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Enhancing Students' Interest in Science and Technology through Cross-disciplinary Collaboration and Active Learning Techniques

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Executive Summary

Twenty-nine rising high school 12th grade students participated in a 4-week summer program designed to increase their interest in science and technology. The program was a blend of hands-on biology, chemistry, and technology modules that addressed the global issue of obesity. Student groups developed websites to address obesity in one of five countries – Egypt, Mexico, Puerto Rico, United States, and the United Kingdom. Three university professors, two from Computer Information Systems (CIS) and one from Biology, formed a partnership to inspire high school students to embrace technology that conveyed scientific concepts about obesity. Survey results showed an increased interest and aptitude in science and technology. After our program, 68% of the students indicated that they plan to pursue a major in science, technology, engineering, and mathematics (also referred to as STEM majors). Of those students who indicated an interest in STEM disciplines, the largest numbers noted their interest in the following majors: biology, engineering, computer science, computer information systems, and chemistry. At the end of the summer, 85% of the students agreed that the summer program activities helped them to better understand how the science and technology modules from the FUTURES/T.A.G.S. summer program were connected to obesity.

Keywords: Active Learning, Cross-Disciplinary Collaboration, Science, Technology, STEM, STEM careers; High School Summer Program, Interdisciplinary Programs

Introduction

> *"Achieving the goal of scientific and technological literacy requires more than understanding major concepts and processes of science and technology. Indeed, there is a need for citizens to understand science and technology as an integral part of our society. Science and technology are enterprises that shape and are shaped by human thought and social actions."* (Bybee & DeBoer, 1994, pp. 384)

Today's real world problems often have both scientific and technological aspects. Science tries to understand the natural world while technology tries to solve practical problems. Technology can expand our capacity to understand and control the natural and human-made environment. Students must learn to use technology as a tool to help understand science and increase creativity in scientific investigations. The challenge of

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science education is to prepare students to become scientifically and technologically literate decision-makers and problem solvers.

Students do not learn and retain solely by reading or hearing lectures about science, they must experience science. Science experiences should be connected to students' everyday life as well as the science and technology related social issues with which their local communities, nations, and all humanity struggle (Solomon & Aikenhead, 1994).

A collaborative program between Fostering Undergraduates through University Research and Education in the Sciences (FUTURES) and Technically Aspiring Global Students (T.A.G.S.) provided 29 students with an innovative blend of science and technology to better prepare them for science, technology, engineering, and mathematics (STEM) majors in college. The program set out to accomplish this goal through the use of active and collaborative learning that enabled students to access, analyze, interpret, synthesize, apply, and communicate information regarding global obesity.

FUTURES is a four-year science education program designed to provide innovative math and science enrichment experiences for a cohort of students as rising 11th graders in high school through the end of their freshmen year in college. During the first year's summer program, students participated in SAT preparatory workshops coupled with science modules in biology, chemistry, and earth science. Although it enhanced the students' content knowledge, test-taking strategies, and how to perform basic laboratory procedures, the post summer assessment revealed that there were no significant increases in the students' interest toward careers in STEM. In an effort to increase students' interest in STEM careers, FUTURES modified its summer program for Year 2 to include more hands-on biology and chemistry activities as well as a technology component. To implement the technology component, the FUTURES program collaborated with T.A.G.S., an outreach program designed to inspire high school students to embrace technology while encouraging their academic, social, and personal development.

The FUTURES/T.A.G.S. summer program theme was "Addressing Global Obesity". This four week summer program blended hands-on biology and chemistry modules with a technology component that introduced students to HTML coding. Students were divided into five (5) teams in order for them to collaborate, with each team looking at the real world issue of obesity in their given country (i.e., Egypt, Mexico, Puerto Rico, United Kingdom, and the United States). The student teams used active learning to create websites to address obesity issues and identify possible solutions integrating what they had learned in the aforementioned science modules.

The rest of this paper is organized as follows. In the next section we provide a literature review on the status of STEM in the U.S. along with active and collaborative learning. Based on this foundation, in the subsequent sections we discuss our innovative approach, hypotheses, methodology, results, discussion, and finally the conclusion.

Literature Review

Science, Technology, Engineering, and Mathematics (STEM)

> *"Today, more than ever before, science holds the key to our survival as a planet and our security and prosperity as a nation. It's time we once again put science at the top of our agenda and work to restore America's place as the world leader in science and technology."* ~ President Barack Obama

In November 2009 President Obama launched the "Educate to Innovate" campaign to motivate and inspire young people across the country to excel in STEM. A growing number of jobs require STEM skills and America needs a world-class STEM workforce to address the "grand challenges" of the 21st century, such as developing clean sources of energy that reduce our dependence on foreign oil, discovering cures for diseases, and addressing health issues such as obesity. Success on these fronts will require improving STEM literacy for all students, expanding the pipeline for a strong and innovative STEM workforce, and greater focus on opportunities and access for groups such as women and underrepresented minorities (White House, 2009).

The National Academies' report (2006) expressed their concern about the declining state of STEM education in the United States. In their report the committee developed a list of ten actions that federal policy makers should take to advance STEM education in the United States to ensure competitive success in the 21st century. Two of their top recommendations were to:

1. Increase America's talent pool by improving K-12 science and mathematics education; and
2. Enlarge the pipeline of students prepared to enter college and graduate with STEM degrees.

Active Learning

If you tell me, I will listen.
If you show me, I will see.
But if you let me experience, I will Learn.
~ Lao-tse, 5th Century B.C. Chinese Philosopher.

Active learning, also known as discovery learning, emphasizes the intrinsic motivation and self-sponsored curiosity of students who fashion content and are actively involved in its formation (Bonwell & Eison, 1991; Leonard, 2002). In his classic article, Bruner (1961) states that learners are more likely to remember concepts if they discover them on their own, apply them to their own knowledge base and context, and structure them to fit into their own background and life experiences. In active learning the instructor serves as a catalyst directing projects that center around solving a problem. Students that are actively involved in the analysis, synthesis, and evaluation of content gain a better understanding of the information than they would otherwise have through passive, instructor-centric learning.

In active learning, the mode of instruction must allow the students to create authentic, hands-on learning experiences in order to learn new information. In active learning students become participants in their own education, increasing the likelihood of retention. The elements of active learning include talking, listening, reading, writing, and reflecting (Chickering & Gamson, 1987; Meyers & Jones, 1993). These elements, which involve cognitive activities, allow students to clarify, question, consolidate, and appropriate new knowledge. Characteristics of active learning include focusing on developing skills and higher order thinking (Bonwell & Eison, 1991).

Although there are mixed results in the literature concerning the impact of active learning (Drake, 2012), there are numerous examples of how active learning improves student learning outcomes (D. Johnson, Johnson, & Smith, 1998a, 1998b; Springer, Stanne, & Donovan, 1999). The use of information technology as a tool to help facilitate active learning has also been shown to impact student learning. Blumenfeld et al. (1996) used online resources from the Internet to enhance the science learning activity of middle school students while Hmelo-Silver, Duncan, and Chinn (2006) used software tools in the instructional processes.

Collaborative Learning

Collaborative learning is defined as a method of learning in which students are placed in teams of two or more people to explore a significant question or create a meaningful project through capitalizing on each other's resources and skills (Chiu, 2000; Dillenbourg, 1999; Dillenbourg, Baker, Blaye, & O'Malley, 1996). The benefits of collaborative learning include the development of interpersonal skills (Jun & POW, 2011), active involvement in the teaching/learning process (Lafifi & Touil, 2010), enhancement of critical thinking (Cheong, Bruno, & Cheong, 2012; Gokhale, 1995), learning conflict resolution and taking ownership of the project/results (R. T. Johnson & Johnson, 1986). In the following section we discuss the innovative approach used to structure the summer program.

Innovative Approach

The FUTURES/T.A.G.S. summer program was developed to assist in promoting President Obama's "Educate to Innovate" campaign through inspiring students to major in STEM disciplines. The FUTURES/T.A.G.S. summer program, whose theme was "Addressing Global Obesity", was unique because it was designed as a hands-on program that encouraged students to experience science and technology through addressing the real world issue of global obesity. The summer program was designed utilizing these fundamental concepts: 1) addressing a real world problem, 2) cross-disciplinary collaboration between science and technology, 3) hands-on activities, and 4) team development of websites.

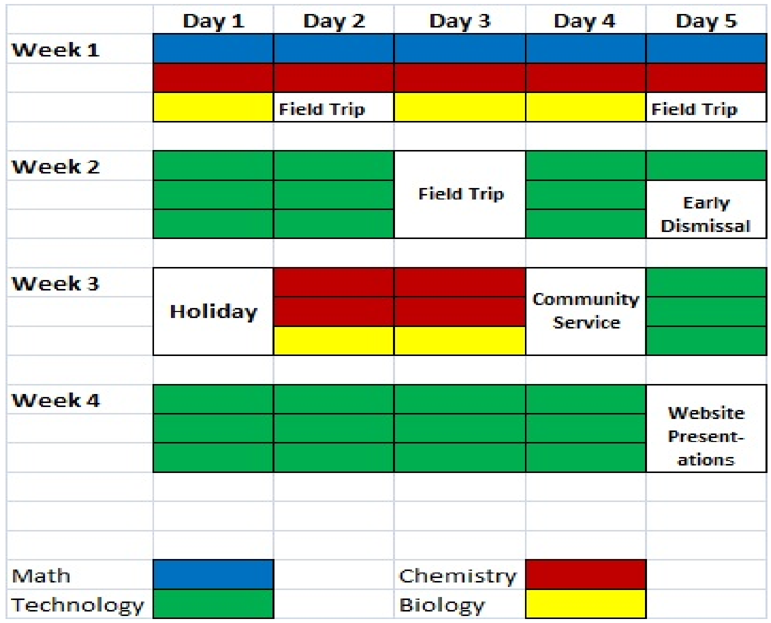
We provided this cohort of 29 students with opportunities to increase their insight into, and appreciation of, the investigative process by connecting science and technology to their daily lives during a 4 week summer program. These students in turn used active and collaborative learning to research and address the real world problem of obesity from their country's perspective. The countries (i.e., Egypt, Mexico, Puerto Rico, United Kingdom, and the United States) were chosen from a February 2010 report of Global Prevalence of Adult Obesity.

Students were organized into teams of 5-6 members to allow them to collaborate on the development of the country websites. The teams applied their experience and knowledge across four content areas: biology, chemistry, mathematics, and technology (See Table 1 for more details on the program schedule). These activities allowed students to use active learning techniques and group discussions to understand more about obesity and strengthen their critical thinking skills. For example, in the biology and chemistry modules, students learned how to use basic scientific equipment such as micropipettors and centrifuges to isolate and analyze fat content. The mathematics and technology modules allowed students to use spreadsheets to collect, record, and display their data about nutrition, diet, and exercise. The culmination of these activities was the development of a website for each student team to present their findings on and interpretation of obesity. The students had nine days of daily instruction to build their team website. Building the websites allowed the teams to display the new knowledge learned and develop a medium to reflect and express their new knowledge in a creative way.

In order for students to develop their websites the software and resources resided on the Virtual Computing Lab (VCL). VCL is cloud computing technology that allows an "image" of software applications and resources to be used anytime and anyplace as long as students had access to the Internet.

Utilizing collaboration in the FUTURES/T.A.G.S. program allowed us to design a program to integrate our students' experiences in science and technology and help them investigate the "real world" health problem of obesity. In the following section we discuss the hypotheses that were used to evaluate the summer program.

Table 1: FUTURES/T.A.G.S. Schedule for the 2010 Summer Program



Hypotheses

Three hypotheses were developed in order to evaluate the effect of the summer program. The first hypothesis was developed to determine what impact the program would have on the students' selection of STEM majors. The hypothesis states:

H1. The summer program would positively impact the students' overall interest in one of the STEM majors.

The second hypothesis was developed to survey the students' perception of their knowledge acquired in the science component. The hypothesis states:

H2. Student's perception of their competence in science research skills will increase as a result of the summer program.

The third and final hypothesis was developed to test the increase in content knowledge and skills that the students gained in the technology component of the program. The hypothesis states:

H3. Student's content knowledge and skills in technology will increase as a result of the summer program.

In the following section we will discuss the methodology used to evaluate the three hypotheses.

Methodology

We developed several instruments to capture qualitative and quantitative data on the students as it related to their knowledge and perception of science and technology. The pre- and post- surveys were administered to determine the students' perception of science skills, intended college majors, and overall interest in science and technology. The pre- and post- web assessments were administered to determine whether the students increased their knowledge of web development and technology.

The pre- and post- surveys consisted of a total of 34 questions. The questions were grouped into the following categories: perception concerning science, likes/dislikes regarding the program, computer knowledge, STEM careers, and science abilities. Fifteen questions evaluated the students' perceptions regarding interest and enthusiasm relative to the science modules for which a 5-point Likert scale (i.e., strongly disagree, disagree, neutral, agree, strongly agree) was used. Four open-ended questions allowed students to comment on likes or dislikes regarding the program. Eight questions asked students perceptions regarding their computer knowledge. The last 7 questions asked students their interest in STEM careers and their perception of their scientific competence and reasoning abilities.

The pre- and post- web development assessments were administered to document the participants' growth in skills used to design and build websites. The pre-web development assessment consisted of 18 questions: three questions regarding their knowledge and experience with VCL and 15 multiple choice questions on HTML code and tags. The post-web development assessment consisted of 27 questions: 12 questions regarding their knowledge and experience with VCL and 15 multiple choice questions on HTML code and tags. In the next section we discuss the students' responses from the instruments used to test our hypotheses.

Results

Twenty nine students participated in this study (14 females and 15 males). The participants attended 13 different high schools in the Durham Public Schools system. Twenty-seven students were African-American, one Asian-American, and one Native-American. Ninety percent of the students were rising 12th graders and 10% were rising 11th graders (see Table 2 for student demographics).

Table 2: FUTURES/T.A.G.S. Student Demographics

Criteria	Males	Females	Total
Ethnicity			
African American/Black	14	13	27
Asian American	1	0	1
Indian	1	0	1
Classification			
Rising 12th graders	13	13	26
Rising 11th graders	3	0	3

Test of Hypothesis 1: Students' Selection of STEM Majors

The first hypothesis was developed to test the impact the summer program had on students' selection of college majors. Of the 29 students that were a part of the program, only 22 students (76% response rate) completed both pre- and post- surveys. Analysis of an open-ended survey question which asked students to list their intended major showed that only 12 of the 22 students (54.5%) were committed to studying a STEM area prior to the FUTURES/T.A.G.S. program. It is our hypothesis that the FUTURES/T.A.G.S. summer program had a positive impact on the students' interest in the STEM disciplines. Thus, the students' commitment to major in one of the STEM areas increased to 15 out of the 22 (68.1%) by the end of the program.

Furthermore, the FUTURES program continued to track the students throughout their matriculation into college. All 29 participants went to college with 80% enrolled in 4-year college and 20% in 2-year college. Seventy five percent of students have declared STEM majors which is a further increase from the 68.1% at the end of the summer program. These longitudinal results show the continuous impact that special programs such as FUTURES/T.A.G.S. can have on significantly increasing participants' interest in STEM majors.

Test of Hypothesis 2: Students' Perception of Their Competence in Science Skills

The second hypothesis was developed to survey the students' increase in their perception of the science skills acquired as a result of their participation in the summer program. The students rated their science skills between "Moderately Competent" and "Adequately Competent" on a 5-point Likert scale for 11 research process skills included on the surveys of which four of the skills were relevant to this study. The four skills were working with other science professional in a group, organizing data, preparing a scientific research poster/talk, and interpreting data. Table 3 shows the results between the pre- and post- surveys.

Table 3: Students' Competence Ratings Across Various Science Research Process Skills

	Pre Summer Program		Post Summer Program		Statistically Significant Difference (P<.05)
	% Competent	Mean ± Std. Dev.	% Competent	Mean ± Std. Dev.	
Working with other science professionals in a group	83%	4.29 ± .751	96%	4.44 ± .583	
Organizing data	96%	4.25 ± .532	88%	4.28 ± .678	
Preparing a scientific research poster/talk	80%	3.96 ± .841	72%	4.16 ± .850	
Interpreting data	60%	3.72 ± .678	80%	4.12 ± .726	P=.012

Table 3 shows that two of the four skills increased over the course of the summer. Those two skills were working with other science professionals in a group, which increased from 83% prior to the summer program to 96% at the end of the summer program (13% increase) and interpreting data (60% prior to the summer program to 80% at the end of the summer program (20% increase with a p-value of .012).

Test of H3: Students' Technology Performance

The third hypothesis was developed to test students' increase in content knowledge and skills in technology. For this we analyzed and summarized the pre- and post- web assessments to determine if there was an increase in proficiency of the students' technological skills. The results from our findings suggest a substantial increase from the pre- to the post- assessments. There was an average overall gain of 27.2% from the 24 students who took both the pre- and post-assessments, with two students receiving more than a 60% gain. Furthermore, of the 24 students, only one student showed a decrease in his/her score and one student showed no change. (See Table 4 for a detailed analysis of the percent change from pre- to post- assessments)

Table 4: FUTURES/T.A.G.S. Pre- and Post- Assessments Analysis

Percent Change from Pre to Post Web Development Assessments	Number of Students	Percent of Students
Under 0%	1	4.2%
0 - 9%	4	16.7%
10 - 19%	3	12.5%
20 - 29%	8	33.3%
30 - 39%	1	4.2%
40 - 49%	3	12.5%
50 - 59%	2	8.3%
60 - 69%	2	8.3%

In the following section we will further discuss the results and the overall impact of the summer program.

Discussion

Due to the different high schools, the students' science course selection and preparedness varied. All of the students had taken high school biology classes, but only a few had taken a chemistry and/or technology class. Their participation in the FUTURES/T.A.G.S. summer camp was a unique experience for them because it incorporated active learning activities and group participation in a collaborative environment to research and discuss the global societal issue of obesity. Through their research the teams proposed different causes of and solutions for obesity as it related to their country. For example, Team Mexico proposed that the lack of safe drinking water and the subsequent abuse of soda as a beverage at home and school was one of the several causes of obesity in that country. Another example was Team Puerto Rico, who discovered that cultural customs for food preparation (i.e., deep frying foods) along with the reduction of strenuous daily physical labor contributed to the rise of obesity in their country. There were numerous other examples where the teams demonstrated their ability to analyze the information to construct reasons and solutions for obesity rather than just simply repeating the information they found. Consequently, a major strength of the FUTURES/T.A.G.S. program was the teams' use of active learning to construct knowledge.

Student engagement was one of the other strengths of the program. Most of the students consistently attended the FUTURES/T.A.G.S. summer program and 85% of the students agreed that the in-class activities (i.e., laboratory modules and discussions) were interesting, relevant, and aided understanding. Moreover, 85% of the students agreed that the summer program instructors helped them to understand how the activities in the FUTURES/T.A.G.S. science and technology modules were connected to the common theme of obesity.

Students were also able to voice their opinion of the summer program by answering the following three open-ended questions:

1. What did you like most about the FUTURES/T.A.G.S. Summer Program?
2. What did you like least about the FUTURES/T.A.G.S. Summer Program?
3. Are there any changes that you would like to see made to the FUTURES Summer Program for next year?

There were 36 responses received from the students to the questions above. From the students' responses, four major themes emerged which covered 92% of the comments. The major themes are provided below with their accordance counts and percentage of all responses received followed by a selected response.

- Students valued the hands-on labs and felt that in helped them to better understand the material/subject areas as well as keep them engaged and interest. (Responses: 13 or 36%)

  "I liked the chemistry labs the most. It was very hands on and kept me interested the whole time."

- Students valued the collaboration component of the program. (Responses: 7 or 25%)

  "What I liked most about FUTURES is the web design portion that we did with T.A.G.S. I liked this part because we got to work in groups and team build."

- Need for clear understanding of the integration of the different components of the program as well as the same scheduling structure/organization. (Responses: 6 or 17%)

  "The organization at FUTURES can improve. T.A.G.S. gave us a day schedule and we knew exactly what was planned for us."

- Students were concerned that more time was needed to complete the deliverables (i.e. website). (Responses: 5 or 14%)

  "I did not like the limited amount of time to complete our website and posters. We were only given about four days to complete our websites and I felt we needed more time."

In the next section we provide concluding remarks and future research.

Conclusion

Through the FUTURES/T.A.G.S. summer program, high school students were provided the opportunity to increase their insight into and appreciation of the investigative process by connecting science and technology to their daily lives. This was accomplished by incorporating active learning exercises in a collaborative environment to research and discuss the global societal issue of obesity. In this summer program, the science modules were taught in the Science Building and the technology modules were taught in computer labs in the School of Business. During the four week summer camp, students were taught by university professors from the School of Business, Department of Biology, and Department of Chemistry. Undergraduate and graduate students from each of the respective disciplines served as counselors and were available to help facilitate instruction and provide additional help outside of class. Students were able to work outside of the dedicated instructional time by using VCL. Based on the high evaluation ratings that were received, we believe that the summer program succeeded in helping students continue to acquire knowledge and skills in biology, chemistry, and computer information systems. Survey data from the end of the summer indicated that 68.1% of students planned to pursue a major in STEM. Of those students who indicated an interest in STEM majors, the largest numbers noted that they were leaning toward the following majors: biology, engineering, computer science, computer information systems, and chemistry after the summer program. Additionally, the further tracking of the students throughout their matriculation into college showed that 75% of the students actually declared STEM majors.

Future collaborative summer programs will carefully examine and map the integration of STEM fields. We will also look for more ways to expose students to a variety of possible STEM careers as well as enhancing and strengthening the student engagement through active learning activities. We believe that this cross-disciplinary summer program played a major role in solidifying students' choice of STEM majors and can be replicated in other universities.

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Biographies

Donna M. Grant is an Assistant Professor of Computer Information Systems at North Carolina Central University (NCCU). Dr. Grant received her Ph.D. in Computer Science from DePaul University, where she also earned a M.S. in Information Systems and an M.B.A. in Finance. Additionally, she earned a B.S. in Mathematics at Northwestern University. To date, Dr. Grant has published her work in the Encyclopedia of Gender and Information Technology, the Informing Science Journal, the Journal of Information Technology Education, several other journals and numerous conferences. In 2011, she received the NCCU Award for Teaching Excellence. Prior to receiving her doctorate, Dr. Grant spent 22 years in the IT industry where she worked as a Director of Information Technology at Ameritech.

Alisha D. Malloy is an Assistant Professor of Computer Information Systems at North Carolina Central University (NCCU). She is also an IBM Emerging Technology Institute (ETI) Visiting Researcher responsible for portfolio innovation through tech development and IBM research projects, academic research collaborations, acquisitions, etc. She holds a Ph.D. in Computer Information Systems from Georgia State University, a Master's in Engineering Management from Old Dominion University and a Bachelor's in Engineering from the United States Naval Academy. Dr. Malloy spent over ten years of information technology experience in the military and ICT industry. Dr. Malloy's research interests include Cloud Computing, Healthcare Informatics, IT adoption and diffusion in K-16, Networking and Telecommunications. Dr. Malloy has published in Journal of Information Technology Education, ACM/Kluwer Journal on Mobile Networks and Applications (MONET), Computers, Encyclopedia of Information Systems and several other publications. Malloy is a member of the PhD Project, the Association of Computing Machinery, the Association for Information Systems and the Institute of Electrical and Electronics Engineers.

Gail Hollowell is an assistant professor in the Department of Biology at NCCU. She received her B.S. from NCCU and her master's and Ph.D. from Howard University. Her research interests include infusing research in the undergraduate science curriculum, the impact of technology in the science classroom, and studying what motivates students to learn science. Dr. Hollowell is the program coordinator for NCCU's Howard Hughes Medical Institute Undergraduate Science Education grant, which is designed to engage more minority students in the study of science and math. She received the Biology Department's Outstanding Faculty Teaching Award in 2006 and the NCCU Award for Teaching Excellence in 2007.