3D STEM Fluency
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Goal & Objectives
What types of curriculum support do elementary students need to successfully develop computational thinking practices within 2D and 3D environments?

The goal of this research will be to understand what types of support elementary students need in order to design and implement games and simulations through computational thinking in both 2- and 3-dimensional environments. This study is part of an ongoing research effort taking place at an after school program called El Pueblo Magico (EPM) in which students participate in problem solving tasks in small groups with prospective elementary teachers. Specifically at EPM, students are allowed to come up with a game or simulation idea and then plan out its design and implement it using agent based programming tools, either AgentSheets or AgentCubes. Neither the prospective teachers nor elementary students have a background in Computer Science (CS). Because of the population’s lack of expertise it is necessary for there to be a scaffolded curriculum that allows the groups to focus separately on the design, implementation, and feedback loop of the games or simulations they are trying to create. The purpose of this scaffolding also aims to emulate the practice of CS professionals and to develop computational thinking skills. This study will focus on developing support materials to enhance the development of computational thinking skills, which will be evaluated through analysis of qualitative data collected at the research site through audio/video recordings, planning artifacts, program source code, and undergraduate cognitive ethnographies.

Motivation
Technology use is on the rise in the U.S., and with that growth comes the need for an innovative workforce to design the tools of the future. Over the course of the next 10 years it is expected that the number of jobs available for software designers alone will grow by 270,900, which is an increase of about 30%, according to the Bureau of Labor Statistics (2012). The CS educational system will need to address how it recruits and retains students to the “pipeline” if we are to fill this need. Approximately 30,000 students graduate with a Bachelors in CS per year, but that number is on the decline (NSF, 2011), and will only just meet the need for software designers. At this rate of graduation, there will not be enough people to fill the workforce demand for all of the possible CS jobs (software designers, network managers, etc.). This will affect the country in two important ways: (1) the economy will not be able to compete with other countries’ and, (2) national security will become threatened as other countries surpass our own in technological innovation and ability. These are serious issues and must be addressed within the education system now, if they are to be prevented.

The best way to address the pipeline issue is to get people interested in CS at a younger age and provide those that are interested with quality and relevant curriculum as they learn. Typically, students do not have the opportunity to truly explore CS until high school. However, there have been many successful studies done with middle school aged students where they both enjoy and successfully learn CS principles (Basawapatna et al., 2010, Resnick et al. 2009). This study aims to extend that success further by giving elementary students the opportunity to learn CS through an after school program scenario.

Additionally, women and minorities do not participate in CS at levels proportional to their representation of the national population (NSF, 2011). It would benefit the field to recruit from the pool of underrepresented populations, but serious consideration needs to be given to how they are being taught and whether the curriculum is relevant to their interests. The proposed research site provides access to these underrepresented populations at an elementary level. The participants are predominately Hispanic and with an approximately
equal split of female and male students. Studying how students similar to the site population gain an interest in CS and how they go about learning CS principles is of great importance to addressing the pipeline issue.

**Theoretical Framework**
The theoretical grounding of this work relies on work done in the field of Learning Sciences, Math & Science Education, and Computer Science Education. Through the use of culturally relevant pedagogy, an apprenticeship model of learning, and understanding of the Zone of Proximal Development (ZPD), Computational Thinking, and agent based programming, this study will extend the understanding of how students can learn about Computer Science.

All learning is social and grounded in context, and it is especially important to consider this within STEM (Bang & Medin, 2010, Nasir et al., 2008, Roseberry et al., 2010). By allowing groups to choose what they will create, the students are able to bring in their own prior experience with games, and the outside world for simulations, into the learning space at the research site. Another theoretical underpinning of the work is that the groups learn within an apprenticeship model. The study will seek to practice the apprenticeship model that Lave & Wenger (1991) have presented in their work by allowing people to serve as experts in their development of programs. Whether that is being an expert in AgentCubes, a specific game they are trying to make, or a worldly experience they are trying to simulate, members of the group will typically be relying on experts in one form or another. By relying on these experts, the project also relies on the idea of the Zone of Proximal Development. Experts will help the students to grow in their knowledge, and in this sense, AgentSheets experts will help the students in their understanding of Computer Science.

This study will work towards getting students to develop computational thinking (CT) practices. Computational thinking is an idea put forth by Jeannete Wing (2006, 2008), which is the practice of using abstraction, organizing data, and using algorithms to solve problems. The Computer Science Teachers Association (ISTE & CSTA, 2011) elaborate further on this idea by providing following guidelines of what CT looks like:

> “Computational thinking (CT) is a problem-solving process that includes (but is not limited to) the following characteristics:
> 1. Formulating problems in a way that enables us to use a computer and other tools to help solve them.
> 2. Logically organizing and analyzing data
> 3. Representing data through abstractions such as models and simulations
> 4. Automating solutions through algorithmic thinking (a series of ordered steps)
> 5. Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
> 6. Generalizing and transferring this problem solving process to a wide variety of problems

These skills are supported and enhanced by a number of dispositions or attitudes that are essential dimensions of CT. These dispositions or attitudes include:

- Confidence in dealing with complexity
- Persistence in working with difficult problems
- Tolerance for ambiguity
- The ability to deal with open ended problems
- The ability to communicate and work with others to achieve a common goal or solution

This definition will guide process of evaluation and analysis of computational thinking and its use at the research site.

**Previous Work**
The methodology for this project will require iterative evaluations and implementations of the curriculum that students experience at EPM. Since this project is ongoing, some work has been developed over the course of the past two years, and it is important to continue the development process. The following is a short history of what has been done at the site followed by what will happen through the course of this study.

Up to this point, there have been various implementations used to get students interested in creating games and simulations in a 2D environment using AgentSheets. During the first year of using AgentSheets at the site, elementary students were given a similar curriculum that middle school students have used in the past. This
consisted of step-by-step instructions for creating games such as Frogger or Pac-Man. Due to the limited reading ability of the students, this was a problematic situation. Students were forced to focus significantly more on developing and depending on their literacy skills, rather than on their computational thinking skills. In the first semester of the second year of implementation, a planning tool was introduced and students were given the opportunity to design solutions for specific problem types. These included designing a maze game or a virus simulator. The planning tool was a set of papers that allowed students to draw and explain what agents they wanted and what they wanted those agents to do. Figure 1 shows what students would have been able to work with for this situation.

**Figure 1.**

**Agent Name:**

**Depictions:**

![Depiction Diagram]

**Describe the Behavior:**

The implementation of the second semester of the second year has allowed for students to bring in more of their experiences and knowledge by leaving open the option of what they want to create. Students must come up with a game or simulation idea and then design the agents and world that they need to create their idea. As discussed earlier, this allowed for the curriculum to be more learner-centered and culturally relevant. Video data of this experience has been gathered and will lead to greater insight of the students’ learning about computing and where the curriculum may still be lacking.

It should also be noted that the undergraduate prospective teachers were given a one-hour training at the beginning of each semester over the use of AgentSheets. Typically, they created a maze game in which they used arrow keys to guide an agent through a maze while dodging obstacles. In the second year of using AgentSheets at EPM, the undergraduates were also given training on pedagogical techniques they could use with the students. This consisted of helping the elementary students talk about their design of the agents in specific ways and to record their ideas.

During all previous work, the groups have relied on me as an expert in AgentSheets at the site. This is due the apprenticeship idea outlined in the theoretical framework.

**Participants**

**Elementary Students**

The elementary students at EPM are predominately Hispanic and have a representational split of males and females. They are in grades 2-5 and many have been participating in EPM since it began almost 2 years ago. Since they previously participated in EPM, it is important to note that some of the students will have a greater
expertise around working with AgentSheets than the undergraduates and this expertise has started to show during the course of this current semester.

Undergraduate Prospective Elementary Teachers
The undergraduates do not have any background in CS, and many of them do not even come from a STEM field. In the trainings, most have expressed nervousness towards doing CS because of their inexperience. This study will also examine how they reflect on their experience through the cognitive ethnographies and how they may be helped to successfully work with the elementary students.

Methodology & Analysis
The future of this study will require the currently collected data to be analyzed so that the curriculum may be further improved on a semester by semester basis. This iterative process will continue throughout this next year so as to allow the elementary students to grow in their understanding of CS. The data that will be collected will comprise of audio/video recordings of the groups as they work, the planning tools (both formal and improvised), the source code of the completed/incomplete games or simulations, and cognitive ethnographies written by the prospective teachers working with the elementary students.

The Process
The process that the groups will go through is as follows. (1) Groups decide on a game or simulation to create. (2) The groups create a general statement about what they want the game or simulation to do. (3) The planning tool is used to allow students to refine their thinking as well as scaffold the abstraction, organization of data, and algorithm development process. (4) The game is created using an agent based programming tool, such as AgentSheets or AgentCubes. (5) Groups share their creation and ask for feedback from other students at the research site. (6) The groups may choose to work further on their game or simulation based on the feedback. (7) If the game or simulation was created using AgentSheets, the groups will have an option to 3D it by importing the source code into AgentCubes.

Audio/Video Recordings
The audio/video recordings will allow for a qualitative analysis of the groups processes of making a game or simulation. They will bring about an understanding of the students’ patterns and practices of programming. The groups will undoubtedly use informal processes that the planning tools have not accounted for and this will give insight into how those processes may be incorporated into a formal set of tools, or simply add to the growing knowledge of pedagogical techniques used by myself as a helper, or by the prospective teachers within the groups. Another key component of the recording data will be to show how the students go about using abstraction to transfer their ideas into a program. How students choose to organize their ideas and data, and the sophistication they use over time, is important to understanding their growth in using computational thinking. Finally, for students that implement using AgentCubes, the data will be analyzed to understand the process of the students’ development of 3D fluency and how to program within that environment.

Planning Tools
Collection of the formal and informal planning tools will be used to assess what is and is not working within the curriculum, both in 2D and 3D environments. The intention of the planning tools are to scaffold students’ development of computational thinking by giving them a place to organize data, find ways to use abstraction of concrete ideas, and develop algorithms for controlling the behavior of their agents. Since programming within 3 dimensions would be new practices to the students, especially in the realm of computing, it is important to understand what will and will not help them through this process.

Game/Simulation Source Code
The source code of the games or simulations will be collected and examined in comparison to the intended plan created by the group. This analysis (along with examining the recordings) will emphasize issues students had
with implementing their plan. It will also bring to attention their techniques in exhibiting computational thinking over time, by showing how they choose to program the behavior. Furthermore, the source code for groups that build a game in AgentSheets (2D) and then redesign it using AgentCubes (3D) will show what types of understanding and transitions they need support for in the future.

**Cognitive Ethnographies**

The cognitive ethnographies are reflections written by the undergraduate prospective elementary teachers that are working in the groups with the students. These will offer another perspective of what the students are doing and learning, as well as show what the future teachers think about the activity. These undergraduates are the target audience of the final form of this work, so their thoughts will be an essential piece of working to make CS in elementary schools a success.

**Proposed Timeline**

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<thead>
<tr>
<th>Summer, 2012</th>
<th>Analyze collected data from the 2012 school year. Redesign the curriculum with input from the research site team.</th>
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<tbody>
<tr>
<td>Fall, 2012</td>
<td>Implement new changes and collect data. At conclusion of the semester, reflect on what may need to be changed for spring.</td>
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<tr>
<td>Spring, 2013</td>
<td>Implement new changes and collect data. Begin analysis of data collected during the fall semester.</td>
</tr>
<tr>
<td>Summer, 2013</td>
<td>Analysis of data. Share findings through publication. Begin designing for implementation in everyday elementary classrooms.</td>
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**Project Outcomes**

**Personal Development**

From this research I intend on gaining insight into how elementary students learn about CS principles and develop computational thinking. There is little, if any, research on elementary students doing CS, so there is a significant void in developing a dissertation around this topic. I am planning on using this data to both contribute to the greater knowledge about elementary students and CS, as well as using it as a starting point for developing a dissertation around bringing CS to everyday elementary classrooms.

**Support STEM Education within Home Department**

There is a growing need for people within our society to become more involved with computing practices. This is especially true in the area of education where technology is generally talked about in terms of its use and not its development (ISTE, 2007). In cases where the development of technology is discussed in education, especially in the case of CS, there is an emphasis on the skills of syntax and not on design, and primarily at a secondary level (ISTE, 2002). More recently, a shift has occurred to focus on design (NRC, 2011), but it is unclear what this will look like in practice, especially in elementary school settings. This research will contribute to an understanding of how prospective elementary teachers may learn about CS, as well as implement CS practices in their future classrooms. From this understanding, future CS curriculum and course development will be enhanced within the School of Education. This may also contribute to the understanding of learning at an undergraduate level at CU.

**Benefit CU Community**

CU-Boulder is one of the few universities in the country that has a group, Scalable Game Design, which focuses on K-12 Computer Science Education. This uniqueness, and the quality of work that comes out of this group, has gained attention and recognition in many ways. This study will add to the expertise and prestige of the CU community, as well as help it become a leader in 21st Century education.
References


