Empowering Teachers to Raise Career Awareness in Computing: Lessons Learned

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ABSTRACT

Students' attitudes towards Science, Technology, Engineering and Math (STEM) has been a topic of enduring interest in the field of STEM education over the past decade – but why? After all, there is no sense in which people are concerned about students' attitudes towards the learning of English or history. So what drives the interest in these topics? Previous research has suggested a relationship between teachers' and students' attitudes towards a subject area. In order to increase student representation in STEM, we need teachers who have positive attitudes and can serve as role models to encourage their students to pursue STEM careers. In this paper we argue that in order to engage students' interest in the technical career paths, we must start with inspiring and training teachers to instill such interest in their students at early age. We present our experiences and outcomes from a teacher training program. Through the training, we were able to help teachers explore ways to incorporate programming into their curriculum, gain STEM career awareness and develop an understanding of importance of soft skills in STEM. The results show that teachers were able to gain confidence in incorporating their subject matter into Scratch-based classroom activities and teaching this material in a classroom setting and gain a better understanding of careers in STEM.

Keywords: Information Technology, Game Design, Programming, Computer Science, High School, Computing Education and Workforce, Teacher Education, STEM

1. INTRODUCTION

There is a major concern in the United States industry, businesses, and government agencies who report a greater need for STEM knowledge and skills to fulfill future jobs [9]. Nationally, it is predicted that 80% of new jobs will require at least some mathematics, science, and engineering, and 50% of the technical workforce will retire soon, making it more important than ever to inspire students in these fields [10]. The literature reveals numerous obstacles that youth encounter that impact their interest in STEM education. In this paper we will focus on one obstacle which could be attributed to lack of teachers' STEM awareness and training which impacts their interest in promoting STEM in their classrooms. To engage students' interest in the technical career paths, we must start with inspiring and training teachers to instill such interest in their students at early age.

This claim is supported by research indicating that extrinsic motivator for interest in persons and things, and consequentially interest in STEM and non-STEM careers are educators. Ultimately, the goal of educators is to develop students' interest and motivation in learning [2].

Social factors, such as peers, parents and teachers, have been emphasized as important influences on students' future choices. Previous research has indicated that students' lack of interest in STEM careers can be attributed to discouragement experienced in their K-12 years [5]. It is crucial that K-12 students have role models in STEM fields and opportunities to communicate with people who can encourage and guide them along pathways to STEM careers [4]. For middle and high school students, teacher support and teacher expectations of success are significant supports. Teachers are exceptionally well situated to provide either discouraging or encouraging role models and affect students' attitudes, interests and career choices [7]. Thus teachers' influence is an importance factor for students' selection of careers in STEM.

In a longitudinal study following students from secondary school to university education, Bottia et al. [1] found that female high school teachers had a crucial influence on female students' career selection. As these effects could be found in various subject areas, computer science (CS) teachers' attitudes and practices could also positively influence students' attitudes and encourage them to follow a CS career path. The more students are exposed to computers and positive role models in their K-12 years, the more likely they are to pursue studies in a CS related field [11].

Overall, the literature suggests that K-12 schools need teachers as role models who can provide learning experiences related to students' interests during their K-12 years and encourage them to move toward a STEM career. Encouraging students requires that the teachers have positive attitude toward STEM, understands their students' attitudes about the subject, and aim to positively influence their attitudes [8] [9].

Stagg [12] found that teachers were not well informed on student aspirations towards science and careers in STEM let alone careers outside STEM. This situation is not supported by the fact that most careers teachers come mainly from non-science backgrounds. These findings suggest that there is a need to develop an effective policy approach to enable students to be more aware of career possibilities associated with science. Also, teachers need to be well informed on STEM careers and existing opportunities that can lead students' path to STEM.

Present study aims to provide activities to motivate teachers to use technology in their classrooms and encourage students to pursue a STEM related field, Computer Science in particular. Research indicates evidently that the field of computer science is facing one of its most challenging times. Many academics and industry leaders in the field of computing agree that CS education is imperative for the economy, with computing and information technology jobs still in high demand. Yet, this message does not seem to be getting to high school students. Additionally, guidance counselors, teachers and administrators at the middle and high school level do not understand what CS is and what jobs are available for students studying computer science and information technology. In this study, we implemented a novel strategy to develop high school teachers'' understanding and appreciation of careers in the STEM fields, Computer Science in particular, and their motivation to encourage students to pursue STEM career areas. Teachers participating in the project explored STEM principles through game design; investigated and understood the use of physics engines in game development; and developed Computational Thinking (CT) while learning scripting and programming languages. They also explored various career opportunities in STEM and the importance of inspiring more students to pursue STEM careers.

Following their participation, teachers reported that they integrated technology in their teaching and collaborated with students in creating Scratch projects. Promising findings also emerged in terms of teachers' understanding of critical technologies and STEM careers.

2. PARTICIPANTS

The teacher training was part of a three-year research funded by NSF project [3] [4] to support 96 low-income rural and urban high school students. We found it to be extremely important to have a separate training for teachers from the same participating school districts. The participating teachers were recruited from 14 different school divisions) same school divisions as the students). Of the 41 teachers, all were female and almost two-thirds of them were White/Caucasian (63.3%). Participating high school teachers taught subject areas which included reading, math, science, social studies, technology or technology education, English, art, business, and foreign language. One participant was a resource teacher. A little more than half of the teachers (56%) had at least a master's degree, and their years of teaching experience ranged from 1 to 20, with a median teaching experience of 5 years.

3. THEORETICAL BACKGROUND

The model for this study was based on the Kolb's Experimental Learning Model which describes how students learn, as shown in Figure 1. This model served as an inspiration and guidance in the content development and delivery rather than approaching the instruction in a linear way. Kolb [6] argues that knowledge is constructed through the transformation of experience during experiential learning. Kolb's experiential learning style theory is typically represented by a four stage learning cycle in which the learner 'touches all the bases'. Effective learning is seen when a person progresses through a cycle of four stages: of (1) having a concrete experience followed by (2) observation of and reflection on that experience which leads to (3) the formation of abstract concepts (analysis) and generalizations (conclusions) which are then (4) used to test hypothesis in future situations, resulting in new experiences. Kolb [6] views learning as an integrated process with each stage being mutually supportive of and feeding into the next. It is possible to enter the cycle at any stage and follow it through its logical sequence. However, effective learning only occurs when a learner is able to execute all four stages of the model. Therefore, no one stage of the cycle is as effective as a learning procedure on its own. Hence, the optimal learning takes place when learners have adequate balance of these four stages during their learning experience. According to Kolb, learning requires that individuals first should detect, depict, or grasp knowledge, and then a phase of construction should take place to complete the learning process. This construction is a transformation of the grasped knowledge into a mental model through experiencing this knowledge. Kolb proposed that the optimal learning would pass through a cycle of the Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation.

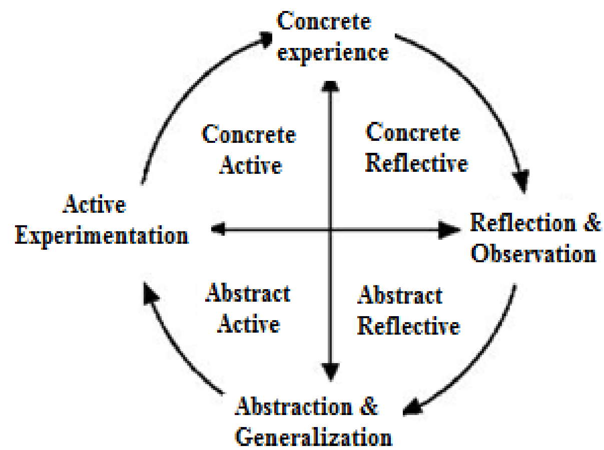

Figure 1. Kolb [6] Experiential Lerning Model

The programming activities for this project were aligned with the four steps of the Kolb's experiential learning model. The Kolb cycle implies that it is not enough to have an experience to learn. It is critical to reflect on the experience to formulate concepts which can be applied to new environments. Finally, learning will be tested in new situations and new settings. In this way, theory, action, reflection and practice are linked into a dynamic cycle and complement each other. Generally, the model stresses the continuous nature of learning and the appropriate feedback which provides the basis for a continuous process of goal-directed action. Kolb's model served as the foundation for developing the instructional activities and content delivery based on different learning styles.

4. TOOLS AND ACTIVITIES

Instructional Activities

In each of the three project years, participating teachers were provided 90 hours (per teacher, per year) of training in learning, creating, and integrating game-based instructional modules on STEM career exploration. Two groups of teachers each participated in two-week long face-to-face training on Scratch during the summer each year and several Saturdays during the academic year. The workshops were designed to help teachers create educational games in their teaching subject area. Teachers had an opportunity to learn coding using Scratch which is an object oriented software program. Teachers needed no programming knowledge prior to participating in the project. In addition, teachers participated in online courses via Moodle, an open-source content management system. In addition to the training and online learning opportunities, a STEM summit was offered every year for all teachers, administrators, parents and guidance counselors in the participating divisions to provide information about emerging STEM issues in education (e.g., computational thinking in K-12 curriculum, critical and emerging technologies of the future, research-based instructional practices that help all learners including students with special needs to explore STEM fields).

The aim of the project was to (1) create awareness among the teachers about the importance of STEM and their role in students' attitude towards STEM career, (2) introduce teachers to various careers/areas in STEM, and (3) introduce creative ways to get teachers engaged in use of computing tools (i.e. Programming skills) in teaching. For example, we chose to teach programming to teachers by letting them explore programming skills in a graphically rich environment, namely Scratch. During the course of the project, we also emphasized on developing soft skills necessary in STEM careers: (a) the ability to solve problems, (b) the ability to acquire strong oral and written communication skills and (c) the ability to work with others and effectively contribute to team projects. We also had continuing discussions on two important factors: (1) non-programmers can learn to write programs as evidenced by the project and (2) teachers have great influence on students' future choices. During the project, the teachers also had an opportunity to have contact with STEM expert teachers for guidance.

Programming Tools

The programming components included Scratch lessons to reinforce the basic programming concepts. We decided to experiment with Scratch since it is specifically designed to help young people learn important mathematical and computational ideas, while also gaining a deeper understanding of the process of design and programming. We also wanted the teachers to create games without writing a single line of code with Scratch's drag-and-drop techniques and get them excited about the fact that they could still create things without writing code while learning about programming concepts and in return, convey the same message to their students. Also, we were trying not to be too ambitious since more than half of the participants had no prior programming experience. Through various exercises in Scratch, in addition to teaching programming fundamentals, we were also able to reinforce the following concepts: (a) programming requires that things be organized, (b) programming involves problem solving and planning, (c) programming involves procedural skills and abstract thinking, (d) mathematics is important, and finally (e) debugging requires thinking deductively. Teachers were also able to control their games using Picoboard which is a piece of hardware that allows Scratch projects to interact with the outside world. Teachers also worked with basic programming and electronics concepts to create interactive projects that react to light, sound and touch.

5. DATA COLLECTION

Career Awareness Survey. Research indicates that generally, scholars and students are uninformed or misinformed about the job descriptions of a computing professional Career Awareness Survey was categorized in three sections: Computer Engineering, Computer Science, and Information Technology. The survey for each section was intended to answer the following questions:

1. What is the level of the participants' understanding of the career choice in STEM?
2. What sources have the participants utilized to help students gain information about STEM careers?

The participants' perceived understanding of the Computer Engineering, Computer Science and Information Technology careers were firstly quantitatively evaluated using a five point Likert scale (1=Strongly disagree to 5=Strongly agree), requesting participants to indicate their personal understanding and knowledge of the career description of possible careers.

Teacher Feedback Form. The teacher feedback form was used to gather teachers' overall perceptions of the training they received during the teacher academy in summer. The feedback form consisted of 14 closed-ended items measured on a 5-point scale (strongly disagree to strongly agree) and six open-ended items. The teacher feedback form was posted online and administered on the last day of the teacher academy.

Teacher Survey. The teacher survey was developed to gather data about teachers' perceptions, understanding, and practices with regard to several key topics. Specifically, the survey addressed perceptions of STEM teaching, understanding of critical technologies, instructional practices, use of technology, and importance of digital media, professional learning, student outcomes, and organizational support. In Year 2, the survey was slightly revised to add items addressing teacher collaboration. The survey consisted of 10 primary selected-response items with sub-questions and one open-ended item. In Years 1 and 2, the survey was administered three times: prior to participation (pre-survey), half-way through participation (post-survey 1), and following the conclusion of project activities (post-survey 2). However, in Year 3, the survey was administered only twice (a pre-survey and a post-survey) because the duration of this project year was shorter compared to Years 1 and 2.

6. FINDINGS

Career Awareness Survey

The Career Awareness Survey was administered prior to and following participation in the training to measure teachers' understanding of possible computing careers. The survey was compiled using the job descriptions specified for the Computer Science, Computer Engineering and Information Technology. The teachers'' perceived knowledge of computing career were evaluated using a responses for the two-highest response options (*know a lot* and *know a great deal*) for each career, requesting teachers to indicate their personal understanding and knowledge of the career description of thirty three computing related careers.

By the end of the training teachers knew a great deal about careers in computing and agreed that school administrators, counselors and teachers have a responsibility of constantly acquainting themselves with new career developments and ensure that students are familiar with computing career opportunities to make better decisions about their career path in college.

Teacher Feedback Form

Teachers were asked to complete a feedback survey. Results show that teachers were quite satisfied with the training provided in summer. All (100%) teachers agreed or strongly agreed with eight of the 14 items. The percentage of teachers expressing agreement with the remaining six items ranged between 83% to 92%. Mean ratings for all 14 items were equal to or exceeded 4.00 on the 5-point scale, which denotes agreement. The highest mean rating was for presenters being knowledgeable about subject matter and the lowest mean rating was for the range of topics covered at the summer training. It should be noted that the lowest mean rating was 4.23, which was quite high on the 5-point scale.

Teachers reported that participation in the program increased their content knowledge and skills related to computing and innovative ideas in incorporating programming into their curriculum and provided them with resources or information that they could access in the future. Additionally, teachers expressed intentions to incorporating the new computing knowledge and skills into their teaching.

Teacher Survey

Understanding of critical technologies and STEM Careers- A teacher survey was completed by participating teachers prior to and following participation in the training to measure teachers' understanding of existing technologies and STEM-related concepts, such as biotechnology, quantum computing, biomechanics, green technology, artificial intelligence, nanotechnology, etc. We presented teachers with 26 critical technologies (Table 1). The survey included responses for the two-highest response options (*know a lot* and *know a great deal*) for each technology. Prior to participation, two teachers reported *knowing a lot* about one to six technologies.

Table 1. List of Critical Technologies

Critical Technologies Concept	
Astrobiology	Bioremediation
Biomaterials	Cryptography
Biomechanics	Green Technology
Biotechnology	Biodefense
Cybersecurity	Bioinformatics
Recombinant DNA	Gene Therapy
Alternative Fuels	Genomics
Proteomics	Modeling Complex Nonlinear Systems
Data Mining	Business Intelligence
Neural Network	Software Development
Robotics	Geo-technology
Polymer tech	Nanotechnology

Following participation, teachers' knowledge of critical technologies improved; forty teachers indicated *knowing a lot* about one to seventeen critical technologies. This finding is quite encouraging and suggests that the project made progress toward meeting the expectation of helping teachers develop an understanding of critical innovative technologies in STEM fields.

Instructional Practice **-** Teachers' regular instructional practice was examined by assessing the frequency with which teachers engaged in the practice (never to every day). Results show promising findings with relation to teachers' use of Scratch and their promotion of programming. After participating in the project, an increased number of teachers reported using Scratch weekly to reinforce the concepts that were being introduced in the classroom. Similarly, there was an increase in the number of teachers who reported making connections between disciplines, paying attention to creating learning settings that are sensitive to gender differences, asking students to take notes, promoting student involvement in programming, providing exploratory activities, and adopting new methods of teaching. In addition, a majority of teachers (90% to 100%) reported communicating course goals and objectives to students, giving students a chance to ask questions in class, asking students to work in groups, and emphasizing problem-solving.

The findings indicate that a higher number of teachers reported making connections between disciplines, paying attention to creating learning setting that are sensitive to gender differences, asking students to take notes, promoting student involvement in programming activities providing exploratory activities, adopting new methods of teaching and using Scratch to reinforce concepts. In addition to using various teaching strategies, teachers also integrated the use of participatory electronic technologies in their teaching. Electronic technologies used by teachers included smart boards, promethean boards, and wiki.

With regard to the use of Scratch, findings were promising. Each year, the majority of teachers reported never using Scratch in their classrooms prior to participation in the project. After participation, there was a large percentage of teachers who used the programs at some point during the year, from once to less than monthly (Year 1, 63% teachers reported using Scratch; in Year 2, 67% reported using Scratch; in Year 3, 89% reported using Scratch). This finding suggests that following participating in the project, most teachers at least attempted to implement Scratch in their classrooms; it further shows that teachers did fulfill their intentions of implementing knowledge and skills learned from the training as indicated in the feedback form. Thus, the project met the objective related to teachers' integration of the new software into their instructional practice. It is interesting to note that teachers who taught technology or technology education implemented Scratch more than teachers who taught other subjects such as reading, math, science, social studies, and geometry, $r = 0.01$, p (one-tailed) < 0.05.

It is important to mention that the project did face some institutional barriers that might have hindered some teachers from making use of their new knowledge, skills, and resources. Three teachers informed project staff that the division in which their schools were located had strict policies when it came to using new software. This particular school division required all software requests to be approved by a committee, which is a long process; therefore, three teachers from that division could not implement Alice or Scratch in their classrooms. One other teacher from a different school division could not implement the software due to lack of infrastructure (e.g., computers).

Importance of Digital Media **-** Teachers were asked to indicate their thoughts about the importance of the effects of different types of digital media on their teaching and on their students' engagement and achievement. Twenty-one items were used to examine teachers' perceptions about the importance of digital media. Results show that teachers' perceptions of digital media did improve over time. Although teachers assigned varying levels of importance to different types of digital media, there were four types that were consistently considered very important by teachers (received mean ratings that were close to or above 4.50 at both the pre and post-survey): interactive lesson plans, research information for student use, information for own professional development, and primary source materials. Teachers' views on the importance of interactive simulations and games or activities for student use out of school showed positive improvements.

Professional Learning **-** For the project evaluation, professional learning was defined as teachers' understanding of STEM concepts, principles, and processes as well as their technological skills and knowledge of various resources for STEM teaching. A professional learning scale was created with five relevant survey. Prior to participation in the project, teachers reported that they, on average, had a moderate understanding of STEM concepts, principles, and processes. Following their participation in the training, teachers' mean ratings on the scale increased significantly (by 1.28 on the 5-point scale), which was statistically significant. In addition to teachers' ratings, teachers' comments each year indicated that they found STEM concepts to be the most helpful content presented at their training sessions.

Organizational Support. Several teachers did report no significant improvements in the support received from their schools and administrators; further, the support they did report tended to be mid-range—higher than the mid-point of the 5-point scale, but not quite attaining the level of "agreement." Thus, although support may have been adequate for traditional teaching functions and instruction, it may not have risen to the level of adequacy for innovation. Support from the school is very crucial to introduce and sustain changes in computing instruction.

7. CONCLUSION AND DISCUSSION

Overall, the project seemed to achieve many of its primary aims with regard to training and preparing teachers in STEM-related computer technologies. In all, 41 teachers participated in the training during the course of training. Through the project trainings, teachers seemed to develop a better understanding about critical innovative technologies in STEM fields. Through the trainings, the teachers did learn to use the key programs that formed the core of the professional development. Teachers also began using Scratch in their classroom STEM instruction, although few teachers did so fairly infrequently. In addition to Scratch, teachers integrated various electronic technologies—smart boards, promethean boards and wiki—in their teaching. However, teachers were not fully satisfied with the support they received from their schools.

It is our belief that empowering teachers with computing skills and tool will impact students' perception of computing as career. The project seems to have been successful in increasing teacher's skills and knowledge in computer programming. The project was well received by participating teachers as they reported satisfaction with the training in general. Teachers reported that the training increased their STEM and software-relevant content knowledge, their skills related to the various topics presented, and their ability to incorporate computing into their curriculum regardless of the subject matter being taught. They specifically indicated improvements in their basic programming skills and skills related to using Scratch in their classrooms. Teachers also reported having better understanding of an increased number of technologies during the course of their participation and their responsibility for bringing more awareness to their students about importance of STEM.

Evidently, teachers cannot advocate for students without training and resources. The challenge in changing the face of computer science requires increased attention and a coherent set of programs aimed at supporting the endeavors of teaching and learning computer science in high schools. Like other reform efforts in the public school system, availability of computer science courses in schools requires district-wide institutional support as well as a local school-level commitment by administrators, counselors, and teachers in mathematics and science.

If teachers are given the tools, they can work to disrupt the organization of schooling that limits opportunities for students to be introduced to computing and programming. Though teachers might have some experience in making some educational changes in other arenas, they might lack the specific skills necessary to narrow access to computer science education for all students. Teachers with the proper training and knowledge in computer science hold considerable promise in reaching out to students in an effort to build strong computing programs at their schools. If given opportunities to develop mastery of content matter and pedagogical content knowledge, teachers can better introduce students to the dynamic field of computer science. Broadened collaborative activities allow teachers to know one another and develop professional networks. Increasing the number of computer science teachers will increase the number of students interested in the field. The aim of this project was to provide appropriate STEM training to teachers and present a pragmatic model of how to support classroom teachers in building sufficient knowledge to act as advocates for computer science in their schools. The future of the STEM workforce in the United States will depend on how well-prepared educators are in order to prepare students to fill STEM-related jobs.

8. ACKNOWLEDGMENTS

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