Invited Professional Paper

NICERC's Cyber Interstate ™: The Next Generation of Cyber Worker can be Found at the Intersection of Classroom Content and Teacher Support

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Abstract - Since 2012, the National Integrated Cyber Education Research Center has existed with the express goal of supporting local workforce development in the areas of STEM, cyber, and computer science. In that time, a variety of subject matter experts have contributed to writing content that is now in use by more than 8,000 teachers across the country. In addition to providing that content to United States public school teachers at no cost, the organization and subject matter experts also provide free professional development to ensure that teachers are as prepared as possible when they present this content in their classrooms. Lastly, the organization also provides opportunities for extracurricular engagement by students outside of the traditional classroom model. Content for events such as robotics competitions, science fairs, and maker spaces are also provided by the organization. This paper will investigate a variety of research studies that support the organization's mission as well as particular studies that identify the organization's offerings as a critical need to education in the 21st century.

Keywords

education, STEM, robotics, cyber, computer science, middle school, high school, professional development

1 INTRODUCTION

In order to build a sustainable, knowledge-based, cyber-skilled workforce that can support the needs of government, industry, and academia, the National Integrated Cyber Education Research Center (NICERC) has developed a robust academic outreach and workforce development program. NICERC and the educational programs it distributes benefit K-12 teachers by providing dynamic, cyber-based curricular resources for the classroom as well as extensive professional development opportunities for educators. These resources benefit students by allowing them to interact with a variety of innovative, project-driven learning environments that increase student engagement and content retention. As a result of this program, the community and the nation benefit from a new cyber and STEM (science, technology, engineering, and mathematics) literate workforce that will ensure America's competitiveness and strengthened national security.

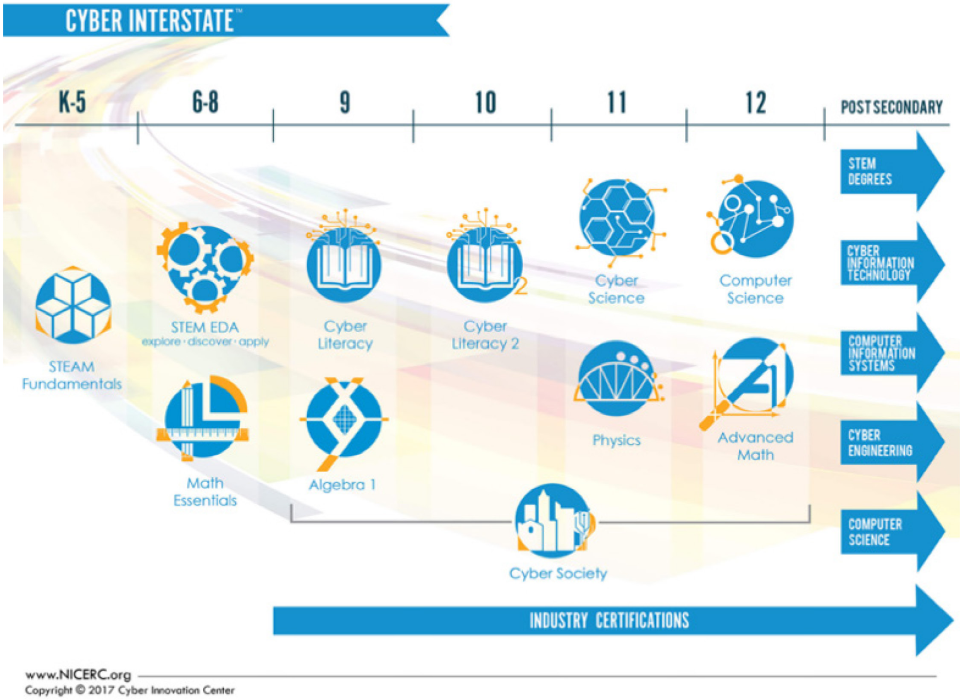

Figure 1: The NICERC Cyber Interstate.

The Cyber Interstate ™ (NICERC, 2016a) outlines NICERC's extensive library of curricula that provides opportunities for students to gain an understanding of cyber issues, engage in cyber education, and provide a foundation for entering cyber-based degree programs and career fields. Cyber Interstate curricula supplies schools with a variety of rigorous programs that showcase a systems-level understanding of real-world applications of STEM and cyber and builds the foundation for an expansion of cybersecurity knowledge. These project-driven, application-based courses engage students in primary, secondary, and post-secondary grade levels.

NICERC's current network of teachers that are accessing Cyber Interstate content is both extensive and expansive. Over the last 4 years, NICERC's innovative, project-driven curricula, content, and resources have been made accessible to more than 8,000 teachers in all 50 states and two U.S. territories. More than twenty state departments of education have enlisted help from NICERC to create or implement curriculum frameworks, course standards, and/or graduation career pathways. Also, in that time, NICERC's impact has reached nearly 2 million students, many of whom have gone on to study cyber engineering or related content in college, obtained workplace-ready credentials and certifications, or have even transferred directly into the workplace from high school.

Also included in NICERC's mission is the continued support of all classroom teachers. NICERC's professional development opportunities span across various cities and states, nationwide. At professional development workshops, teachers gain hands-on experience with projects and technology that provide new, innovative ways to engage students in the classroom. These workshops deliver a hands-on, context-based approach to math and science content while incorporating components from the humanities and liberal arts, which allows those teachers to embed the curricula across multiple disciplines and empowers them to prepare students to become the next generation of cyber engineers and STEM professionals. The professional development offered through NICERC delivers a collaborative and comprehensive solution that fosters systemic and sustainable change in the educational environment, thus enhancing the expansion of knowledge among students. NICERC utilizes master teachers, university faculty, and doctoral-degreed educators from regions across the country to support the sustainable and scalable distribution of curricula and professional development. Through NICERC's teacher professional development model, more students are ultimately impacted (over a greater period of time) than would any program aimed at students alone (GB Cazes, personal communication, September 2, 2016).

2 REVIEW OF THE LITERATURE

The research contained in this paper will present many of the studies that have been performed across two specific areas: the impact of STEM and cyber content and classroom technology. Media outlets are writing about the costs incurred by districts as they implement all sort of new courses and technology. Costs include the increase in teacher workloads, the decline in student performance, or the potential misuse or even non-use of district and school-purchased technology. Once the current and recent studies have been examined in this section, the paper will seek to understand some of the obstacles to successful implementation of content and supply recommendations that will help districts and schools make better use of human and financial capital.

2.1 Problem-based or project-based learning?

A variety of studies have been performed over the last decade on the pros and cons of problem-based learning (PBL; Kostaris, Sergis, Sampson, Giannakos, & Pelliccione, 2017; Mishra & the Deep-Play, 2012; Navarrete, 2015; Niemel & Helevirta, 2017; Wirkala & Kuhn, 2011). Throughout the reporting on the topic, one thread that appears time and time again is that problem-based learning is beneficial to student engagement and retention. Wirkala and Kuhn define problem-based learning as “a teaching and learning method in which students engage a problem without preparatory study and with knowledge insufficient to solve the problem, requiring that they extend existing knowledge and understanding and apply this enhanced understanding to generating a solution” (2011, p. 1157). Navarrete defines it as an “authenticity of experience” (2015, p. 5) that helps students make connections and provides satisfaction in the work that they do in the classroom.

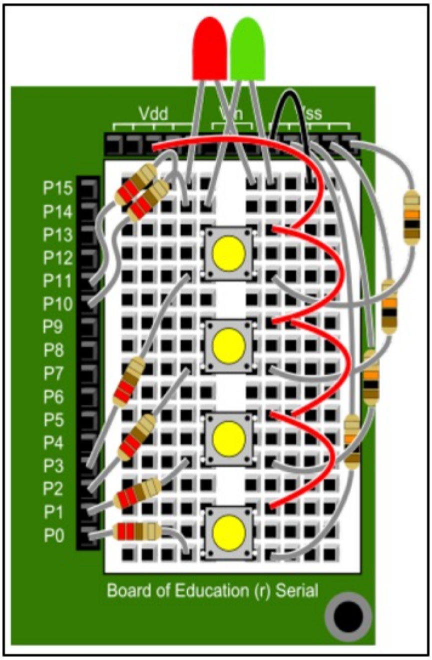

Figure 2: Parallax BOE-Bot ™ breadboard with sample Bank Vault circuit.

On the other hand, NICERC refers to their content as a project-based curriculum because they propose the implementation of projects to deliver a variety of problem-based scenarios to students at one time. One example of project-based learning within NICERC's content occurs in the *Cyber Literacy* 2 curriculum content titled, "Bank Vault BOE-Bot" (NICERC, 2016c). Within this title, students are given the project of designing a four-button bank vault using their BASIC programmed Parallax BOE-Bot ™. In addition to students building their own pushbutton and LED circuits, the bank vault project includes the discussion of the security inherent in a PIN pad-style system as well as how to design an algorithm that verifies whether or not the code entered matches the code stored. The project presentation includes students testing the systems created by their peers as well as reflecting on their own designs and how they bridged the gap between the human-computer interaction so that the bot can properly interpret a variety of human styles of input. The teacher typically concludes the lab by having students attempt to break in to the bots of their peers in order to trigger additional conversations on security and brute force decryption versus the benefits of designing a piece of code to break in to the vault for us. The intent is not to instruct students in the creation of vault-hacking bots but to highlight the conversation on security and how to improve the vault design through iteration.

2.2 Soft Skill Development

Many recruiting and job sites are caught up in the current buzz around employees lacking a credible set of soft skills (Brathwaite, 2017; Doyle, 2017; Lesonsky, 2017; Ward, 2017). No matter what the industry, the ability to work well with others, think critically, organize your space and your thoughts, and even communicate well are paramount skill sets that employers need. Lesonsky goes so far as to observe that it's seemingly "easier to remedy a lack of hard skills than a lack of soft ones" (2017, para. 6), presumably because hard skill knowledge can be taught quickly but skills like teamwork, organization, and communication take time to perfect.

Included as part of NICERC's list of curricula overview bullets is the fact that soft skill development is integrated directly into the lesson content. Again, reflecting on the "Bank Vault BOE-Bot" (NICERC, 2016c) module, students working with the content will typically work in pairs as they make their way through what NICERC refers to as their Programming Design Process (Claire Floyd, personal communication, June 21, 2017). Throughout the lesson content, they will identify a variety of student roles. They will need to discuss and agree on a circuit solution to build, and they will prepare a programming solution to supplement the circuit. In related liberal arts content, they will be charged with dissecting a variety of interpretations of the 4th Amendment to the U.S. Constitution, or weigh the benefits of artificial intelligence in the home. Additionally, even throughout NICERC's middle school STEM EDA (science, technology, engineering, and mathematics: explore, discover, and apply) content, students may be working in small groups of three to six as they create and discuss the physics of flight as they build gliders for a VFW parade or compare and contrast series and parallel circuits as they build flashlights to combat a cyber-attack on the local power grid. These group tasks will allow students to practice any number of soft skills across multiple grade levels.

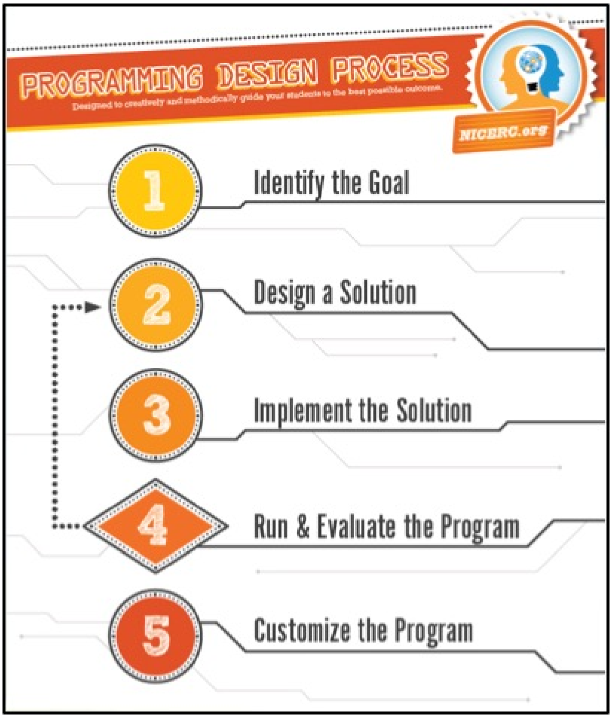

Figure 3: The NICERC Programming Design Process.

2.3 Technology in the Classroom

"Today's teachers are faced with the challenge of educating digital natives, the technologically connected students of the 21st century" (Gardner, 2013, p. 4). In order to do so, many schools and districts have invested heavily in classroom technology to support the teachers' supposed ability to connect with these digital natives. In many cases though the goal of the investment falls short. Either teachers do not receive adequate preparation to use the technology, they lack the time to prepare to incorporate the technology into their classrooms and content, or the technology purchase just does not line up with the school's or student's specific needs (Carver, 2016; Clatworthy, 2014; Dickey, 2011; Hew & Brush, 2007; Katehi, Pearson, & Feder, (Eds.), 2009; Kostaris et al., 2017; Mishra, 2012; Navarrete, 2105; Niemel & Helevirta, 2017; Wirkala & Kuhn, 2011). In fact, Hew and Brush (2007) found that a school's decision to support teachers with technical support staff often results in less productive teachers as the teachers then come to rely on the support personnel to answer simple questions rather than gaining the self-confidence to solve even simple problems themselves. Carver (2016) eludes to research he found that indicates how students are scoring "higher than the teachers on all areas of accessing, managing, integrating, evaluating, and creating information" (p. 111), when it came to specific technology skill levels.

The Cyber Interstate, NICERC's online repository of content and curricula for classrooms, includes not only print materials in digital form, but also an extensive supply of presentations, video clips, spreadsheets, and resources that teachers can use in their classroom. Additionally, the teacher materials frequently include references to technological resources that can help teachers deliver content and provide necessary hands-on connections for students to experience within the content. Finally, NICERC's professional development model treats teachers to a students' point of view that helps teachers visualize how to use both the content and the technology in their own classrooms. This unique approach to professional development has been often cited by teachers as the most significant aspect of the NICERC program (NICERC, 2016b); seeing the content in use by NICERC's subject matter experts (SME) often tips the scales for teachers who may have been hesitant to try teaching from new content.

When teachers combine NICERC's model of professional development with the plethora of available plugged and unplugged activities, they often find an ample supply of resources and support needed to implement 21st century ideas and content into their classrooms. For example, the team of SMEs that deliver professional development for NICERC events always includes current or former teachers who have used NICERC content in their own classrooms. The act of NICERC personnel establishing a personal rapport with teachers new to the content allows the new teachers to begin to build and expand their network of support that will exist outside of their own school or district and will last for years to come. Additionally, the contact with the SMEs in many cases does not stop at the conclusion of the professional development. All SMEs are encouraged to engage with their workshop guests long after the end of the sessions. As a result, many teacher-SME relationships continue for months or years after the first encounter, often times leading to productive communication and exchange of ideas. In some cases, as the teacher communicates with the SME and reveals implementation ideas for the content that may not have been considered by NICERC, the teacher is always encouraged to contribute their ideas back into NICERC's library of content where they can see their ideas published alongside the material that thousands of other teachers across the country use on a daily basis.

This idea of a two-way sharing of ideas and resources is a cornerstone of the NICERC model that was made popular by a grant from the Department of Homeland Security (DHS) which decreed that all NICERC content that was to be created and supported by the grant would remain free to public school teachers in the United States, in perpetuity. Since NICERC was created as a non-profit institution, and as soon as they fell under the financial support of the DHS grant, they were restricted from selling the content for profit. As such, in order to keep the content up to date and fresh, it was decided early on that teacher support and input would be a critical component of the model.

3 RECOMMENDATIONS

Among the many studies that have been conducted on engaging students in today's variety of 21st century classrooms (Carver, 2016; Clatworthy, 2014; Dickey, 2011; English, 2016; Hew & Brush, 2007; Katehi et al., 2009; Kostaris et al., 2017; Mishra, 2012; Navarrete, 2015; Niemel & Helevirta, 2017; Wirkala & Kuhn, 2011), many themes remain consistent. The common thread appears that, quite plainly, teachers need adequate levels of support in order to be effective in the classroom. One underlying theme in that thread is that teachers need support to become confident in the content that they will be presenting. Another theme is that teachers need support in the form of useful and effective professional development training. Finally, a third theme is that teachers need support in the form of adequate technology to implement the content.

The research contained earlier in this paper focused mainly on cyber content implementation, teacher professional development, and classroom use of technology. The material that will be referenced in this section will include recommendations that can be used to address many of the issues uncovered by the research. Each underlying theme from the research identified above will be discussed in detail.

3.1 Confidence in the Content

In Clatworthy's 2014 essay on the future of public education, he writes about the fact that education "was not specifically assigned to the federal government by the U.S. Constitution" (p. 3), and that it was a duty left for the states to handle. In fact, it was only in 1779 that Thomas Jefferson introduced a bill to formally organize an educational system in Virginia (Gardner, 2013). Since then, the education system in the United States has not changed all that much. Other than class sizes and the technologies that are available in the classroom, students are still expected to be able to read and write, gain competency in mathematics and science, and develop social skills that will help them become productive members of our society.

In the last ten years though, educators have begun to introduce significant changes within the classroom. With the arrival of education-based interactive digital components, technologies such as electronic whiteboards, portable digital tablets, and even virtual world environments have been gaining more and more support as classroom teaching aids (Dickey, 2011; Gardner, 2013; Niemel & Helevirta, 2017). Administrators and teachers must ask though, if the end goal of the educational institution is to produce productive members of society, what good is the technology described above if the end result is not being achieved?

First and foremost, teachers must have access to rigorous and relevant content that will have a positive impact on their students. Learners must not become apathetic to the material lest we risk them disconnecting from school as a whole and worse yet, drop out before graduating. But rigorous and relevant content is not enough. The content must also be approachable for the teacher so that they can develop the confidence to implement it in their own classroom. The teacher must be able to show confidence in the material and also show that the material has value and meaning for the student. Only then will the student realize the relevance that the content has to their own future. Only then will truly meaningful connections be made!

Confidence in the content also refers to an appreciation from the student perspective. Once a student is able to feel confident in a subject or topic, that student will be more willing to contribute to the classroom environment, possibly even becoming a voice for others who may not be as confident to speak up if they are struggling. Kostaris et al. (2017) supports this belief that student-centered reflection and support often results in a performance increase of all students, but mostly with low performing students. In fact, in a flipped classroom model where students are responsible for not only pre-learning but reflection and interaction during a project, low performing students "showed an overall increase of 30.1% in their engagement level" (2017, p. 269) when these reflection and interaction periods were led by their peers.

NICERC content regularly engages students with periods of peer-led interaction and reflection. Teachers familiar with the content often remark on the ability of the content to engage all students, including those whom teachers may have reported as being previously disconnected from learning. English (2016) reports that if we "want students who can think critically, solve problems, and communicate their thoughts clearly" (p. 6), then we must get them working together and solving problems collectively.

What's needed to make these connections is material that is approachable for both teachers and students. NICERC is able to do this through the Cyber Interstate content, not because it is easy or not challenging, but because it is relevant with an appropriate level of rigor. All of the content was written by veteran educators from a mix of both K-12 and university. This blend of authoring helps to ensure these features.

3.2 Access to Adequate Technology

This paper has addressed two threads with regards to integrating academic activities: content and professional development. This section will discuss the final thread: classroom technology. While some classroom subjects can be presented without the tools of a 21st century environment, those numbers are fewer and fewer. For example, in order to teach the rudimentary skills of algebra, a classroom does not need a 1:1 ratio of computers to students. In order to present the classical works of literature, students do not need to hop on the internet every day to learn about the newest research being performed on the subject. Will technological devices help in these circumstances? Certainly, but they are not a necessity. What this section will discuss is the benefit of 21st century tools in the instruction of cyber and STEM content for high school students.

Much has been said already about Carver's (2016) studies on teachers' use of technology in the classroom. In those cases, teachers often felt a reluctance to use technology in the classroom if they felt that their students were outpacing their knowledge in the use of that technology. Hew and Brush (2007) continue along that same path by reporting that teachers felt a distinct lack of time to adequately prepare for the use of new technology in the classroom. In Mishra's (2012) work, we find the sage advice that technology should not dictate instruction. Technology can help supplement content provided it is a useful and reasonable interactive medium. Niemel and Helevirta (2017) lament the fact that while more schools are connecting up-to-date devices and high-speed connections, businesses that reside near these developed areas are still showing indications of a lack of adequately trained talent.

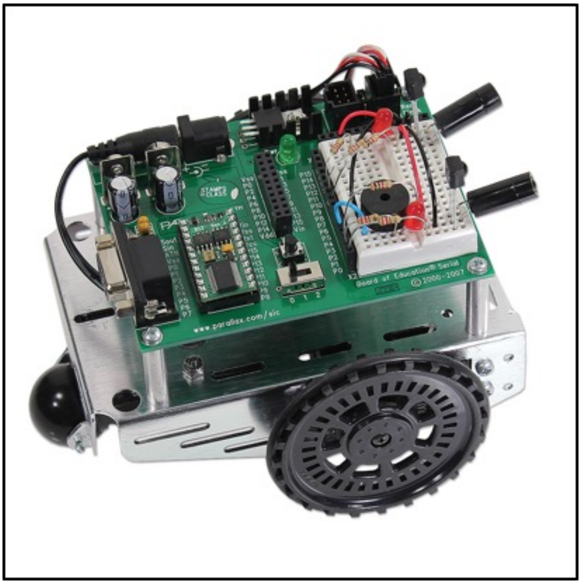

Figure 4: The Parallax BOE-Bot ™ robot.

While much of NICERC's content requires investments in technology, care has been taken to ensure that the investments are reasonable and justifiable. For example, within NICERC's *Cyber Literacy* content, students must have access to a web-enabled laptop and a programmable robotic platform. This platform, the Parallax BOE-Bot ™, is a reasonably priced device (currently less than $200, Parallax, 2017) that works best when paired with two students. It is programmed using the BASIC programming language and requires nothing more than a web-enabled laptop or desktop computer. Additionally, the bot has a small breadboard on its top surface, allowing users to build circuits that can then interact with both the programs they write to the microcontroller as well as the environment the bot is working in. While teachers may justifiably balk at having to learn the BOE-Bot on their own, by attending a professional development workshop hosted by NICERC, teachers can spend as little as two or three hours with the bot and leave comfortable in the knowledge that they can create almost any program and build almost any circuit on the device, and subsequently present the content to students.

When considering NICERC's middle school content titled *STEM EDA*, the technology investment is not quite as intimidating as a BOE-Bot. Within *STEM EDA* content, teachers will find a series of modules, each tailored to a unique topic. For example, there are modules on such physical science standards as egg drop, aerospace, volcanoes, and catapults, but there are also modules that discuss a variety of cyber themes within coding, genetics, and electricity. All told, there are 12 modules that each appear in three grades, for a total of 36 middle school content modules. What is unique about the *STEM EDA* content is that while web-enabled computers are beneficial, they are not required for all content. What is required however, is a set of easy-to-source class supplies that will help teachers relate the content to students.

In the *Explore: Aerospace* module for example, teachers will need access to foam board, dowel sticks, cup hooks, rubber bands, masking tape, duct tape, straws, clay, poster board, and markers, so that students can make their own small-scale test gliders, full-scale model gliders, and VFW parade posters. Some research about gliders, WWII, and aeronautics can be performed online, but this is not a critical component of the lesson. What is important is for students to connect the learning with the real-world experience of flight. In order for teachers to be confident in their ability to present this content in the classroom, NICERC's professional development model again, flips the role of the teacher and welcomes them to the workshop in the role of a student. This model is infallible, as even the most inexperienced teacher can sit in on this type of session, see the lesson presented by master teachers as if it were their classroom, and reflect on the content and the pedagogy as it is being displayed. They immediately develop an understanding of how the supplies correlate to the lesson and how various components of technology will enhance the learning that is happening.

4 CONCLUSIONS

Today's learners are remarkable in their adaptation to and almost expectation of technology in their lives (Carver, 2016; Clatworthy, 2014; Dickey, 2011; Hew & Brush, 2007; Katehi et al., 2009; Mishra, 2012; Navarrete, 2015; Niemel & Helevirta, 2017). While cell phones, tablets, or laptops are ubiquitous within their lives, there is still much to be done to ensure that their teachers are as comfortable with those devices (Carver, 2016; Clatworthy, 2014; Dickey, 2011; Kostaris et al., 2017; Mishra, 2012; Niemel & Helevirta, 2017; Wirkala & Kuhn, 2011). The research within this paper has shown that it is not enough to simply invest in technology or curriculum, but that much more must be done to create a learning environment that is welcoming to students, comfortable for teachers, and conducive to learning.

Since 2012, NICERC has been creating and distributing relevant and rigorous classroom content for K-12 teachers in the United States. Not only is the content free, but when used in conjunction with NICERC's model of professional development, the content is easy for most teachers to implement. The NICERC professional development model engages teachers from a students' perspective, granting teachers a unique view of the content. This model allows many teachers to report that content that they may have previously had no experience in teaching becomes both approachable and somewhat comfortable within the first few months of classroom use (Kevin Nolten, personal communication, July 27, 2017). While NICERC does not profess to be the silver bullet that will transform education or create a STEM and cyber-capable workforce overnight, the ability of the content and professional development to begin a systemic transformation in education should not be dismissed. The ability to empower teachers with engaging content with minimal professional development disruptions throughout the school year will promote more productive educators who can once again return to focus on their classroom.

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