AC 2012-4434: USING CYBER DISCOVERY TO ASSESS CHANGE IN STUDENT STEM-RELATED ATTITUDES

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Abstract

Computer science has been identified by the National Science Foundation (2010) as a science, technology, engineering, and mathematics (STEM) discipline in which there has been a shortage of students and workers. Identifying ways to increase interest in computing careers has thus become increasingly important in light of the rapid evolution and use of cyber technology in society, as well as growing threats to cyber security in both personal and public domains.

To address this issue, mathematics, science, engineering, and liberal arts faculty members at Louisiana Tech University developed an intervention program, called "Cyber Discovery," that is designed to expose high school students and their teachers to both the technical applications and social implications of cyber-related activities. This integrated approach to teaching strives to educate new scholars who understand not only the science, technology, engineering, and mathematics (STEM) but also the political, social, historical, ethical, and legal aspects of this evolving discipline. K12 teachers attend professional development workshops throughout the year. The workshops help the teacher prepare for the week long residential camp during the summer that both the teachers and student attend.

Results of the project will be included, as well as activities developed such as: historical/policy essay competitions, cryptographic treasure hunt, and robotic challenges. Additionally, the paper will report on the efficacy of this program in stimulating interest in cyber careers. Accordingly, data will be presented related to students' perceived value of STEM, as well as Holland's Investigative career interest type and science self-efficacy.

Introduction

Cyberspace technology is a ubiquitous part of the world in which we live. Unlike earlier times in our history, this new technology is no longer confined to the more developed nations. Citizens in rural, impoverished, developing countries often have limited access to food, water, and electricity but still have solar-charged cell-phones and a satellite-enabled Internet connection. Boundaries between nations are practically obsolete in cyberspace as citizens of one nation openly and easily interact with others half a world away. The various types of interaction can range from simply socializing among new friends to reporting on or even instigating political unrest. Personal, business, academic, and military applications across cyberspace are now intertwined.

Concerned about the need for stronger cyber-security in the face of growing cyber attacks, law enforcement and military officials have sought to develop systems and train personnel to protect the national cyberspace infrastructure. In an effort to grasp the scope of the new battleground in cyberspace, the Department of Defense in its 2006 doctrine entitled *The National Military Strategy for Cyberspace Operations* [1] defined Cyberspace as

> **"… a domain characterized by the use of *electronics* and the *electromagnetic spectrum* to store, modify, and exchange data via *networked* systems and associated physical infrastructures."**

In other words, the domain of cyberspace is more than just computer applications and the Internet. It includes the use of everyday devices like cell phones, televisions, and music players.

Cyber Discovery

Cyber Discovery was developed by a collaboration of math, science, engineering, and liberal arts faculty. The primary goal of the summer camp and course is to help teachers and students become better cyber-citizens who help, rather than hinder, security efforts by making them aware of the benefits and dangers of cyberspace. Faculty members from the College of Engineering and Science teamed up with the College of Liberal Arts to develop an engaging experience aimed at high school teachers and students. Developing a cyber-curriculum that is truly interdisciplinary in focus – cutting across both the sciences and the liberal arts –demonstrates a national model for implementing similar programs at other institutions. This integrated approach to teaching strives to educate new scholars who understand not only the science, technology, engineering, and mathematics (STEM) but also the political, social, historical, ethical, and legal aspects of this evolving discipline.

Designed using the u-Discovery model pioneered by the College of Engineering and Science at Louisiana Tech [2, 3, 4], Cyber Discovery seeks to establish and strengthen partnerships between the university and area high schools. As a general philosophy, the goal is to empower the high school faculty to incorporate cyberspace education into their curriculum by providing them with the necessary skills and understanding to create relevant subject matter. Unlike the original u-Discovery model which was focused exclusively on STEM education, Cyber Discovery aims to show how non-STEM subjects such as history and ethics play as important of a role in cyberspace education as STEM subjects. This is accomplished by integrating both STEM and non-STEM topics throughout the workshops and camp in a highly interdisciplinary manner. For example, in the camp, English teachers are educated in using robotics and Mathematics teachers are shown how the politics during the founding of our nation still affect how we use technology today.

The Cyber Discovery, held in the early part of June, consists of a week-long residential camp attended by both students and teachers preceded by two teacher-only workshops. Although during the week-long residential period, the focus is primarily on the students; however, ***the real focus is on the teachers***. When preparing for any effort aimed at recruitment of students to attend a college or university, a question naturally arises about how to impact students in the most effective way. Rather than try to host a camp that would serve 100-200 students in a traditional summer camp atmosphere, our aim was to engage teachers in order to build a foundation for long-term sustainable recruitment of high school students into college. Thus, the professional development of the high school teachers is our key mission. The workshops, a vital component to the entire process, give the teachers exposure to the material to be presented during the main camp session by having the university faculty team walk them through some of the projects and discussions that will be given during the regular camp. During the camp, the teachers then become an integral part of the team, concentrating less on learning the material and more on **aiding** and **observing** the students. The aim is to show how they can bring the same or similar material back to their classrooms.

Those who have developed summer camps in STEM know very well that there needs to be a "hook" in order to convince students to give up a week (or more) of their summer. In our case, the "hook" was the

engineering/robotics portion of the camp. In terms of providing professional development, the question arises, "How can you get teachers to give up an entire week away from their families?" The answer is two-fold. First, you must pay for their time through a teacher stipend. Second, you must realize that in order to engage teachers in anything that is meaningful and has potential to impact their experience in the classroom, you must put them in a situation where they are forced to engage their students. Thus, the teachers who participated in the Cyber Discovery were passionate about the camp because of their students. In essence, while the robotics was a "hook" for the students, the students are the "hook" for the teachers.

The week-long portion of the camp is a total immersive experience for all individuals involved. During the camp, the university team uses a variety of media formats to present material including lectures, slides, and movies. Students are engaged with various hands-on labs, informal discussion sessions, and writing challenges. The material covers a range of interdisciplinary topics from fields such as Engineering, Mathematics, Computer Science, English, History, and Political Science. As we discuss later, some of the activities are for a single day while others are week-long challenges. Overall, the curriculum is designed to fully engage the students for the entire week utilizing various skills and interests of the individual members.

During the week-long camp, each school works as a team of two teachers and six students. Participating schools are encouraged to send one teacher from a STEM discipline and one teacher from a humanities or liberal arts program. The teachers in turn are encouraged to select student teams that balance academic disciplines with roughly half of the team having interests in science/math and the other half in the traditional humanities. The leadership at the participating schools also select these students based on their personal experiences with them.

> *"An alternative to simply progressing through a series of exercises that derive from a scope and sequence chart is to expose students to the major features of a subject domain as they arise naturally in problem situations. Activities can be structured so that students are able to explore, explain, extend, and evaluate their progress. Ideas are best introduced when students see a need or a reason for their use – this helps them see relevant uses of knowledge to make sense of what they are learning."*[5]

One aim of Cyber Discovery is for participating students to have a broader exposure to applications of mathematics and science and to be more likely to choose careers in which a broad technical background is required. Moreover, the teachers who participate in the program gain a deeper appreciation for the mathematics/science or humanities they teach and a greater awareness of the broader contexts of what they teach.

To address the difficulty of engaging students for an intense full day, we divide a typical day at the camp into various topics and incorporate various means of group interaction. We have sessions that involve the entire camp group, sessions where the schools work independently as a group, and sessions with mixed small groups where individuals are randomly assigned to help create diverse new interactions.

Sample Activities

In developing the curriculum, the university faculty team selects topics from the various disciplines so that they integrate with the content being discussed for the entire day.
The following is a list of a few of the activities used throughout the camp:

Hands-On-Lab, Boe-bot: Serving to introduce basic programming concepts and notions of logic, controls, and problem solving, the Boe-bot is a robotic platform previously used extensively in the university's own freshman engineering curriculum. Being very hands-on, the activities involving the Boe-bot serve as a "hook" used to engage the students while showing them issues with cyber vulnerability stemming from code security, signal transmission, and programming. The initial activities involve simple dead reckoning concepts and autonomous navigation via sensory input but then advance to establishing a wireless connection to remotely control the robot.

Cyber Policy and Ethics: Students were presented with issues related to cyber policy and ethics from historical and philosophical positions. Faculty encouraged students to critically examine their engagement with information technology and assess its impact both on classical ideas of democracy and American democracy in particular. Students were also exposed to the historical use of information technologies in domestic and international politics, and the dangers that their use posed to various historical actors. Students were encouraged to discern and apply "lessons of history" to contemporary situations today.

For example, on the day that behavior modification was discussed, a psychology professor outlined the basic concepts associated with changing a person's behavior. An historian followed with a discussion of propaganda strategies throughout the 20th century. A question posed on the topic lead students and teachers into discussions that integrated the liberal arts and sciences. Teams were required to produce an essay addressing the question of the day.

Hands-On-Lab, Cryptography: Starting with a historical perspective on cryptography, hands-on / minds-on sessions are held each day. Faculty from the Computer Science and Mathematics departments lead discussions on issues in cryptography. Rather than focus on the technical college-level details of cryptography, the emphasis is on establishing answers to questions such as "*Can we share information without revealing information?*", "*What makes a problem computationally difficult?*", and "*How can public keys be used to share private information?*" We model several of our cryptography topics after Computer Science Unplugged [6], a series of hands-on activities in computer science designed for elementary through high school students.

Students are not only exposed to essential cryptographic concepts but also the underlying mathematical and logical background. By discussing the mathematics behind modern cryptography, students and teachers are exposed to the important notion that our safety in cyberspace is only as strong as the state of knowledge of solving complex mathematics.

Movie and Discussion: Each night of the camp, students and teachers are shown various Hollywood films pertaining to cyberspace. Before each film is shown, an English professor offers prefatory comments and handouts that guide students in discerning relevant themes. Films screened have included *Tron*, *Sneakers*, *The Net*, *Live Free or Die Hard*, and *War Games*. Every morning, students and

teachers from different schools meet to discuss the topics of the film shown the previous evening. During the discussions, the participants are challenged to analyze the various issues that arise in the movies, assessing their validity in our current and future lives. The overall goal is to get the students to contemplate what living in a "cyber culture" entails.

Hands-On-Lab, Architecture: Even man-made structures have an impact on cyber security, from the type of construction material used to the layout of access points to various rooms. To emphasize the relationship, Architecture faculty present background material and then encourage the students to consider the need cyber-infrastructure places on new and existing buildings. As part of the preparation for the final Cyber Challenge, the teams use 3-D modeling software (Sketch-Up) to design and construct buildings to be used to defend their territory. Initially, the students submit a draft model for which the Architecture faculty analyze and give feedback. The students then alter the model, resubmit, and due to the limited time constraint have one shot at its construction. This forces the students to consider how their designs function and what their vulnerabilities are *before* the models are ever fabricated or tested.

Cyber Treasure Hunt: Along the lines of the *National Treasure* movies, for each camp we design a cyber treasure hunt that inter-twines all aspects of the academic content of the camp. This challenge requires teams to apply content that is covered in the academic sessions together with social interactions. The Cyber Treasure Hunt requires students to use cryptographic skills, historical context, physical mapping, wireless communication, and general problem solving as they navigate their way through the maze of clues throughout the entire campus.

On the first day of the camp, each school is presented with a locked box. After performing what amounts to a brute-force attack on the box and determining the appropriate combination, the student open the box to reveal a collection of puzzles. The puzzles themselves lead to other puzzles that are scattered across the campus. These puzzles are of a nature that reflects the topics of the camp. One puzzle, for example, requires the students perform a walking Boe-bot program whereby each clue is presented in the form of a Boe-bot program in PBASIC and leads them to another clue in another part of the campus. Several puzzles involve using cryptographic concepts learned in class with a few requiring material handed out in other lecture topics including one puzzle that requires the use of a copy of the U.S. Constitution as a cipher. To encourage some teams that are falling behind to persist, several clues are time-sensitive. For example, for the first year of the camp, the final clue given on the penultimate day was transmitted over radio waves on a specific frequency, at a specific location, on a specific time, all of which the campers had to discover by solving previous clues. This transmission revealed a final cryptographic key that unlocked an encrypted map image pinpointing the location of the hidden treasure.

Cyber Challenge: Throughout the week, activities and assignments are included as part of a week-long competition where points are awarded based on placement in each assignment. On the final day of the camp, teams participate in two final components of the competition. The "Cyber Challenge" is a robotics competition centered around the Boe-bot, where students use the engineering and computer science knowledge acquired during the week-long activities. From a broad description, the challenge involves all teams using their Boe-bots to navigate an arena to collect items, marbles, while simultaneously preventing others from doing the same and defending their own collection. On the final days of the camp, the teams program their Boe-bot to work wirelessly so that each can be remotely navigated. They also use pre-made and self-designed attachments to their Boe-bots to help in the task. At the same time, the building they design is used to store and protect the marbles as they are collected.

The second creative component of the final day's challenge, judged by professional writers in the region, involves having the students develop their own story-lines surrounding the overall competition.

Cyber Science Motivation and Vocational Personality

The central assessment goal of Cyber Discovery was to examine the extent to which differences exist in important interest, motivational, and personality factors. Pre-and post-camp differences in cyber interest and motivation were hypothesized to be a function of the positive effects of the camp, while we were interested in examining patterns of vocational personality type to assess the accuracy with which students were selected for participation in the camp. That is, certain vocational personality types were expected to be correlated with participants' preferences for liberal arts versus science and technology. Holland's RIASEC model [5] represents a theory of vocational personality which posits that individuals choose occupations on the basis of 6 interest types: (a) Realistic; (b) Investigative; (c) Artistic; (d) Social; (e) Enterprising; and (f) Conventional. Realistic types prefer working with objects (e.g., tools) and in outdoor settings, whereas Investigative types are described as intellectually curious and prefer working with ideas. Artistic types typically prefer creative endeavors while Social types prefer helping and working with others. Finally, Enterprising types typically enjoy occupations that involve the use of persuasive skills (e.g., sales) and Conventional types prefer working with data in settings that require organizational skills. Self-identified liberal arts students were expected to produce positive correlations on measures of liberal arts importance and Artistic personality, while self-identified science and technology students were predicted to produce positive correlations on measures of science importance and both Investigative and Realistic personality types.

Participants

The sample consisted of 60 students representing 10 high schools in northern Louisiana and southern Arkansas. Most participants identified as female (56.3%) while 43.7% identified as male. The majority of participants also identified as Caucasian (88.7%), while 8.5% identified as African American and 2.8% identified as multiracial. Age ranged from 16 to 19 (M = 16.66, SD = .73).

Measures

Science motivation. The Science Motivation Questionnaire (SMQ) [8] is a 30-item measure which consists of 4 subscales aimed at tapping student motivation to learn. The 4 subscales are as follows: (a) intrinsic motivation; (b) extrinsic motivation; (c) science confidence; and (d) relevance of science; and (d) self-determination. Items are scored on a Likert scale ranging from 1 (*never*) to 5 (*always*).

Vocational personality. We measured vocational personality types using the Self-Directed Search-Form R (SDS) [9]. The SDS is a 228-item measure consisting of four scales that are designed to tap vocational interests across Holland's six occupational themes [7]. These scales include: (a) Activities (66 items); (b) Competences (66 items); (c) Occupations (84 items); and (d) Self-Estimates (12 items). The Activities scale asks respondents to rate the degree to which they like or dislike various vocational activities. The Competencies and Self-Estimates scales asks respondents to indicate their perceptions of their abilities in certain vocation-related tasks. The Occupations scale measures interests in various occupations. Scale scores are summed across each of the six RIASEC interest types.

Procedure

We collected data at the beginning, during the middle, and at the conclusion of the camp. Upon arriving at the week-long camp all participants were asked to complete a paper and pencil version of the SDS as well as an online survey consisting of the demographic and motivational items described above. To assess situational intrinsic motivation, participants were asked to complete a brief online survey while they were engaged in a cyber activity. Participants were then asked to complete a final online survey to assess their post-camp perceptions of interest and motivation.

Results

Table 1

Motivation Variable Means and Standard Deviations for Boys

	Pre-Camp		Post-Camp	
Variable	*M*	*SD*	*M*	*SD*
Intrinsic Motivation	20.21	3.04	20.53	1.96
Extrinsic Motivation	16.61	2.69	15.69	2.52
Science Relevance	19.62	3.47	19.88	2.88
Science Confidence	16.73	2.6	15.94	1.95

Table 2

Motivation Variable Means and Standard Deviations for Girls

	Pre-Camp		Post-Camp	
Variable	*M*	*SD*	*M*	*SD*
Intrinsic Motivation	17.88	3.45	19.70	3.98
Extrinsic Motivation	15.52	3.06	16.22	3.29
Science Relevance	18.21	4.07	19.61	4.36
Science Confidence	15.00	3.00	15.43	3.20

Table 3
Correlations Among Importance Ratings and Vocational Personality Types

Variable	1	2	3	4	5	6	7	8	9	10
1. Liberal Arts Importance T1	--									
2. Liberal Arts Importance T2	0.66	--								
3. Science Importance T1	0.54	0.45	--							
4. Science Importance T2	0.11	0.43	0.53	--						
5. Realistic	0.12	0.22	0.00	0.25	--					
6. Investigative	-0.19	-0.05	-0.01	-0.13	0.30	--				
7. Artistic	0.08	0.31	-0.22	-0.09	-0.17	0.17	--			
8. Social	-0.04	0.02	-0.27	-0.45	-0.22	0.27	0.40	--		
9. Enterprising	0.03	-0.01	-0.19	-0.31	0.09	0.19	0.03	0.29	--	
10. Conventional	0.22	0.32	0.14	0.16	-0.01	0.10	-0.08	0.17	0.51	--

Note. T1 = Pre-Camp; T2 = Post-Camp.

Conclusion

Results indicated that motivation from pre-camp to post-camp increased in large part for all participants, but girls reported the greatest gains in motivation compared to boys. It is interesting to note that boys actually reported a decrease in both cyber science confidence and extrinsic motivation, yet their intrinsic motivation was found to increase. The discrepancy between the intrinsic and extrinsic results suggests that boys perceived cyber science to offer fewer external rewards (e.g., social recognition) at the end of the camp, but they developed greater intrinsic interest. This is a promising finding, as it indicates that the cyber discovery camp activities can exert motivational changes that can be sustainable into the future given that intrinsic motivation is such a powerful predictor of career-related choice and performance. The science confidence finding is more difficult to interpret because we expected their confidence to grow over the course of the camp. Perhaps boys entered the camp with unrealistic expectations about their cyber abilities, and these expectations moderated somewhat when they discovered how challenging the tasks could be.

In contrast, girls reported increases across all of the motivation variables. The largest of these increases were observed for intrinsic motivation and science relevance. Clearly, then, by the end of the camp girls had developed a greater interest in cyber science and reported feeling as if cyber activities could be relevant to them in their academic and vocational pursuits. Also noteworthy is the fact that girls reported some gains in their confidence, suggesting perhaps that they formed more realistic appraisals of their scientific and technical skills prior to the camp.

Some interesting and rather unexpected findings also emerged with respect to the correlations between vocational personality type and ratings of perceived importance of cyber science. Investigative vocational personality type was actually associated with a slight decrease in science importance at post-camp. This relationship may be moderated by gender as suggested by the declines in some aspects of motivation for boys during the camp. As predicted, however, Realistic personality type was positively

associated with science importance at post-camp. This can likely be attributed to the fact that Realistic types prefer mechanical activities and robotics activities were a central focus of the camp. Artistic personality was also positively associated with liberal arts importance at post-camp. Taken together, these results suggest that assessment of vocational personality is useful as a tool for screening students for participation in the cyber discovery camp.

Future Directions

We are already holding professional development workshops for teachers from the 2012 Cyber Discovery participating schools. This summer there will be 60 more students representing these 10 high schools in northern Louisiana and southern Arkansas. Additionally, Cyber Discovery will expand to include 36 students from 6 high schools in Maryland.

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