Targeting the Technology Gender Gap:
Making Computer Science Engaging and Accessible for All Students

In the current economic climate, securing employment can be difficult in many fields, but much less so in computer science, computer software engineering and programming, and other technology related fields. According to the Bureau of Labor Statistics (2011), in these fields, "Employment growth is expected to be much faster than the average, and job prospects should be excellent," which means an increase in job openings of 20% or more between 2008-2018, with more numerous job openings than job seekers.

Paradoxically, while demand is increasing, there is a steadily declining interest in computer science, especially for women (AAUW Educational Foundation, 2000; Ashcraft, Blithe, & National Center for Women & Information Technology (NCWIT), 2010; Corbett, Hill, & St. Rose, 2008; Margolis & Fisher, 2002) and African American and Latino students (Eisenhart & Edwards, 2004; Margolis, 2008). This is a phenomenon unique to computer science even when compared to other STEM fields. As Caroline Hayes (2010) writes,

> A substantial and persistent drop has occurred over the last 20 years in the representation of women among computer science undergraduates and computing professionals at a time when the proportion of women has been steadily rising in all other STEM fields. This trend is more worrying because it comes at a time when overall interest in computing for both men and women is down, yet a strong and creative information technology workforce is needed for competition in the global economy (p. 43).

With a shrinking pool of female and African American and Latino undergraduate computer science students, the representation of women and people of color in computing professions is in serious jeopardy.

However, it is not just computing professions that require computational thinking* (Wing, 2010) and technology skills. We are in an era where computational thinking skills and computing fluency are required by most professions. Computer simulations are utilized in fields as diverse as law, medicine, and history. Pilots spend hours using flight simulators as a part of flight training. Mechanics use computer systems to help diagnose and repair car troubles. When the computer system goes down in the local grocery store, sales come to an abrupt halt. Technology is truly ubiquitous.

To help address the gap between the number of individuals studying technology and the number of individuals needed in the work force, we need to develop and utilize new ways of presenting computer science material. Introductions to computer science must begin at an early age; elementary and middle school students are capable and interested in computer science content when it is presented in a way that is accessible and authentic. At the other end of the pipeline, we must not turn-off students potentially interested in studying computer science at the undergraduate level. By having students design and create their own computer simulations and games, we have seen how computer science becomes more interesting and increases the perceived value and applicability of computer science for many girls and people of color (Basawapatna, Koh, & Repenning, 2010; Basawapatna, Koh, Repenning, Webb, & Marshall, 2011; Marshall, 2011; Repenning & Ioannidou, 2008; Repenning, Webb, & Ioannidou, 2010; Walter, Forssell, Barron, & Martin, 2007).

As a part of a 3-year NSF funded project, **Scalable Game Design** (http://scalablegamedesign.cs.colorado.edu/), the *AgentSheets* program (Repenning, 2000, 2011; Repenning & Ioannidou, 1997, 2001; Repenning, Ioannidou, & Ambach, 1998) and supporting curriculum has been implemented in middle school classes in several states. While the majority of the classes were technology classes, teachers in content areas such as mathematics and social studies have also implemented modified versions of the curriculum.

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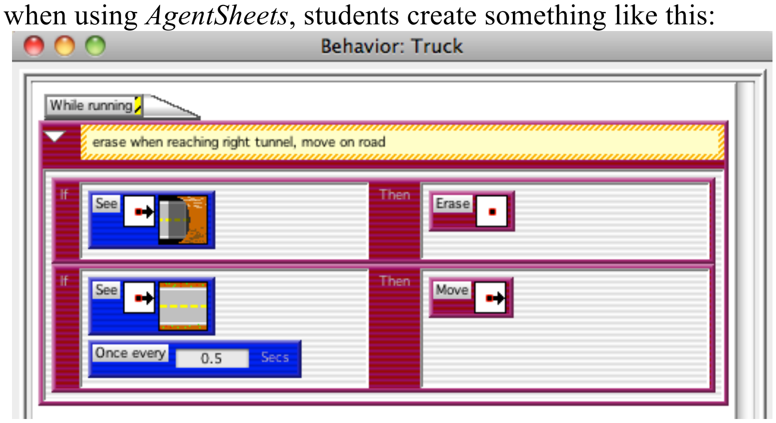
* The term *Computational Thinking* was coined by Jeannette Wing and later defined as, "[T]he thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent [CunySnyderWing10]" (Wing, 2010, p. 1).

AgentSheets is an object-oriented computer program where users can literally drop and drag portions of if-then statements to create computer programs games and simulations. Students are able to focus on the design and creation of their project at a high level without the steep learning curve of a traditional computer language such as C++ or Java. This frees the students from having to focus on the exact syntax of a computer language down to the punctuation and spelling of computer terms, and instead focus on semantic and design aspects when making a game or simulation.

For example, the following C++ code creates high demands for accuracy and attention to detail, which may actually *detract* from the design and creation experience. (Forget a semicolon here and your entire program may not work!)

```
int main ()
{
  char question[] = "Please, enter your first name: ";
  char greeting[] = "Hello, ";
  char yourname [80];
  cout << question;
  cin >> yourname;
  cout << greeting << yourname << "!";
  return 0;
}
```

In contrast, when using *AgentSheets*, students create something like this:



The visual programming language code created by students using *AgentSheets* contains pictures and simple statements of what is being done making the code visually easier to understand and use to create original projects. Students are empowered to be able to get quick results and personalization of games and simulations while still allowing for highly complex projects, such as ecosystem and virus spread simulations, as students' programming and computational thinking fluency develops.

The *Scalable Game Design* curriculum incorporates two main philosophies; that of Lev Vygotsky's (1978) "zone of proximal development" and that of Mihaly Csikszentmihalyi's (2008) "flow", to provide activities that can be done with the assistance of a more expert user on a trajectory of more difficult projects as more skills and understanding develop. Ideally, this creates an environment of optimal intrinsic motivation and creativity where each student is fully immersed and engaged in his or her project.

The approach of the *Scalable Game Design* curriculum using *AgentSheets* has met with great success in middle grades classrooms. During the first two years of the Scalable Game Design Project approximately 45% of the over 4000 student participants were female and 56% of the participants were from racial minority populations. According to Ioannidou, Bennett, Repenning, Koh, & Basawapatna (2011), most of the students across ages, gender, ethnicity and geographical location indicated that they were interested in continuing to study technology (approximately 61% of the females, 71% of the males, 71% of Caucasian students, and 69% from historically underrepresented racial populations).

It has also been beneficial to continue this presentation method in undergraduate computer science classes. Several classes have been taught at CU using *AgentSheets*, but unlike at the middle school level, we have not collected data on motivational and self-efficacy aspects and undergraduate students' opinions of this approach on their interest in further coursework in computer science. Since an undergraduate degree in computer science is the exit point for many individuals working in information technology fields, exploring any differential effects of a particular approach to teaching computer science on motivation and self-efficacy by gender and/or race at the undergraduate level is of interest and importance.

With the help of the iSTEM Chancellor's award grant, my research into the motivational aspects of drop and drag computer programming and its applications, throughout the educational pipeline from middle grades to undergraduate levels, can continue. I am particularly interested in any differential effect by gender of this approach to teaching computer science on motivation and interest in continuing study of computer science and in careers in information technology. I am also interested in exploring the potential of this curriculum for content-area classes by implementing technology-enhanced units in middle grades mathematics classes. The research questions I will address in this study are:

- What are the effects of the implementation of the *AgentSheets* curriculum on students' engagement in class discourse and practices and on self-reported motivation and efficacy in computer science?
- Does this engagement and motivation differ by gender and/or race?

Theoretical Framework

I find the constructionist epistemology to be the most powerful in framing this work. Crotty (1998) defines constructionism as "…the view that all knowledge, and therefore all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context" (p. 42). From a constructionist perspective (Harel & Papert, 1991; Kafai & Resnick, 1996; Papert, 1980, 1993), all meaning is constructed through the interpretation of objects by human beings. These objects are not limited to physical items but also include man-made situations and relationships. Thus both thoughts and emotions are constructed through human interpretation, and this meaning making is seen as social and cultural. Culture in the form of language, predefined terms, historical practices and customs, and prior experiences all work to inform current meaning making by individuals.

As a constructionist researcher, this same definition applies to me. The objects of study are central to the meaning making of the situation and both my thoughts and emotions about the situation are constructed based upon the observed activities of these individuals. I am also immersed in culture that informs my meaning making. My education, language, and prior experiences shape my interpretations of the activities.

When studying social situations as an educational researcher, not only are the activities of the people of importance, but also *their* interpretation and meaning making of the social situation. Giddens (1979) refers to this as a "double hermeneutic" unique to social science research (As discussed in Crotty, 1998, p. 56). The individuals in the situation have already assigned their own meaning within a larger historical and situational culture and I must try to determine what this meaning is, as well as assigning my own interpretation. Under the larger umbrella of constructionism, activity theory informs my work as I consider mediation by tools and artifacts within the collective activity system (Engeström, Miettinen, & Punamäki-Gitai, 1999).

Methodology

From this conceptualization of learning, I find that design research methodology (Bakker, 2004; Brown, 1992; Collins, Joseph, & Bielaczyc, 2004; Plomp, 2007) offers a way to include the members of the classroom community in the development and implementation of the technology-enhanced units. During the 2010-2011 school year, I worked with four teachers in a rural district with a high proportion of

Latino and low socioeconomic status students. We developed and piloted technology-enhanced units that aligned with the district's and Colorado State standards for statistics and data analysis. Students in 12 classes (three 6th grade classes; three 7th grade classes and six 8th grade classes) used pre-existing *AgentSheets* simulations for data collection. Students then compiled and analyzed this data and learned the related statistical tools and graphical representations in place of one of the investigations done in previous years. As a part of this pilot, we developed the curriculum and the pre and post content tests and surveys. The data collected from these instruments will be useful as a baseline for next school year's data.

During the 2011-2012 school year, the same four teachers and one other from another middle school and I will be co-teaching similar technology-enhanced statistics units. One main difference in the 2011-2012 year is that the students will be first creating and programming their *own* simulations before collecting data from them. To integrate the units across different content areas, especially to align with the science and social studies units taught at each grade level, sixth grade classes will base their simulations on erosion, seventh grade classes will create virus spread simulations, and eighth grade students will be using a tornado simulation and creating a forest fire simulation.

Data in the form of pre and post surveys and pre and post content tests will be collected. The surveys help to assess motivational and self-efficacy of students in computer related and mathematics material. In Likert style and open-ended response questions, we will ask students to describe their interest in continuing to take computer coursework in the near and more distant future (high school and college). We will also ask them how they feel as a learner and how difficult or easy computers and math are for them. The pre and post content tests will show what gains are made by the middle grades students in understanding and application of the statistical tools learned in the unit. The tests are also useful for the teachers for grading the students.

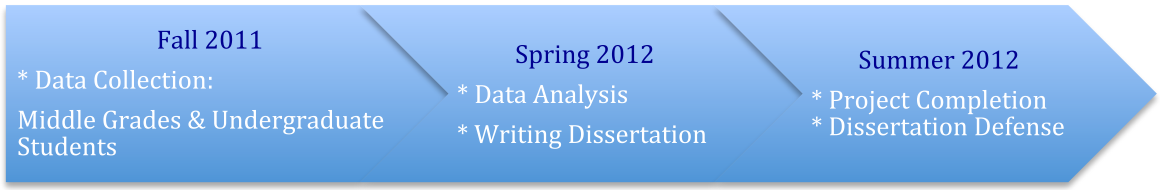
To assess motivation and self-efficacy factors at the undergraduate level, often the exit point of the pipeline, I will be working with the professors teaching the *Educational Game Design* based courses at CU (Alexander Repenning and Clayton Lewis) to gather data from the undergraduate students taking the class. A similar survey will be given to undergraduate students to help assess the constructs of motivation and self-efficacy in computer technology.

Both the teachers and myself as a researcher will analyze data collected from the surveys and content tests. Any statistically significant differences in responses by gender and/or race will be of particular interest. As a participant observer in the classes, I will also keep field notes and videotape interactions and participation in the units. Select students and teachers will be interviewed during the study as well. These additional data sources will be useful in triangulating findings regarding differential participation, if any, student engagement and motivation, and understanding of the underlying statistical concepts covered in the unit.

Project Timeframe

Figure 1 shows a proposed timeframe for the implementation of this study. I intend to defend my dissertation prospectus in the early fall of 2011 and to co-teach the technology-enhanced math classes from October to December 2011. Data collection will occur before and after each unit for each teacher. Pre and post motivation surveys will be administered at the beginning and end of the Fall 2011 semester for the CU computer science classes. Data collection will be complete by the end of the fall semester and data analysis will begin in earnest during the Spring 2012 semester in conjunction with the writing of my dissertation. The projected completion of the project is August 2012.

Figure 1. Proposed project timeframe.



Study Impact

This project will be beneficial in four important ways; it will further my development as a STEM education researcher, it will support STEM education in the School of Education, it will benefit the CU community as a whole by strengthening interdepartmental collaborations and exploring approaches to attract and retain underrepresented populations in computer science, and it will benefit the larger community surrounding CU by further promoting cutting-edge STEM and computational thinking education in local middle schools.

The iSTEM Chancellor's award for this project will allow me to continue and extend National Science Foundation funded research (Grant Numbers DLR-0833612 and IIP-0848962) into the use of *AgentSheets* to introduce and teach computational thinking skills to students from middle grades to university level courses. Addressing students' interest in computer science at both ends of the pipeline to develop future employees in technology related fields is a key aspect of this research. Funding for the **Scalable Game Design** project ends in December 2011, so additional funding to complete my dissertation is needed. While I can do unrelated work such as teaching a course or supervising student teachers, receipt of this award would allow me to focus on this research and will reduce scheduling conflicts with being a participant observer for the classes taught at the middle schools and at CU.

This project will benefit STEM education the School of Education (SoE) by focusing on an area that is missing from the current licensing offered by CU. Of the STEM areas, the SoE at CU only has licensing for science and mathematics teachers. Additional focus on the "T" and "E" of STEM would benefit the school and those students potentially interested in teaching information technology in schools. Also, because there is no technology-education licensing program, of the STEM fields, the SoE as a whole has less interaction with the Computer Science Department and the College of Engineering (aside from Applied Mathematics). In contrast, math education students take classes from both the math departments and the SoE, facilitating interactions between the School of Education and the Mathematics and Applied Mathematics departments. Likewise, science education students take coursework from the science department of their choice and the SoE, increasing interactions among the professors in these departments. Other than through DBER, there is not as much interaction between the SoE and the Computer Science department / College of Engineering. This project would continue the interactions and collaborations between these departments begun with the **Scalable Game Design** project.

This project will not only benefit the School of Education and the CU community as a whole by helping to facilitate interdepartmental collaborations, it will also explore ways to strengthen interest in another area of the nationally recognized STEM community at CU, computer science. If it is found that this approach to teaching computer science helps to maintain interest and increase motivation to take further computer science coursework, especially for underrepresented populations including women and racial minority students, this could greatly benefit the strong STEM community at CU.

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