



## Cyber Science - Interdisciplinary Approach to Cyber Studies

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# **Cyber Science - Interdisciplinary Approach to Cyber Studies**

## **Abstract**

Cyber Science is a course developed through a collaboration of math, science, engineering, computer science, and liberal arts faculty. The primary goal of the 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 while driving them to fundamental concepts across the disciplines. Course content exposes students to multiple topics of cyberspace including: the history of cyberspace, ethical and social issues, computer programming, and need for and use of security in 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 students. During the 2011 academic year the course was piloted at a regional school with 21 students. In summer 2011, the program expanded to 6 participating schools in the region. During the summer of 2012, 21 teachers from 12 high schools participated in professional development for the course. The Cyber Science course was a natural expansion of the Cyber Discovery program developed by Louisiana Tech University. The course consists of discussion sessions, hands on labs, cryptographic problems, film sessions, and a final cyber challenge each of which integrate the history, ethical issues, applications, and theory behind cyberspace, security, and cryptography.

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 but also the political, social, historical, ethical, and legal aspects of this evolving discipline.

Results of the project include activities developed such as: historical/policy essay assignments, robotics challenges, as well as computer science fundamentals. This paper will describe the approaches used in addressing ethical and social issues related to cyber technology, as well as how STEM fundamentals are enhanced by integrating with liberal arts.

## **Introduction**

Cyberspace technology has become an integral part of our world, uniting individuals across international boundaries and offering them an unprecedented level of interaction. Personal, business, academic, and military applications across cyberspace have become intertwined. But there has been a negative consequence to this phenomenon. Individuals with particular personal or political agendas have increasingly exploited vulnerabilities in these applications.

Law enforcement and military officials have become concerned about marked increases in cyber attacks and cyber-security. To this end, they have sought to develop systems and train personnel to protect the national cyberspace infrastructure. Policy makers have wrestled with the definition

of cyberspace which led to the Department of Defense's 2006 doctrine entitled *The National Military Strategy for Cyberspace Operations* [1] that defines 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." Under this broad but important definition, cyberspace extends far beyond the obvious computer and Internet applications to encompass such devices as cell phones, radios, and music and video players. The pervasiveness of cyberspace in everyday life means that citizens must be further educated in both the benefits and dangers of using cyberspace applications. In addition, scientists, educators, and policy makers must take the lead in raising awareness of this emerging area of national need. To this end, academia must strive to educate new scholars who understand not only the science, technology, engineering, and mathematics (STEM) necessary to push cyberspace research and development forward but also the political, social, historical, ethical, and legal aspects of this evolving discipline.

### **Foundation of the Project**

The Cyber Science Curriculum is based on the Cyber Discovery model first established by Louisiana Tech University and the Cyber Innovation Center in Summer 2008. Cyber Discovery culminates in an intensive week-long residential summer program that immerses high school teachers and students in the world of cyber. While STEM concepts such as engineering, computer science, and mathematics (cryptography) are emphasized, they are weaved together with carefully selected content from English, history, ethics, and political science. By integrating the humanities with STEM concepts, students are provided a context for the content being taught. The week-long camp provides the opportunity for teachers and students to 1) better understand the history of cyberspace, cryptography, and cyber security; 2) experience cyber applications and programs; 3) discuss social and ethical implications of cyber; 4) explore possible cyber career fields; and 5) gain an appreciation for the need to secure cyberspace. The dynamic interactive camp curriculum consists of hands-on labs, a cryptographic treasure hunt, writing assignments, evening film sessions, and a Final Cyber Challenge. The Parallax Boe-Bot™ is used as the core teaching platform throughout.

In the months preceding the camp, high school teachers, one science/mathematics teacher and one humanities teacher from each school, attend two professional development workshops. Faculty from Louisiana Tech University's College of Engineering and Science and the College of Liberal Arts conduct the workshops in a team effort. Once high school teachers embrace the STEM concepts and feel confident in articulating them to the students, the university faculty members demonstrate how the camp projects will be used to reinforce the STEM concepts for the students.

Through Cyber Discovery, the high school teachers receive hands-on training in order to guide their students through small group and full group activities from 8:00 a.m. to 11:00 p.m. each weekday. These activities prepare the teams for the Final Cyber Challenge held on Saturday morning. A typical day is divided into various topics, and incorporates various means of group interaction. Sessions may involve all participants, school groups, or mixed small groups where individuals are randomly assigned to help create diverse new interactions. Below is a sample of a typical day of Cyber Discovery.

8:00-9:00	Breakfast
9:00-9:30	Movie Discussions (Mixed Small Groups)
9:30-11:00	Hands-On Lab (Full Group) <i>Topic: Engineering Activity</i>
11:00-11:15	Break
11:15-12:00	Cyber Policy and Ethics (Full Group) <i>Example Themes:</i> <i>Security vs. Civil Liberties</i> <i>Behavior Modifications</i> <i>State-Sponsored Threats</i> <i>Non-State Threats</i>
12:00-1:00	Lunch
1:00-1:45	Cyber Policy & Ethics Case Study (School Groups)
1:45-2:00	Break
2:00-3:00	Hands-On Lab (Full Group) <i>Example Topics:</i> <i>Cryptography</i> <i>Manipulation</i> <i>Exploitation</i>
3:30-5:30	Team Time (School Groups)
5:30-6:30	Dinner
7:00-9:00	Move Time (Full Group) <i>Themes related to Cyberspace</i>
9:30-11:00	Team Time in rooms (School Groups)

Cyber Discovery began in Summer 2008 with a total of 10 teachers and 30 students from 5 high schools. In 2009, it was expanded to 16 teachers and 48 students from 8 schools and grew to 20 teachers and 60 students from 10 schools in each of 2010 and 2011. The strong reputation of Cyber Discovery not only attracts more applications from schools than spots available, but some high schools have up to 100 students vying for the 6 spots allotted to each school.

Five years have passed since the pilot of Cyber Discovery in 2008 and the impact of the program on the students is becoming more and more evident. One assistant principal stated, "*Cyber Discovery changed our school; it became 'cool' to be an academically minded student. The Cyber Discovery students became the leaders of their 10th grade class and now the school.*" The students who attended the pilot program in 2008 have now graduated from their respective high schools and enrolled in universities. Three students from the pilot program reported changes in their college plans as a direct result of their Cyber Discovery experience. One male student who was originally focused on liberal arts decided to supplement his education by pursuing a dual degree in Computer Information Sciences and Business, while one female student changed her major from pre-med to biomedical engineering. Another male student decided to major in

mechanical engineering and then pursue a masters in electrical engineering after exploring engineering concepts through the Cyber Discovery program.

The impact on the teachers who have participated in the Cyber Discovery model over the last few years is equally as significant. Those teachers have become the leaders of their schools for developing new curricula in cyberspace. Several have integrated science into English courses, while others have developed STEM-specific courses that integrate with social studies or history [3]. Many of these teachers have sought out additional professional development opportunities through Louisiana Tech University and the Cyber Innovation Center, and have requested more innovative programs in which they can participate with their students.

## **Cyber Science**

After three successful years of Cyber Discovery, Louisiana Tech University and the Cyber Innovation Center recognized the need for a foundational course in Cyber Science. Curricula was designed, developed and implemented using key aspects of we now call our NASA-Threads model. In 2009, Louisiana Tech University was awarded the NASA-Threads grant to develop an advanced high school physics curriculum that weaves together physics fundamentals, hands-on activities, technology, NASA applications, and communication in an active delivery format that is both fun and challenging for students. Project-based learning components of Cyber Science were developed and delivered following the model developed through Tech's STEM Talent Expansion Program and Cyber K-12. Through the synergistic successes of TechSTEP, Cyber K-12, and NASA-Threads, a framework emerged for achieving meaningful professional development in STEM, while at the same time providing a rich experience for students who, in turn, enter STEM majors in the future.

These programs stimulated interest in STEM/Cyber topics at the high school level by partnering area high school math, science and liberal arts teachers with college faculty through Discovery Weekends and week-long professional development for teachers with their students. Seeing the week-long curriculum offered through Cyber Discovery as a key component to the professional development for those who will teach the high school course, an academic year master plan was developed and a first draft for a curriculum was created. Cyber Science was the logical outgrowth of our efforts.

Cyber Science is a project-based course that builds on our NASA-Threads model where a specific technology platform is chosen (rather than a textbook) to form a "core" for the entire curriculum. Students engage in projects that incorporate robotics, cyber-technology, computer literacy, information literacy, social policy, and ethical issues as well as team-building strategies throughout. In its current layout, students participate in an engaging final project at the end of the semester that allows them to incorporate all of the skills they have gained through the entire course.

The Cyber Science course differed from NASA-Threads in that Cyber Science was a design of a completely new course without any reference to textbooks or GLEs. Thus, the design team used the Cyber Discovery curriculum as a reference, as well as brainstormed what they felt should be the fundamental concepts taught in a semester-long course. The design team looked at the three

main components of the course: robotics, computer science, and political science. They brainstormed ideas for fundamental concepts in each of those areas. Numerous ideas were developed during this phase including robotics competitions and projects, computer science fundamentals, political science concepts that relate to cyber issues, as well as methods to incorporate computer skills into the topics.

Several content threads are used to showcase information and communications technologies in this hands-on environment. We know that project-based learning modules offer faculty a way to engage students in cyber-technologies while instilling a fundamental understanding of STEM principles. In addition, key content strands nurture the development of 21st Century Skills – problem solving, critical thinking, creativity, communication, and innovation. We have developed the following project-based content strands:

- Cyber Security - provides students with a basic understanding of computer hardware, software, networks, and encryption.
- Digital Forensics - provides students with a basic understanding of computer hardware, data storage and collection, networks intrusion, and data degradation.
- Cryptography – provides students with a basic understanding within a historical reference of how mathematics is used for encryption and decryption in cipher systems.
- Artificial Intelligence – provides students with a context for understanding the issues of human and machine interaction and learning.
- Threat Assessment – provides students with basic understanding of recognizing and dealing with cyber threats within a political, social, and ethical framework.

Cyber-security and digital forensics are key content threads in the Cyber Science course. These components are designed in a manner that allows for the integration of topics in a way not currently achieved in high school curricula. The Cyber Science course incorporates 21st Century Skills to ensure students develop problem solving, critical thinking, creativity, innovation and analytical thinking skills. This course is offered either as an elective or a computer science requirement to high school students.

## **Curriculum**

Cyber Science integrates fundamental science and mathematics content with liberal arts and appropriate use of technology into a curriculum targeting the sophomore/junior year of high school. These content areas are continually linked together by the use of hands-on projects throughout the physics curricula. The fundamentals, which are grouped into blocks of similar topics, provide the backbone of the educational experience. The class is divided into various topics, and incorporates various means of group interaction. Some classes involve the entire class of students, some are with mixed small groups where individuals are randomly assigned to help create diverse new interactions, and some assignments are individual.

The integration of topics across the disciplines was achieved by carefully selecting the right liberal arts content, essay assignments, and case studies to coincide with the computer science, engineering, and mathematics content being discussed. Below are summaries of the major areas.

**Robotics/Engineering:** The use of a robotic platform serves as a way to introduce basic concepts of programming, logic, and controls. In addition, the use of a hands-on robotic activity provided an excellent “hook” that was used to show concepts of cyber vulnerability within the context of code security, wireless signal transmission, as well as programming. The robotic platform also serves as a mechanism for teaching problem solving. By using a hands-on platform throughout the curriculum, students are able to work with “real” problems. This project-based approach allows the students to gain an intuition about how to solve problems, and helps them understand the fundamental mathematical and science topics.

**Cyber Policy and Ethics:** Students are 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.

**Computer Science/Cryptography:** After presenting a historical perspective on the use and development of cryptography, hands-on / minds-on sessions were held each day. Rather than focus on the technical college-level details of cryptography, the emphasis was 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 modeled 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. These classes not only expose students to cryptographic and code-breaking techniques, but also the mathematics and logic behind the techniques employed. Showcasing the mathematics behind modern cryptographic systems allows students and teachers to see that we are only as safe in our online world as the state of knowledge in solving sophisticated mathematical problems.

Cyber Science creates an educational experience where exciting hands-on projects drive students to learn more and to develop confidence in their abilities. At the same time the authors have recognized and taken great care to be sure that the course materials should not be intimidating or require excessive preparation time for teachers who employ the materials.

The first week of the course is a good introduction to the material that will be covered throughout the curriculum. The robotics lesson, introduces the students to the BOE-Bot platform, basic programming skills, and terminology. The computer science lesson the next day, introduces the students to flow charts and control flow. Learning this topic will help the students in all their programming components as well as help them to obtain a good basis for the computer science topics. Following the computer



science component, the political science lesson takes a philosophical approach to the course and challenges the students to reflect on what the word cyberspace really means. The instructor prompts the students to create a list of cyber related words. Students are then tasked to pick one of the words, research it using credible sources, and then present their results using MS Word. To complete the assignment, on Thursday, students are introduced to MS Word where they learn basic MS Word tools as well as the different formatting capabilities of the program. Students are encouraged to present their material in a creative manner. Friday is then used as a project day for the robotics component of the course. Students learn about the servos and get the opportunity to program the BOE-Bot to navigate around an object.

Many of the weeks are formatted in a similar way with the relation of various components from lessons to subsequent lessons throughout the week. Some robotics projects the students do in the course are maze navigation, control the BOE-Bot using keyboard input, navigation of a course using light detection, a “mine” finder, and others. Some computer science topics discussed in the curriculum are binary numbers, understanding algorithms, recursion, sorting, networks, in addition to many others. Some political science topics are security, pros and cons to cyberspace, digital natives versus digital immigrants, and ethics.

While careful planning ensures that this curriculum is not intimidating to teachers, it is important that the curriculum be rigorous and challenging. Additionally, the authors recognize that it must be appropriate for and within the grasp of high school students and must meet local and state education standards. Collaborative partnerships developed with area high schools ensure that all of these conditions are met.

## Curriculum Samples

The image is a screenshot of the NICERC (National Integrated Cyber Education Research Center) website. The header features the NICERC logo, which includes a stylized head with a brain and a gear, and the text "NICERC National Integrated Cyber Education Research Center". Below the logo is a navigation menu with links for "About", "Camps", "Events", "Curricula", "News", and "Contact". There are also social media icons for Facebook, Twitter, RSS, and YouTube. The main content area is titled "Cyber Science" and includes a brief description of the program: "Cyber Science is an innovative, project-driven course that integrates science, technology, engineering, and mathematics (STEM) disciplines with liberal arts. Cyber Science uses a robotics platform to teach important cyber concepts and fundamentals. Throughout the course, students are engaged in a systematic approach to problem-solving using robotics and computer science in the context of the humanities. Seamlessly integrating the different disciplines provides students with a dynamic learning environment and a unique educational experience. Through Cyber Science, students are not only able to make meaningful connections between STEM and liberal arts, they also learn how to become better cyber-citizens." Below this description is a "TEACHERS" button and two images: one showing a person working with a robot and another showing hands working with a computer. At the bottom, there is a section titled "Cyber Science Sample Lessons:" with a list of links: "Sample Cyber Science Lesson Proboscitars", "Sample Cyber Science Lesson Heuristics", "Sample Cyber Science Lesson Liberal Arts", and "Sample Cyber Science Lesson Line Following".

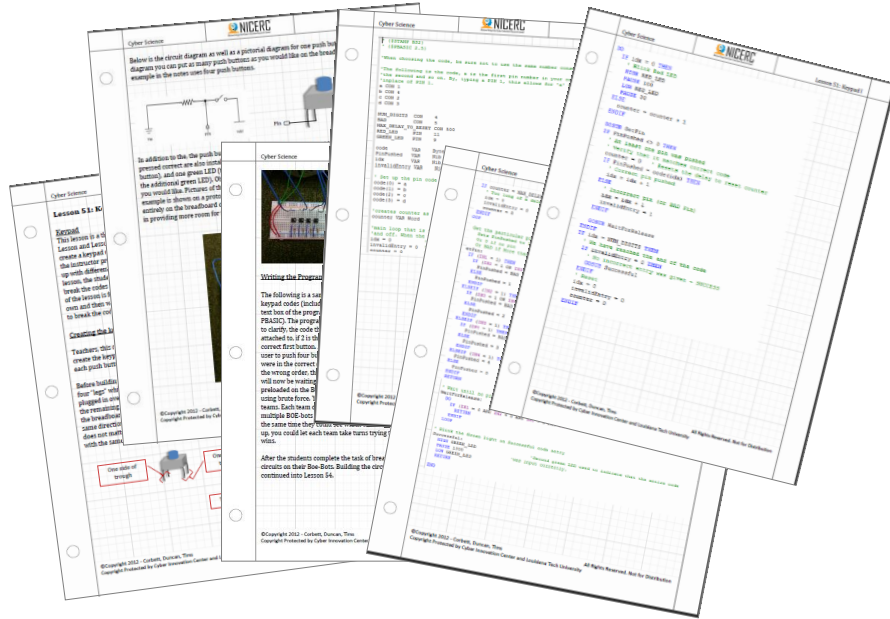
An online curriculum ([www.nicerc.org](http://www.nicerc.org)) complete with fundamentals, detailed project descriptions, and course assignments are provided freely via the Internet for those that have completed professional development. The online content eliminates the requirement of a textbook, reducing overall curriculum cost to the materials and supplies for the projects. In addition, teachers and students have access to high quality media that helps both students and teachers visualize difficult or abstract concepts.

From the online curriculum, each day’s lesson plan, master notes, and supplemental materials are easily accessed by the teachers. The curriculum is interlaced with many innovative projects throughout each unit. Cyber Science is centered around cyber related themes using three interdisciplinary threads – Engineering, Computer Science, and Liberal Arts. Typically, Monday and Fridays are Engineering, Tuesdays are Computer Science, and Wednesdays are Liberal Arts with Thursday being a day to work on assigned projects from the week. This course is designed

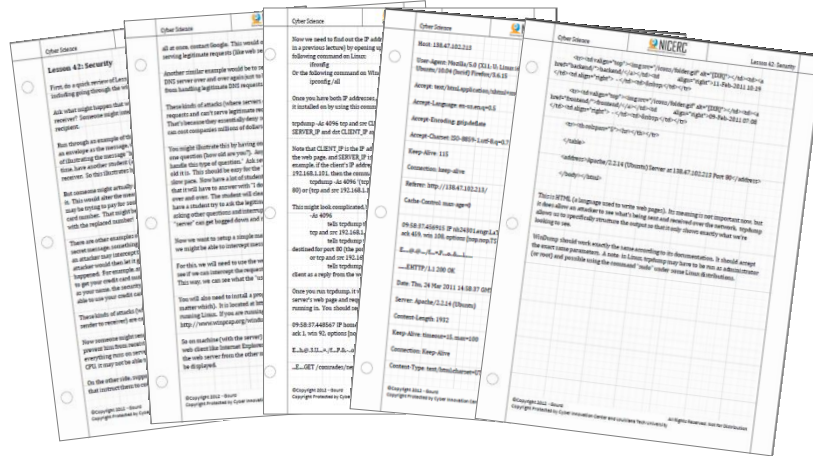


to be interdisciplinary with a true integration of the threads where subsequent lessons build upon previous concepts. The sample week here shows how this integration is achieved. This sample week is found towards the middle of the course.

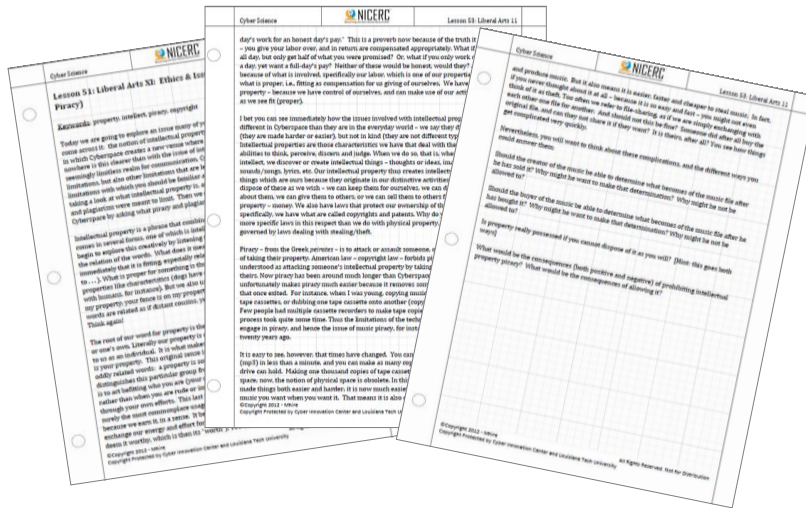
### Engineering Thread for Cyber Science



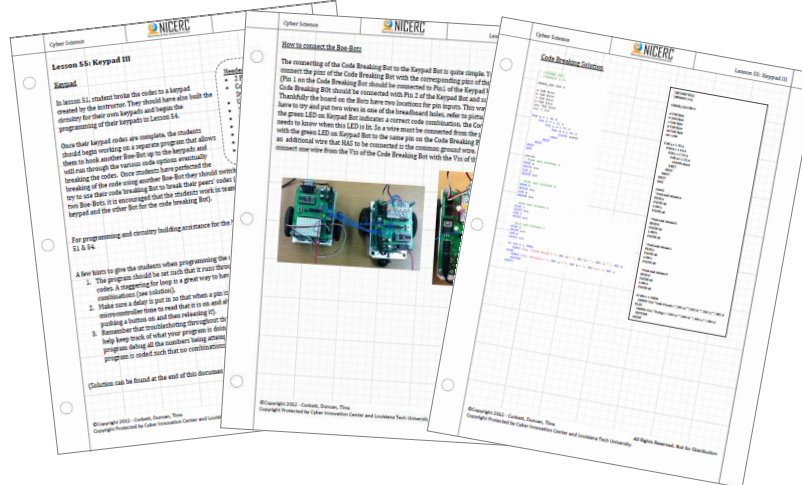
### Computer Science Thread for Cyber Science



## Liberal Arts Thread for Cyber Science



## Project Thread for Cyber Science



Highlighted here, in this sample week's lessons, is the cyber theme of security. This sample week illustrates the congruency of all the weeks in the curriculum where the lessons use the theme of security throughout the threads. In the keypad lesson (engineering thread), students are given a keypad built on their Boe-Bot breadboard using tact switches. The student must brute force attack the keypad to break the code. In the computer security lesson (Computer Science thread), student refer back to a previous lesson on computer networking. This time though, they look at security holes in the network. They are presented with questions like, "What might affect a sender's message? What if someone changes the message before the intended receiver gets the message?" This leads the students to the computer science topic of man in the middle attacks. Then, the students are challenged with the thinking about the idea of intellectual property and ethics (Liber Arts thread). They are tasked with writing a paper on the concept of piracy and ethics of owning non-physical property. At the end of the week, students are tasked with a keypad project (Project Thread) that builds on the concept of security. Students write a Boe-Bot program that will run through the possible combinations of the keypad code. Now, instead of them brute force attacking the keypad manually, they create a program that will solve the keypad code within seconds rather than minutes.

## Survey Results

One aim of the Cyber Science course 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 participated in the program gained a deeper appreciation for the mathematics/science or humanities they teach and a greater awareness of the broader contexts of what they teach. The purpose of the workshops is for the university faculty to introduce the high school teachers to fundamental topics of the curricula. The Cyber Discovery model goes beyond project-based curricula that simply instructs teachers on how to deliver a project. Rather, the model utilizes project-driven curricula that empowers teachers with the fundamentals to teach STEM and encourages the use of projects to drive the fundamentals home. These lessons and the other skills developed through the program can later be applied in the classroom. High School teachers are encouraged to provide feedback throughout this process, as they know their students' capabilities and interests best.

Additionally, workshops serve as an opportunity for the university faculty and the high school teachers to collaborate and to develop a mentoring relationship. The mutual respect and spirit of collaboration at the root of the mentoring relationship serve both the university faculty and the high school teachers well as they engage the student teams in the camp curricula and challenges. These mentoring relationships continue after the camp ends and are mutually beneficial. High school teachers seek out their university mentors on incorporating innovative lessons into the existing high school curricula and university faculty develop a better understanding of the level preparedness of the high school students.

A sample of responses from participating schools is shown below. Schools responding had teachers from both the STEM fields and the humanities that attended the summer workshop.

I am comfortable with the projects presented in the given sections of the course.

#	Question	Very Uncomfortable	Uncomfortable	Neutral	Comfortable	Very Comfortable	Mean
1	Robotics	0	0	3	2	2	3.86
2	Computer Science	0	1	1	3	2	3.86
3	Liberal Arts	0	1	1	4	1	3.71

I see how the projects allow me to drive students to learn the fundamental content of the course.

#	Answer		%
1	Strongly Disagree		0%
2	Disagree		0%
3	Neither Agree nor Disagree		14%
4	Agree		71%
5	Strongly Agree		14%
	Total		100%

On a scale of 1 to 10, indicate the level to which you would like to see the following projects/topics covered in more depth during a teacher workshop.

#	Answer	Average Value	Standard Deviation
1	Boe-Bot Programming	7.00	1.87
2	Binary Counter	6.50	1.29
3	Keypad	4.20	2.05
4	Boe-Bot Cryptography	6.00	2.55
5	Hall Effect Sensors	6.60	1.52
6	Man in the Middle Attacks	6.00	2.19
7	Steganography	6.00	1.00
8	Digital Forensics	7.80	1.92
9	Liberal Arts Discussions	7.25	1.71
10	Debates	6.25	2.50

The average values for this question indicate similar trends to teacher's comments. The teacher comments showed that they were confident in what was covered in the workshop.

### Observations

Because the sample size is small, it is difficult to determine concrete results from survey data. However, qualitative results of teacher comments provide insight into the effectiveness of the workshop, and help to refine future workshops.

Sample teacher comments:

*"Loving it!!! Absolutely loving it. This is the most fun I've had in a classroom in some years. Thanks for the great training efforts this summer."*

*"If we didn't have these workshops I wouldn't be able to do it. ... I mean I have a degree in chemistry with a minor in physics, and I wasn't taught this way, so I've had to learn how to learn this way and then how to teach this way."*

*"The fact that the workshop makes you work through the projects the same way as the kids you experience the same frustrations that they will experience in the classroom is great knowledge."*

## **Conclusion**

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 an event that would serve 100-200 students, 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.

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