Enhancing K-12 Education with Engineering Outreach

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Abstract
Many states throughout the country are greatly in need of improvement of their K-12 STEM educational systems and Alabama generally falls within the 10 lowest performing states with respect to education. According to rankings of smartest states, Alabama's ranking has been consistently falling and last year dropped 2% down to number 45 out of 50 states, with less than 80% of the population have graduated from high school accounting for more than half of the state's income gap, which is a high percentage compared to the rest of the nation[1]. The current graduation rate in 2006 was 66% graduation rate which is below the national average of 69%. Our program has been supporting the local community for the last 6 years, through engineering and computing outreach programs. These programs have improved students STEM exposure, logical reasoning, reading and problem-solving skills. We accomplish this by infusing specialized computing and educational gaming technology into the classroom and afterschool programs to reinvigorate K-12 students in our local area as a model for student computing engagement. Our research investigates methods to energize students through intrinsic motivation to work harder and to achieve a brighter future and to support the future STEM workforce.

We want to build STEM workforce by providing more technology training to students at earlier ages to potentially increase future enrollments. With traditional federal grants it is hard to provide interventions for very young students because outcomes are harder to substantiate. A prominent problem caused by many factors has been falling enrollment rates in STEM (e.g. computing based majors). In 1999 more students than ever were interested in computing degrees after the dot com bust of 2001, Student interest in computer science was falling worldwide and between and reaching an all-time low in 2006 with incoming freshman interest in computer science dropped by 70% in the U.S. and based on information by the Higher Education Research Institute at UCLA and also publicized by publicized by David Patterson in CACM, Sept. 2005 [2]. The Taulbee survey found that computer science enrollment at research universities dropped by 50% [3]. It also indicated that 84.9% of bachelor's degrees were awarded to men in computer science. As a result, literature was explored to provide tools and ideas to apply to take a step towards providing a solution. This trend is slowly improving, but there are still many issues that create many problems for computing (lack of comprehensive computer science AP, course consistency, in many states there is no certification for teachers that are administering this exam, very little exposure to computing other than keyboarding and class that provide drills and practice with personal productivity software (e.g. Microsoft Word, Excel, PowerPoint, etc.).

In order to keep attracting the brightest minds in a more diverse context, the computer science community must ensure that new computing-based technologies and curricula meet the diverse needs of the global population and find ways to attract and retain a more diverse student groups. Mentoring and more exposure to computing can increase recruitment and retention.
We have found great interest in video games in that all of our K-12 students play games, and we can utilize this interest as motivation for students to create their own video games and animated stories. We will leverage the growing phenomenon of gaming industry, and play in general to draw more students into computing fields. In many cases, this is a great technique for recruiting. In searching for innovative ways to make computer science more appealing to students,

educators must think fundamentally about what culturally and socially relevant innovations can be used to enrich computer science and related STEM disciplines. Making changes to the methods of student's first introduction can greatly affect future interests and enrollments. When creating and modifying curricula, we must identify ways to motivate students of both genders and a wider variety of backgrounds. Our recruiting includes traditional populations that are already highly involved in computing, but also sees to recruit beyond traditional populations.

Our research has two thrusts of teaching object oriented programming to very young audiences and of increasing student excitement about computing applications with the long-term goal of increasing involvement in technology classes, in the use of computer applications and interest in technology careers. The goal of this work was to provide challenging interactive activities for young students that integrate their courses with computer technology. The authors utilize game development and interactive storytelling as a motivator for introductory programming training. The authors identified that many of our young second through fifth grade students showed much promise and ingenuity in programming when using visual programming environments. Our hypothesis was that our young students would fare as well as introductory college students when completing introductory programming tasks. The environment utilized for this experiment was Alice 3D and our hope was that our youngsters would perform at levels complimentary to those of our college students to illustrate that there is no age limit on ingenuity, when the proper training and tools are provided. This work discusses the outcome of a college introductory assignment that we would give to both elementary school and college students enrolled in an introductory computer science course.

Introduction

In the American school system, many students feel that they are not appropriately challenged. Many students do not have the motivation to do the work and in many cases they stop attending school. In addition to the students that simply drop out, the ones who are high achievers do not feel stretched to meet their full potential for a multitude of reasons. The reasons include the "no child left behind" clause, where more focus is being placed on those students who are struggling. This practice leaves more advanced students bored and neglected. This issue highlights the necessity for a more challenging curriculum, instead of just meeting the minimum criteria. In order to uphold the state requirements, teachers have to be focused on all their students passing the assessment exams to graduate on to the next grade rather than imparting education to stimulate their minds. This is an issue that needs to be addressed at a fundamental level.

There is a need to be truly innovative in education to address the needs of all students and give them a curriculum that will motivate them to excel. Therefore greater resources are required to support creative and challenging curricula with provisions for enhanced materials, teacher support and training. One method is to take advantage of intrinsic motivation. "Intrinsic motivation, also known as self-motivation, refers to influences that originate from within a person, which cause a person to act or learn" [4].

In our local school district, we investigated and found similar trends to the ones mentioned above. To alleviate some of these problems and to introduce students to technology, a computer based program Auburn University Computer Science & Software Engineering STARS Computer Club (STARS Computer Club) was started. This included using visual programming software

called Scratch, Squeak, Lego Mindstorms and Alice 3D. In our program, we incorporated concepts from physical science, computing and reading comprehension.

The STARS Computer Club was adopted as an innovative method to challenge the exceptional kids and give marginal students (i.e. those disinterested in school) motivation and a foundation to get back to work and be directly involved in improving their educational future. To assist students at all levels, we introduced them to multiple environments (i.e. from struggling through gifted) which helped develop a stronger foundation and passion for learning. The aim of the program was to motivate students to be more actively involved in their education by developing their own intellectual capacity for learning[8]. When designing our initial program, we brainstormed methods to target student interest, learning styles, and cognitive needs while developing enrichment activities to have the greatest impact on student motivation and their acquisition of knowledge.

Background

The issue of falling enrollment rates in computing based majors has become a prominent problem. Student interest in computer science is falling worldwide and between 2000 and 2005 incoming freshman interest in computer science dropped by 70% in the U.S. [2]. The Taulbee survey found that computer science enrollment at research universities dropped by 50% [5]. It also indicated that 84.9% of bachelor's degrees were awarded to men in computer science. As a result, literature was explored to provide tools and ideas that could be integrated and applied to take a step towards providing a solution. In order to keep attracting the brightest minds in a more diverse context, the computer science community must ensure that new computing-based technologies and curricula meet the diverse needs of the global population and find ways to attract more diverse student groups.

There is growing interest by youth in video gaming. There was a 15% increase in computer game sales in 2006 [6], and our hope is that we can leverage this phenomenon to draw more undergraduate students into the field. In 2008, with an ailing economy "Video game sales keep bucking recession trend… as an exception to the worldwide gloom". There is theory that the gaming industry "may be recession-proof" [6,7]. With such strong interests in video gaming, in many cases this may prove as a great technique for recruiting students into the field of computer science. In searching for ways to make computer science more appealing to students, educators must think fundamentally about what culturally relevant innovations can be used to enrich computer science. Making changes to the methods of student's first introduction to computer science can greatly affect future enrollments. When creating and modifying curricula we must identify ways to motivate students of both genders and a wider variety of backgrounds.

In our background review, we investigated other approaches to technology use in the classroom. Many elementary students struggle to read, write and comprehend in the classroom[6] and many programs have been created to help with basic reading proficiency. Some programs have looked at solutions of utilizing computers to aid students in improving their reading literacy [5,8]. It has been documented that programs need to better take advantage of the hours that students spend playing video games[9]. Interactive educational games like video games can encourage students to be more responsive and are of greater benefit than inactive games[10]. Students are highly interested in learning to design and create their own video games. As a result, many books have

been created to take advantage of this trend toward game design study and computer gaming as a serious discipline that can improve student's intrinsic motivation for programming [11,12]. We have also utilized these texts in creating undergraduate and graduate classes and students created their own educational video games. Interaction with and creating video games has proven to greatly increase student motivation in the classroom[13,14].

We have studied these approaches and have found that an integration of computing with basic skills acquisition can be beneficial to students at all levels. The tactic of stealth of adding educational concepts to fun situations like game programming can be a way to provide support for a broad array of concept areas. Williams 2009 performed studies in the classroom with Squeak and SimBuilder, where young children in grades 2-4 improved their reading comprehension and learned to program video games that depicted lessons from physical science classroom content (e.g. interactive ecosystem development). Seals 2002 engaged students with AgentSheets in the classroom where K-12 teachers and their students were able to create interactive simulation microworlds with minimalist programming instructions [15].

For the last six years at Auburn University (AU), we have been facilitating a computer science after school program. In this program, the AU CSSE (Computer Science & Software Engineering) STARS Computer Club, we have been utilizing introductory computer gaming and digital story creation to reinforce content matter dissemination with the added benefit of improving the computer efficacy of K-12 students and their teachers. Our teachers have been part of the process to support classroom management and help to reinforce content matter. One of the goals of the Computer Club team is to scaffold student's improving their problem solving skills, computer science knowledge, basic programming skills and to provide more opportunities for K-12 students and their teachers to have great access to educational software. A second goal of the program is to improve current and future college enrollments in computing and related fields. Many students are highly motivated by computer video games and we hope to graphically entice students into a long term affair with computer technology and in the long run increase our computer science enrollments.

The authors were inspired by "children's narrative development through computer game authoring"[16]. This narrative looked at the benefits of children ages 12-15 in creating stories using medium interactive 3D virtual reality computer games. It used an authoring tool requiring very little prior programming knowledge and they discovered that this created a strong motivational influence for the young students.

The "Computer Club" paradigm

The STARS Computer Club model to invigorate education was created to address our local battle to improve education and student interest. The state of Alabama has a difficult battle to improve education with our state's graduate rates dropping to 60%. High attrition rates and many other factors are very discouraging to educators that are faced with their educational initiatives not being successful. Many of our constituency no longer want to invest in the future of education or to improve the level of education in the state. This has resulted in lower general wages and a lower tax base in the state. We want to challenge students to achieve more in school and our hope is that intrinsic motivation that can be gained by this model can reduce dropout rates by getting students excited about learning [4].

Our plan was to introduce STARS Computer Clubs into all Auburn City Schools. In the first five years of the project, we focused our activities on Auburn Elementary and Middle Schools and in the upcoming year plan to incorporate Auburn Junior High and High School to provide enrichment activities to get students excited about education. Auburn University's department of Computer Science and Software Engineering started computer clubs in the elementary schools at the 3rd, 4th and 5th grade levels. We studied students in their usage of computing technology and found that these experiences have a positive effect of getting students excited about learning to utilize new technology, and excited about demonstrating their understanding of science concepts by creating digital simulations with visual programming techniques. The increased excitement and motivation caused by involvement in computer clubs has improved the grades of some students in other areas as well. This program has a long-term benefit to the state to invigorate education and increase future graduation rates with hopes to interest more students in technology related fields.

Our plan was to develop a model curriculum for teaching computational thinking from grades 4 through high school. This curriculum will be based on an experimentally verified cognitive hierarchy of computational thinking skills. The Computer Club program began three years ago to provide more exposure for our local youth to educational computer technology and improve their computer literacy with structured educational activities. Our impression was that extracurricular and enrichment activities promised to provide great educational benefit to the partnering schools in our area. Based upon our experience, we plan to develop a methodology and lesson plans that can be exported and reused by any school which is interested in teaching a computer based curriculum. We intend to use web sites, videos, pod casts and publications to widely disseminate the "Computer Club" model as broadly as possible. The "Computer Club" methodology will improve basic problem solving and stimulate computation thinking though various visual programming experiences to enhance logic based reasoning, reading comprehension, and clarity of science concepts. The projects include Scratch visual programming, Alice visual programming, LEGO robotics and two programming competitions.

During year one of the program, the after school programs used the Squeak programming environment[17]. Their projects were to improve their reading achievement with "Reading like a scientist" activities to stress the importance of reading as the requisite tool to become a proficient scientist. After learning about the phenomena each student designed a physical science lesson. The next step was to integrate reading materials into the project and design requirements into the creation of an animated or interactive physical science model. The culminating event of year one's activities were for the students to display their worlds as exhibits at Engineering Day. Engineering Day, better known as E-Day, is Auburn University's annual open house for the school of engineering. The impact of the initial program was that student's written communication by 4th graders increased average scores by 10% and 5th graders increased average scores by 77%. Also all students had an improvement to their reading comprehension & writing skills assessments. Self-efficacy of students improved in the areas of computing and problem solving. 5th graders felt they learned new computer skills and improvement in problem solving skills. Based on the results of our initial program we strongly believe that the "Computer Club" program will improve the level of educational motivation in the local area, the state and our country.

In year two of the program, we were equally impressed with the worlds created and the accomplishment of the participating Elementary school students. During year two of the program, we used the Alice 3D programming environment in an effort to provide more interest by broadening from 2D world to 3D worlds. The students were introduced to Alice3D with tutorials for three weeks and then supported for three weeks in order to create their own 3D interactive stories. Many of the students interacted with each other and we found that in many cases the elementary student's level of creation was very sophisticated and they had grasped some object oriented programming concepts; and, with the support of visual programming were performing in many cases equal to our undergraduates who were taking introductory programming classes.

Computer training activities

The students that were chosen for this were students that may have had instruction on using Squeak, but not Alice. Thus, they all should have come into this with the same lack of experience as the undergraduate students, who were enrolled in ENGR 1110, Introduction to Engineering. We were told by the instructor of ENGR 1110 that no in class instruction would be given to the students for using Alice but that they would be required to go through the 4 tutorials that are available for Alice. The elementary students were told that they would be given an assignment that college kids would be given. Likewise, they were started on the tutorials. To be sure the tutorials were actually completed; the ENGR 1110 students received grades for the work. The elementary students were asked a few questions about the topics to ensure the tutorials were completed. All students were required to complete the four tutorials in succession before they received the Alice assignment.

For the elementary school students, we used the first 4 weeks to go through the tutorials and then gave them a 50 minute session for the next two weeks to complete the assignment. The only down side is that all students were not able to come all 6 weeks, so some were behind the others and did not get to start on the assignment with the same amount of time as the others. Some students only had time to get the first part of a two part assignment completed. Another issue is that once the student started the assignment, the Auburn University CSSE assistants only gave minimal help to the students. This required the students to either figure it out on their own or go back to the tutorials. This was done deliberately, as the motivation of this was that we conjectured that even the average kids were not being challenged to the degree that they could be and we were going to test this by this study.

Evaluation

During the experience, our aim was to motivate K-12 students and increase their interest about computing technology. This was an opportunity for a realistic introduction to programming which was the same level of difficulty given to introductory engineering students. In one study we introduced elementary students to the same computing challenge that we introduced to introductory engineering students and both groups of students were able to perform with great success. Our results indicated that many students from both Engineering 1110 and the 5th grade class were able to reach the same level of proficiency with the exercise and received 100% as their grade for greater than 85% of the participants. Some of the 5th grade students' grades were slightly lower, but for the group that had ample time (i.e. students that attended all planned

sessions) many completed with great proficiency. We feel that this result is very impressive that nine year old students were able to fulfill the requirements of a basic programming assignment with near equal proficiency as 18 and 19 year old college freshman. In prior semesters working with elementary students, the authors have had opportunities to work with students from all performance levels and we have even worked with students labeled as under achievers and when you set high expectation they will often reach beyond our expectations and their own expectations to give the motivations to improve in all course work.

This work gives us a vision for developing and exposing more K-12 students to technology at younger ages and K-12 faculty to more educational software. The software application that we utilized for this study is intended for high school students, but for this study the hypothesis was that elementary students can make great strides at programming give the proper support. With this tool children did not have to worry about the cognitive baggage of having to learn an entire programming language and to remember all the syntax which is normally required of most traditional programming languages. This study showed that utilizing tools that support visual direct manipulation programming are a mechanism to provide students the tools to express their imaginations through simulations.

Community building and computing identity

Auburn Stars Leadership Corps (starscomputingcoprs.org) participate in various outreach and mentoring activities on and off campus. The aim of this project is part of a national STARS computer clubs has worked with local school system to structure students inclass enrichment activities in Squeak, Alice and Lego Mindstorms to introduce young students to computing building their computing identity and reducing their technophobia. We also worked with after school activities to expose students to computing based online mathematics activities to increase computing identity. Also during the summer, we had STARS undegraduate and graduate support students that worked with 2 summer camps that served 9-12 graders in a full weeks of engineering and 8 hours of computing activities. (Activity supported 35 (9th-10th graders) and 38 (11th & 12th graders). The general success of this group has been the following activities: STARS Computer Clubs partners with Auburn City School Board for K-12 Outreach and worked with 8 organizations during 2011-2012; conducted Alice computer camps for six weeks in 6 elementary schools in the Auburn City Schools system for approximately 125 students; supported Middle School E-Day for 8 hours with 4 hours set up and preparation with Drake Middle School with interactive exhibitions in Unity 3D and Java (200 students); supported High School E-Day for 8 hours with interactive exhibitions; conducted Peer Tutoring with support for 30 hours per week of individual tutoring for 10 weeks supported by 8 tutors utilized a set schedule daily.

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