Enhancing K-12 Education with Alice Programming Adventures [*]

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ABSTRACT

This paper describes the integration of the Alice 3D virtual worlds environment into many disciplines in elementary school, middle school and high school. We have developed a wide range of Alice instructional materials including tutorials for both computer science concepts and animation concepts. To encourage the building of more complicated worlds, we have developed template Alice classes and worlds. With our materials, teachers and students are exposed to computing concepts while using Alice to create projects, stories, games and quizzes. These materials were successfully used in the summers 2008 and 2009 in training and working with over 130 teachers.

Categories and Subject Descriptors

K.3.2 [**Computing Milieux**]: Computers and Education-Computer and Information Science Education

General Terms

Human Factors

Keywords

Alice, virtual worlds, K-12 education, middle school, introductory computer science

1. INTRODUCTION

K-12 students enjoy using technology with their iPods and cellphones, and they enjoy surfing the web, "googling" for items and participating in social networks such as Facebook. Despite using these technologies, they have only vague notions of what computing is. This is not surprising as computer science is not taught as a subject in elementary school, middle school, nor many high schools.

An NCWIT scorecard report[8] from 2007 states several facts about the low number of students in computing. One fact is that American high school students considering the study of computer science has declined 70 percent over the past five years, with the percent decrease of women even steeper. Another fact shows that girls represent 56% of Advanced Placement (AP) exam-takers, yet less than 15% of those taking the AP computer science exam.

Our project exposes students in K-12 to computing by integrating computing into the K-12 curriculum via the Alice programming language[6, 3]. Alice is a 3D virtual worlds programming environment that is easy for novices to use due to its drag-and-drop interface and its extensive library of 3D objects. With Alice one can easily create interactive stories or games.

We have used Alice successfully at the college level for eight years and at the K-12 level for four years. At Duke University we have taught Alice in two courses. In CompSci 49S, Animation and Virtual Worlds, Alice is one component of the course for 3 weeks, and in CompSci 4, Introduction to Programming via Animation and Virtual Worlds, Alice is a semester programming course for non-majors. Our Alice courses attract a diverse crowd, with 50% female enrollment.

In the past four years we have taught Alice to over 130 K-12 teachers from a large variety of disciplines and over 200 K-12 students. We are part of an NSF ITEST grant teaching Alice to K-12 teachers in six regions of the country: Durham, NC, San Jose, CA, Virginia Beach, VA, Charleston, SC, Oxford, MS and Colorado Springs, CO. The majority of these sites are focusing on using Alice in a high school programming course. Our site's target audience is middle school and high school, and even some of the higher level grades in elementary school. Our focus is not a programming course but rather to integrate Alice programming into the whole curriculum in all disciplines.

Our approach is teaching both computer science concepts and topics on animation. We have developed Alice template classes, example worlds, and over 40 short tutorials at different levels. Students use Alice to create stories as reports for projects in any of their courses. With our advanced tu-

torials, older students can learn more Alice. K-12 teachers build Alice worlds for use in lecture, or as coursework for students to view or build on. All our materials are freely available on our website [16].

Our use of Alice fits in with components of the model curriculum document for a Level I course by the CSTA [9] that includes problem solving and computer programming. A 3-5 grade student should be able to create and follow an algorithm and code and test a simple sequential program. A 6-8 grade student should be able to code and test a program to solve a problem using variables, decisions, and loops.

This paper describes the materials we have developed from our experiences with teachers and students. Our materials range from Alice animation concepts for enhancing worlds to computer science concepts. Section 2 describes previous work with Alice. Section 3 describes the K-12 materials we have developed. Section 4 explains sample Alice worlds we have created, especially for use in Math. Section 5 shows feedback from teachers on 3D objects. Section 6 is our conclusion.

2. PREVIOUS WORK

There are other tools besides Alice to engage K-12 students in computing such as Scratch[18], Logo[12], and Lego MindStorms[11]. We have chosen Alice to work with as we have seen first hand how Alice engages and excites all levels of students from elementary age to college age. Alice is easy for students to use to create a simple 3D animation, and with guidance students can create complex animations.

The previous work in Alice is increasing steadily, including an Alice symposium [1] at Duke University in June 2009 with twenty-six paper presentations on Alice, mostly as introductory programming courses at the college level or the K-12 level with teacher training. Alice is being used in extracurricular activities, summer camps and outreach programs [14, 4, 2, 7] with some programs just for girls [5, 15]. Both [10] and [17] hold extensive workshops for K-12 teachers and work with them in developing lesson plans.

We have taught Alice to both K-12 teachers and students. Since 2007 we have run one-hour Alice sessions for over 180 4th-6th grade girls. In summer of 2008 we ran a three-week Alice workshop for about 35 teachers, and two one-week camps on Alice for middle school kids. The teachers developed Alice worlds for their disciplines with lesson plans and got some experience with kids as their last week overlapped with the kids camps. In summer of 2009 we ran three one-week workshops on Alice for 100 K-12 teachers. The teachers' disciplines included science, social studies, foreign language, language arts, math, english as a second language, art, music, business, and media.

3. ALICE TUTORIALS AND CLASSES

From our experiences with teaching Alice to K-12 teachers in different disciplines and teaching Alice to K-12 students, we have developed many Alice tutorials, Alice classes, and discipline specific example worlds. The tutorials range from Alice animation concepts to computer science concepts, and from creating objects to creating a large project. We have made the tutorials appealing to students by using titles they can relate to instead of computer science topics.

3.1 Getting Started Tutorials

We have created three types of getting started tutorials. The first type is a short 15 minute tutorial to build a simple animation of one object using built-in methods. These tutorials introduce Alice and pique interest in creating an animation.

The second type of tutorial introduces the richness of Alice in one-hour. These tutorials show the user how to position objects in a world, create methods, glue objects together, change camera views, and create simple events. We have two of these tutorials, a moon scene with an astronaut and a humvee, and a water scene with a fish and fairy.

The third type of tutorial is a four part tutorial (each part one-hour). These tutorials include the topics from the second type of tutorial, include a richer story with more interaction (more types of events, additional camera control topics) and include additional topics such as invisible objects, lighting, 3D images (billboards), 3D-text, and sound. We have created two of these tutorials. One is a skateboarder story including a girl maneuvering a skateboard around cones and over a jump. The other is a story with objects attractive to kids including a cell phone and a horse.

These getting started tutorials can be used in a number of ways. The first type can be used with younger kids. The second type are good for those limited with only one hour for training in Alice. The third type can be used after the second type or as a starting point if you have more time for training. One can then learn additional concepts from the short topic tutorials.

3.2 Animation Effects

We have created short tutorials on animation topics to enhance an Alice world. A tutorial on camera views shows one how to bookmark positions of the camera and then move the camera to get different views. A tutorial on lighting shows how to use spotlights to shine lights on particular objects, including colored lights, and for the lights to follow the objects if they move.

A tutorial on scene-changes shows how to fade to black and fade back in on another scene. One must import a special class we created that includes all the ground textures so you can easily switch to a different texture (sand to grass). Fading back from black is tricky as the atmosphere color of Alice is a unique color that is not one of the color options in Alice. This tutorial teaches using variables to save colors so they can be restored when fading back in.

3.3 Creating objects

Creating your own 3D objects for Alice is difficult since software such as 3D Studio Max is needed. Currently within Alice the only object you can create is a person using the people builder, allowing you to select body part shapes and clothes colors.

We have created several tutorials on making your own objects by modifying and gluing existing objects together. One tutorial shows how to make a billboard object, by importing a 2-D picture. Billboards can be used for instructions, backdrops and pictures glued to objects. For example, a pizza delivery car can be made by gluing pizza images and signs with the pizza business name and phone number onto a car.

Another tutorial shows how to create any person in your world. To put President Obama in your world, place a 3D-person in the world, make their head invisible, drop a 2d-

image of Obama's head into the world and glue it to the invisible head. This capability allows students to create scenes from the real world, such as a presidential debate. Another tutorial builds on this by showing how to use texture mapping (from 2-D images) and existing shapes (mostly from the shapes folder in the library) to create new objects. This tutorial shows how to build the earth by texturing a map of the world around a sphere, how to create a building, and how to create a 3D-head to put on a 3D model (the 2-D heads may look better as the 3D heads may look stretched).

One can create a more sophisticated object by gluing many objects together. The shapes folder contains objects such as spheres, cylinders, cubes, and rectangular boxes that can be colored any color or texture-mapped with an image. One of our tutorials shows you how to create a helium molecule composed of six colored spheres and one partially visible sphere (the electron cloud). The electrons rotate around the protons and neutrons.

3.4 Computer Science Concepts

We have several tutorials that teach computer science programming concepts. To make them more attractive to kids and teachers, we have written these tutorials with a focus on how the concepts are used first, and then giving the name of the concept. For example the title of the tutorial on inheritance is "Creating a fancier chicken - Inheritance". This tutorial starts with a chicken, increases the size of the chicken, changes the color of the chicken and makes a smarter chicken by teaching the chicken how to jump (writing a chicken method). The chicken object is then renamed, saved out and imported into another world.

We give examples of how other computer science concepts are handled. Two tutorials about variables are "How to create a Timer" and "How to create a Score". A tutorial about lists is titled "Moving objects in Unison". "How tall are you?" introduces functions by having a boy and penguin compare their heights by using built-in functions. Another tutorial on a Kangaroo visiting his friends introduces parameters, showing how a method to visit a cow can be changed to be used to visit all the kangaroo's friends.

3.5 Quiz Templates

We created three tutorials on how to create simple interactive quizzes. Teachers were very enthusiastic about creating quizzes, but wanted an easier way to build the quizzes instead of from scratch each time.

We built two quiz template classes and one template world to aid in building quizzes. One template quiz class sets up the quiz in which the user can ask questions with three different types of answers: a number, a string, or yes/no answer. One can call a method to set up each type of question. The other template quiz class sets up a quiz in which the user clicks on specific objects as the answer to the quiz questions. The user can call a method with a parameter object to setup these type of questions. The last template is a world that is setup to create a quiz for matching two objects together. This world was inspired by a teacher who wanted to match an object with a picture of the word for this object written in Spanish.

3.6 Extras

We created tutorials to use other Alice capabilities. A tutorial on folders shows how to add a folder inside the ob-

Figure 1: Pinata Game

ject library. A teacher could create a folder for an assignment and copy in objects that the students would use for the project, so they would be easy to find. Then students would load Alice and see this project folder as one of the folders. A picture of the Alice world to build could be used as an image on the folder. Another tutorial explains how to use the video feature in Alice to export an Alice world to a movie.

3.7 Complete Projects

We developed some tutorials that show how to put together many concepts into a complete game. One is a piñata game. In this game if you swing a bat to hit a moving pinata five times before the time runs out, then the piñata bursts. There is a starting world that already has all 160 pieces of the piñata stored in a list, so the student can focus on writing code to randomly move all the pieces to show the piñata exploding. This tutorial also includes a timer, a score, and shows how to write accents for foreign words in 3D-text objects. Figure 1 shows the piñata game after exploding. In the top right corner is the time remaining (8 seconds) and in the bottom right is the score (5 hits).

Another tutorial is a game in which one guides a wizard to collect six lighted cubes. The wizard earns magical energy points and thus magical power. The game is won if the wizard collects all the cubes and still has power. This game has variables, a score, events, and creating new methods.

4. EXAMPLE ALICE WORLDS

We have developed over twenty-five example worlds to show how Alice can be used in K-12 in different disciplines including language arts, foreign language, art, dance, math, music, science, social studies, and technology. In this section we describe example worlds we have built for teaching math and music.

4.1 Math Alice Worlds

These example worlds focus on how Alice can be integrated into the math curriculum. We show three different ways Alice can be used: interactive games, completing a template world and animated stories.

Integrating Alice through an interactive game requires the teacher to create or find a world that provides reinforcement for the concepts that are being introduced in the classroom.
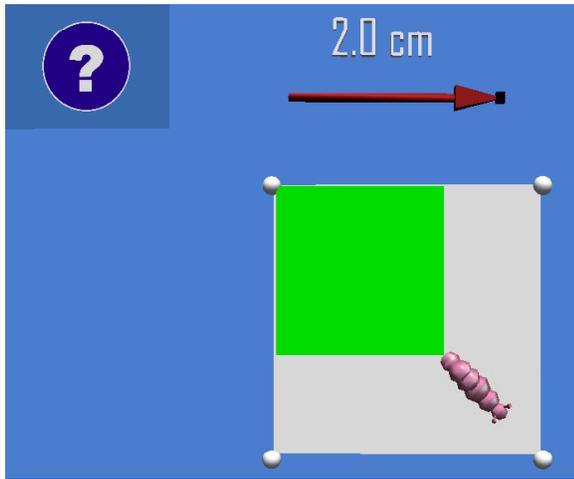
Figure 2: Math Worm

Figure 3: MAD Face method

One of the teachers at our workshop requested an interactive game that would reinforce the place value concept. Building on this idea, a rounding world was developed which requires the player to identify the place value and round the number to that place value. The interactive game has three levels of play: level one practices rounding from tens to hundreds, level two practices rounding from hundreds to hundred thousands, and level three practices rounding from thousands to hundred millions.

Once the player has selected the level of play the game begins. A random number is generated and is displayed on the screen. A husky dog enters and asks the player to click on a specific place value. This place value is randomly determined. When the correct place value is selected an arrow slider moves to that position. The player is then asked to determine what should happen to that number during rounding. This is done by either clicking on the arrow if the number should go up or on the circle it the number should stay the same. If the incorrect answer is selected the lower place value number is animated and gives a hint to the player. Once the correct decision is made the number animates as it rounds to the nearest place value and a point is added to the score.

In designing the interactive game several features were considered. To provide player motivation a score was included, encouraging feedback by the husky, and hints when the wrong answer is selected. Accessibility issues for those who are color blind was also considered when choosing the color for the number groups.

A second way to include Alice in the math classroom is to promote student involvement in programming. A geometry world was created with two versions: one version is an interactive game, and the other version is an unfinished template. The interactive game asks the user to type in answers of area and perimeter for a square, rectangle or circle. The teacher has the ability to modify the program by choosing the shapes and to include various dimensions. The caterpillar animates the perimeter and area as the user enters the correct answer. Figure 2 shows the game with a square of width 2.0. The user has already typed the correct answer of 4.0 and the worm is pulling out the correct area to cover the square.
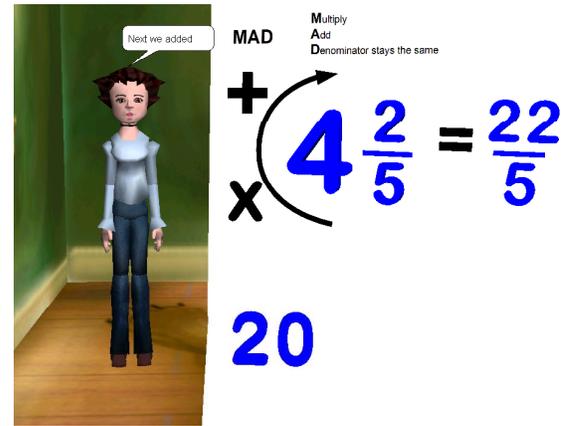
For the student involvement version, the world is not completely finished. The student needs to complete the program by calculating the area or perimeter. This would be accomplished by using the programming and mathematics functions built into Alice. The teacher can set up the template world with any number of questions for the area and perimeter of a square, rectangle or circle.

The third math example is the animation of a mathematical concept. Danica McKellar has written a book to encourage girls with mathematics in middle school [13]. We animated the example on improper fractions from McKellar's book (p. 44–45). The contextual story along with the mathematical concept was animated.

In this world the story produces a scenario that requires the character to solve a math problem. The concept is converting a number into an improper fraction. The story begins with a girl talking to the viewer about a pizza party she is about to have. There are five pizzas on the table when the girl leaves to welcome the party guests. While she is gone the viewer watches the dog jump on the chair and eat some of the pizza. The girl then sees that there are only 4 and 2/5 pizzas left. She decides to use the MAD method (multiply, add, denominator stays the same) to calculate an improper fraction to figure out how many pieces of pizza are left.

The MAD method is then animated while the character explains the steps being taken. Each number and operator moves into place to show the multiplication, addition and denominator steps. A short review of the calculation is repeated and the character determines how many pieces of pizza are left. Figure 3 shows the frowny face made from the numbers and operators in the calculation and shows the girl explaining what is happening in the animation.

4.2 Music Alice Worlds

An example music Alice world is a game to identify an instrument by hearing a sound of the instrument being played. After the player guesses the instrument correctly there is a scene with facts about that instrument. The game continues with other instruments.

Another music example world for teaching music is called Music Theory practice and has two parts. The first part is for treble and bass clef note naming. In this game, different staffs appear with a single note. The letters of notes on a piano appear below it. The player is to click on the letter of

the correct note. In the second part of the world, the quiz is about scale identification. A scale is shown and the player types in the name of the scale and whether or not it is major or minor. In both parts, a score is displayed showing how many answers are correct.

5. OBJECTS NEEDED IN ALICE

In summer 2009 we surveyed the 100 teachers attending our workshops on the 3D objects they wanted in Alice. There are currently over 750 3D objects in Alice including characters, animals, props, vehicles, backgrounds, and shapes. Teachers at the workshops requested over 300 additional objects for use in their curriculum. Many of these objects were general props, backgrounds and animals that could be useful in multiple subjects.

There were requests for famous people, places and buildings. Buildings requested include: U.S. government buildings, significant architectural buildings and monuments, historically significant structures of settlers and Native Americans. Famous characters that were requested include: U.S. presidents and politicians, artists, scientists, philosophers, musicians, mythological characters, writers, and popular fictional children's literature characters and heroes. Teachers also requested learning based objects and environments that would be helpful for math, physics, biology, earth science, history, social studies, geography, chemistry, technology, art, and music. Specific environments included: ancient worlds, art studio, business office, computer lab, science lab, ecosystems, and famous land forms. Subject specific objects included: 3-D prisms, human anatomy, animal anatomy, biological cells, DNA molecule, chromosome with genes, Bunsen burner, balance, beaker, conical flask, pipettes, petri dish, test tube, coordinate plane, electric circuit parts, various chemical molecules, fraction tiles, interactive calculator, maps, magnets, levers, pulleys, screws, phases of the moon, protractor, ruler, artist tools, computer equipment, business equipment, plants at various growing stages, and various scientific rock forms. One teacher wanted Montessori materials, beads and numbered tiles (green with 1, blue with 10, red with 100, and green with 1000), to create animations for math concepts. Science teachers wanted more substantial parts, such as a single bond, a double bond, a triple bond, a trigonal plana, a pyrimidal, methane, ethane, ethene, and ethyne. Math teachers wanted math symbols such as square root symbol and arithmetic operators.

6. CONCLUSION

We had enthusiastic response from K-12 teachers attending our Alice workshops held in summers 2008 and 2009. Teachers from a variety of disciplines found exciting ways to integrate Alice into their subject. We created Alice tutorials to provide teaching resources for these teachers. The tutorials range from beginner to complete projects and include both computer science concepts and animation enhancements. We created many of these materials based on our experiences with these teachers. For example, as a result of feedback from teachers we created tutorials with template classes to make it easier for them to develop Alice quiz worlds. We are following up with teachers during the year and in workshops in the summer. All of our materials are freely available on our website.

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