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Board 319: Integrating Computing Throughout K-12 While Bridging the Digital Divide

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Dr. Borowczak, currently an Associate Professor of Electrical and Computer Engineering at the University of Central Florida, has over two decades of academic and industry experience. He worked in the semiconductor, biomedical informatics, and storage/security sectors in early-stage and mature startups, medical/academic research centers, and large corporate entities before returning to the US public university system full-time in 2018. His current research interest are focused on automation for design, development, and assessment of resilience, robustness, and security of electronic devices and systems which currently includes topics such as: advanced/novel cryptographic logic primitives, assessment and evaluation of assistive technologies on semiconductor design and post-manufacturing operation, development and detection methods for AI-based sabotage. He and his students have published over 100 journal and conference publications. His research has been funded (~$8.5M since 2018) by federal, national, state, and industrial entities.

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Introduction

This work presents two National Science Foundation-supported projects, WySLICE and WySTACK, aimed at integrating computer science into K-12 education. Through professional development and virtual research experiences, these projects have significantly enhanced educators' ability to teach computing concepts across various disciplines. Evaluations reveal positive outcomes in educators' content knowledge, self-efficacy, and the creation of accessible resources for teaching computer science. The projects highlight the importance of authentic, integrated educational experiences in preparing students for future STEM opportunities, impacting over 190 educators and thousands of students by developing more than 300 interdisciplinary activities.

Motivation & Literature Review

Impactful teacher experiences must be built upon strong partnerships, and this is a challenging and purposeful task that the authors have focused on for over a decade (Burrows 2011; 2015; Burrows et al. 2016; 2013; Burrows and Borowczak 2022). Since 2011, the authors have developed, implemented, and assessed, through meaningful and authentic school district partnerships various teacher-focused opportunities. Motivating the transformational impact that experiences can have on educators is Pea and Collins' concept of the fourth wave of science education reform which "involves the emergence of a systemic approach to designing learning environments for advancing coherent understanding of science subject matter by learners" (Pea and Collins 2008).

The author focuses on providing authentic experiences to educators - **relying on the educators to utilize their prior pedagogical knowledge and experiences to create integrated curricular modules**. The approach of integrating computing concepts into existing instruction through authentic educator experiences and creation-focused pedagogy, fostered by educators has been established in the literature through NSF-supported work (Borowczak and Burrows 2018; Burrows et al. 2021; 2018).

As an educational community, and especially in science and engineering education, we understand that exposure to authentic advanced topics serves as one mechanism for students, educators, and our communities to gain interest, knowledge, and entry into available high-demand and high-paying STEM occupations (Labor Statistics 2018). However, for educators to adopt new skills and connections, they must be utilized in conjunction with, or **integrated**, within existing coursework or domain expertise (Burrows et al. 2016). Other prominent researchers agree that teaching advanced content (e.g., programming, automation, circuit design) as an elitist endeavor, instead of as a skill or an experience, is not in K-12 students' best interest (Sengupta et al. 2018; Wilensky and Papert 2010).

There are many examples of K-16 students utilizing technology within computer science (Basu et al. 2013; Berland and Reiser 2011; Sengupta et al. 2015; Svihla and Linn 2012; Vattam et al. 2011). These prior computer science projects and researcher outcomes enables the continued exploration of computing in K-12 settings by using their research as a base. This research shows that K-12 teachers included computing-related content in their curriculum and instruction (Basu et al. 2013; Blikstein 2013; Donnelly et al. 2014; Grover and Pea 2013; Sengupta et al. 2015; Shen et al. 2014; Wilensky et al. 2014).

Situated within the literature, the two projects described below expect educators to start where they are, explore computing topics, and teach and provide resources for topics that they traditionally teach and support.

Projects

NSF CS For All RPP: WySLICE

Wyoming's Schools and Libraries Integrating Computer Science in Education (WySLICE; NSF DRL Grant #1923542 "CS For All:RPP - Booting Up Computer Science in Wyoming") was a unique professional development that brought together educator participants from classrooms and libraries alike. Starting the summer of the pandemic, the project pivoted to an entirely virtual format, and over three summers engaged cohorts of doubling size (y1=20, y2=40, y3=80). Ultimately WySLICE reached over 150 K-12 teachers and state librarians from all disciplinary areas to integrate computer science into their teaching.

The project's support of participants occurred in several distinct phases: A)preliminary assessment and scaffolding, B)week-long professional development focused on "effective integration of CS in X", and C)year-long implementation and support. Phase A and Phase B professional developments enabled educators to gain enough foundational content knowledge in Computing Systems, Algorithms and Programming, and Impacts of Computing to incorporate into their own disciplinary areas and create alignments with their targeted content standards.

The professional development mixed various plugged, unplugged, siloed, and integrated content while also providing significant time for participants to engage with materials, collaborate with one another, and develop/share materials. The main physical manipulative utilized for the "plugged" activites was the Micro:Bit which the team leveraged as an ultra-low-cost programmable platform. The Micro:Bit, a device that can be programmed graphically in the Blocks language and traditionally in MicroPython or Javascript languages, and powered from a phone, tablet, or traditional PC greatly reduces the barrier the entry into the computing domain. This technology was user-friendly to the teacher and librarian participants and supported content integration with existing projects as well as those ultimately created by the community, librarians, teachers, and students.

NSF RET: Site WySTACK

Wyoming Supporting Teachers and Computational Knowledge (WySTACK; NSF CNS Grant #2055621) was, to the authors' knowledge, the first-ever fully-virtualized NSF Research Experience for Teachers (RET) site. The project consisted of three annual cohorts between May 2021 and June 2024. This virtual approach modeled and mirrored the realities of present-day collaborative research and it enabled the researchers and participants (K=12 educators) an opportunity to identify limitations, needs, and requirements for rural-based (e.g., limited connectivity; digitally divided) engagement in authentic computer science research.

Throughout the three-year project, WySTACK supported 36 high school STEM teachers, 12 annually, to virtually participate in research with four CS faculty (two female/two male) working on a diverse set of projects which all maintained a common thread of data science across a wide spectrum of computing from Machine Learning to Cybersecurity and Virtual/Augmented Reality.

The RET Site thematically focused on "the use of data science, modeling, analysis, and visualization for rural impact" which was situated at the intersection of inter-related national, state, university, and college initiatives. Four CS faculty each contributed thematically aligned research projects to the WySTACK RET Site that were related to their own area of expertise. These included AI and High-Performance Computing, Machine Learning of IoT Device Data for Continuous Authentication, VR and Immersive Experiences: Analyzing UI/UX Interactions, and Security and Resilience of Distributed Systems.

Selected Findings

WySLICE

A three-year external evaluation, conducted by the University of Cincinnati focused on three key questions. The executive-level findings from that report (Holton and Culotta 2023) are reproduced here verbatim, of particular interest is the final evaluation question and finding.

To what extent are WySLICE activities effective in supporting teachers' increased content knowledge in computer science?

Overall, WySLICE participants demonstrated mixed results with increased content knowledge in computer science. For some knowledge items there were improved correct responses, while for others there were decreases in correct responses, especially with follow-up items. Still, participants self-reported that they felt that their knowledge had improved significantly as they shared numerous examples of computer science implementation in their classrooms during the year.

To what extent are the various aspects of WySLICE effective in supporting increased teacher self-efficacy as it relates to teaching integrated CS in content?

Overall, at the end of the five-day training, there was significant improvement in participants' self-efficacy for teaching computer science. This was further supported through discussions with WySLICE participants where they shared how they felt more confident implementing CS into their daily practice, especially with working with other professionals who had similar experiences. In particular, they felt more empowered to work with other colleagues to share their new knowledge.

In what ways has WySLICE created resources (plugged and unplugged) that are available to resource-constrained schools to expose students to computer science?

WySLICE participants appreciated the numerous resources they received to help support their implementation of CS in their practice. In particular, they found the micro:bits, the financial incentives, communicating with other WySLICE participants, and communicating with the WySLICE team to be of most value. Participants also noted the program successes and provided recommendations for the design and format of the five-day professional development.

WySTACK

Though a cumulative external evaluation report is not available as of the time of this work, an external evaluation, again conducted by the University of Cincinnati focused on several key questions. Information from several of their reports are reproduced here verbatim.

To what extent are RET activities effective in supporting educators' increased content knowledge of computer science (CS)?

1. *Participants had a high level of understanding in CS with a 89% accuracy rate on knowledge items.*
2. *Participants reported an increase from pre to follow-up for 5 out 7 CS perception items.*
3. *Specifically, their perception increased continuously from pre to post to follow-up for two items*

To what extent do educators increase the incorporation of integrated computer science content within their existing coursework after participating in RET?

1. *All were able to incorporate integrated Computer Science into their lessons or activities*
2. *All plan to extend this incorporation beyond the current school year*

3. *Course participants plan to implement integrated CS in Life Science, Astronomy, Physical Science, Math, Geometry, Machine Learning, Phonics, Reading, etc.*

To what extent do faculty-research mentors and graduate students assist educators to incorporate integrated computer science content within their existing coursework

Participants were satisfied with the training and team

1. *Participants thought it was good use of their time, M=3.8 on a 4 point scale*
2. *Participants were able to develop a sense of community through the virtual format*
3. *Participants rated faculty members and graduate assistants relatively high on a 4 point scale, 3.2 and 3.1 respectively.*

Impact

The two projects, WySLICE and WySTACK, have already had a **direct impact on over 190 educators** (K16 + collegiate) as well as several dozen graduate and undergraduate students. The project participants **have developed over 300 activities that intersect computing and other domains**. Lessons and activities conducted in the same academic year as the educators participated in the projects directly impacted nearly eight thousand students over 600+ days of instruction across all K-12 grade bands and subject areas.

Though originally released through a university-hosted website (https://www.uwyo.edu/wycs) and only in uneditable non-reuseable PDF format, these activities have been re-processed and re-released through a git-backed repository and in a more open and flexible markdown file format through a wikijs frontend. Most of the resources developed by the project team and all the educator lessons are made available through the CXedHub (https://www.cxedhub.com).

Conclusion and Future Directions

This work highlights an approach to integrating computer science education into K-12 settings through two significant projects, WySLICE and WySTACK. Both projects have demonstrated impactful results over their three-year periods, emphasizing the importance of providing authentic, integrated learning experiences for educators and students alike. The projects, both supported by the National Science Foundation, have focused on professional development and research experiences for educators, leveraging technology like the Micro:Bit to integrate computing education across various disciplines. The findings from external evaluations highlight the success of these projects in increasing educators' content knowledge in computer science, improving their self-efficacy in teaching integrated computer science, and creating resources in rural and "digitally desert" areas. The impact on educators, the development of cross-disciplinary activities, and the significant reach to thousands of students highlight the transformative potential of integrating computing concepts into the broader curriculum. This approach not only enhances educators' abilities to teach computer science but also prepares students for high-demand STEM careers by exposing them to advanced topics in a non-elitist, accessible manner.

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