is a tutorial that teaches students basic probability concepts. There are three types of fish: blue, yellow and pink minnow in this world. Each type can have up to four fish displayed in the world at once. The shark then asks the player what is the probability that he will eat a yellow fish, and then he asks what is the probability that he will eat a blue fish. To switch things up a bit, he asks what is the probability that he will eat a fish that is not pink. Lastly he asks what is the probability that he will eat a fish that is pink or yellow. As he asks the question, the fish are rotating signaling that the player should count the amount of fish. If the player gets the answer correct then the score is incremented but if he gets it wrong then the shark moves closer to the fish. The player must get all four questions correct to win, if they do not then the shark will eat all the fish.

Figure 5: Screenshot of Shark Attacks Probability

An exercise that can be done after this world is built is to have the shark eat one of the fish if the player gets the question wrong. This will affect the answers to the questions

later on and make the game harder. According to the North Carolina Standard Course of Study this tutorial fulfills grade 6 learning objective 4.02 which includes studying sample space to determine the probability of an event.

5.5 Energizer: Operations Computations

As mentioned earlier, there is a high rise of obesity in America. More teachers are trying to implement exercise and learning at the same time. These are called Middle School Energizers and one of the teachers during the workshop uses them in her classes. During the second week she was able to recreate one of the energizers in Alice and we recreated one as well.

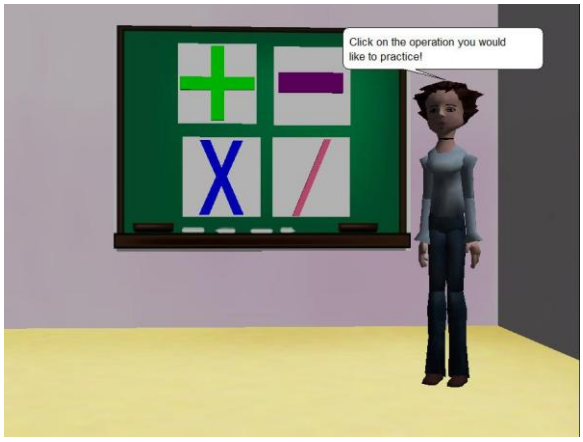

Figure 6: Screenshot of operations chalkboard

Operations Computations teaches North Carolina Standard Course of Study grade 6 learning objective 1.04 and grade 7 1.02. Both include fluency in addition, subtraction, multiplication, and division of numbers. The student/teacher can choose which operation they want by clicking on the symbol. Then random numbers are generated and the problem is displayed. For 10 seconds you must complete the physical activity that corresponds with the operation. Then the player will be prompted to answer the question. For addition the physical activity associated with it is hitting the drums, subtraction – knee lifts, multiplication – twist, and division – running in place.

Figure 7: Example of one of the operations.

Teachers can change the range of random numbers chosen depending on the level of the students. Some end exercises that can be included is adding a score keeper and adding a fifth option to the blackboard. The fifth option can either be a randomly picked operation (addition, subtraction, multiplication, or division) or it can be a combination of two of the four operations.

6. ANALYSIS OF TEACHER'S WORLDS

We collected all the worlds that teachers made during the two-week workshop to analyze them to form data. We made a list of programming and animation concepts, and then we went through each world and counted the number of times each concept was used. We discussed, what was

interesting about the data and then wrote a report on it [16].

We decided that there are 98 basic Alice features and the teachers used 69 different features. On average, 20.78 features were used in each of the Alice worlds built. We discovered half or more of the teachers actively created new variable, used functions, loops, do togethers, built-in methods, etc.

Teacher's worlds were built for one of three categories: (1) presentation only, (2) interactive games (3) example world teaching students to build their own Alice world. Teachers who created a clear lesson plan that said they would make "creating an Alice world" as options for a class project were placed under "Building Alice Worlds." Presentation worlds were just for the students to watch and interactive games were just for the students to play. The total amount of worlds created was 32, 11 of them suggested they would have their students build the Alice worlds, another 11 were interactive games and the last 10 worlds were for presentation only.

7. SUMMARY

In prior work Alice has been integrated into K-12 in a number of disciplines. Our goal this summer was to create Alice worlds that would teach math to middle school students and expose them to computer science through programming. We have created worlds that cover several topics in the North Carolina Standard Course of Study. On the way we have interacted with teachers from North Carolina and taught them Alice. Lastly, we have analyzed worlds that they built and their corresponding lesson plans. Overall they understood the Alice features and used them a lot, however only 11 lesson plans demonstrated that students will build Alice worlds. Next year, we should definitely encourage the teachers to have their students build Alice worlds so students can learn programming concepts. Perhaps, we could demo worlds that require the user to change the code. In conclusion, this was a very successful summer with Alice.

REFERENCES

[1] Susan H. Rodger, J. H. (2009). Engaging Middle School Teachers and Students with Alice in a Diverse Set of Subjects., (pp. p.271-275).

[2] *What is Alice?* (n.d.). Retrieved August 1, 2011, from Alice: www.alice.org

[3] Gaetjens Lezin, D. S. (2008). *Adventrues in Alice Programming Project.* CRA-W DREU.

[4] Lana Dyck, D. S. (2009). *Connecting Computer Science and the K to 12 Classroom.* CRA-W DREU.

[5] Francine Wolfe, D. S. (2010). *Integrating Computer Science into K-12 Education.* CRA-W DREU.

[6] Eileen M. Peluso, E. M. (2009). Incorporating Alice into a Summer Math and Science Outreach Program. *Alice Symposium* .

[7] Harriger, A. (2009). Could Alice Equalize Student Learning? *Alice Symposium* .

[8] Jane Nawrocki, A. H. (2009). How Alice Game Templates Support Student Learning . *Alice Symposium* .

[9] Instruction, N. C. (2006, July). *Math Middle-School Energizers* . Retrieved August 1, 2011, from East Carolina University: http://www.ecu.edu/cs-hhp/exss/upload/MSE%20Math.pdf

[10] (2010). In D. McKellar, *Hot X: Algebra Exposed* (pp. 116-118). New York: Penguin Group.

[11] Carolina, P. S. (n.d.). *Middle Grades Resources*. Retrieved August 2, 2011, from NC Standard Course of Study: http://www.ncpublicschools.org/curriculum/mathematics/middlegrades/

[12]Dann, W. C. (2008). *Learning to Program with Alice.* Upper Saddle River, NJ, USA.: Prentice Hall Press.

[13] Rodger, S. (n.d.). *Adventures in Alice Programming*. Retrieved June 1, 2011, from Adventures in Alice Programming Durham, North Carolina Region: http://www.cs.duke.edu/csed/alice/aliceInSchools/

[14] Stephen Cooper, W. D. (2011). A Pre-College Professional Development Program. *The 15th Annual Conference on Innovation and Technology in Computer Science Education (ITiCSE 2011)*, (pp. 188-192). Darmstadt, Germany.

[15] Susan H. Rodger, M. B. (2010). Enhancing K-12 Education with Alice. *The 15th Annual Conference on Innovation and Technology in Computer Science Education (ITiCSE 2010)*, (pp. 234-238). Ankara, Turkey.

[16] Susan Rodger, Sarah Zhang, Melissa Dalis, Chitra Gadwal, and Peggy Li. *Integrating Programming and Animation in a Diverse Range of Disciplines in Secondary Schools - An analysis of Alice teacher lesson plans and worlds*, Duke University, August 2011.