Board 111: STEM Curriculum for a Minority Girls' After-School Program (Work-in-Process-Diversity)

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Henriette is currently a STEM Fellow at SIUE STEM Center. She has worked at Johnson & Johnson, Abbott Labs, Baxter Labs, Tenneco, Monsanto, Frucon Construction, SC Johnson Wax and HP as a design engineer, a manufacturing engineer and a project manager. She holds an engineering degree from Northwestern University, an MBA from University of Oregon and a MiT from Washington State University where she is currently finishing her Ph.D. in Math/Science Education. Henriette's research agenda is unveiling and understanding the identity of non-typical STEM bound students, especially girls in engineering; through interest and belongingness by promoting empathy-based engineering design in instruction and practice in tandem with community engagement.

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Ann Vogel is Senior Vice President, Charitable Programs of the iBIO Institute. iBIO Institute is a public charity that develops and delivers industry-led STEM programs for teachers and students to inspire the next generation of innovators. Ann leads development and implementation teams for all Institute programs. Under her leadership, the Institute launched a number of successful new programs including: the PROPEL® programs for entrepreneurs, TalentSparks! ® teacher professional development, Stellar Girls after-school STEM program for middle school girls, STEMgirls Summer Camps, and SCI: Science Career Investigation®. Ann has led the Education Subcommittee of the national Coalition of State Bioscience Institutes for five years and has twice been elected to serve on the Executive Committee, which she currently Co-chairs. Prior to joining the Institute in 2006, Ann successfully directed BiTmaP, a first of its kind, U.S. Department of Labor-sponsored initiative with the University of Illinois at Chicago that provides bioinformatics training to IT professionals. Prior to BiTmaP, she assisted in the management of technology start-ups and small businesses in Illinois and California, directing research, business development, operations, quality assurance, sales and marketing. Ann is a licensed acupuncturist, holds an MS in Traditional Chinese Medicine and a BS in Nutrition from the Midwest College of Oriental Medicine. In 2010, Ann co-founded Point of Health Acupuncture and owns Birdhouse Acupuncture, both health and wellness businesses. Ann received her BS in Biology from the University of Illinois at Chicago.

Optimizing the Integration of Computational Thinking into a STEM Curriculum for a Minority Girls' After-School Program (prek-12, Work-in-Process-Diversity)

Introduction. This work-in-progress curriculum for a STEM + computational thinking (STEM+C) for minority girls' exploratory integration study is a joint effort amongst a community center, iBio Institute (an education-focused non-profit), and the Southern Illinois University Edwardsville STEM Center. These partners will design, test and implement the integration of computational thinking (CT) practices into a research-based STEM program designed for elementary-aged minority girls. The goal for the program is to inspire, motivate and bolster minority girls' STEM and CT abilities and perceptions. Studies indicate girls prefer areas of social caring and improving the world [1] - [3]. Therefore, our intent is to integrate the iBio's Stellar Girls STEM project-based units, which explore real-life global issues such as feeding, healing, and fueling the world, with new CT content and activities. The study is longitudinal, spanning two school years, in 10-week, twice weekly, 90-minute sessions (60 hours a year) and will include both qualitative (primarily) and quantitative methods. Preliminary results of this exploratory study' are based on observations, and select student pre- and follow-up interviews, perception surveys and teacher conversations. These results suggest students enjoy the class and understand basic computer skills, but that optimal learning clarity of what CT is, how to recognize it, and how to teach it may be fundamental to its integration.

Background. It is well-known that by middle school, interest for mathematics and science is lower for girls than for boys and decreases for all students equally during puberty. The National Research Council identifies interest as a critical factor in predicting future engagement in STEM [4]. Studies focused on girls in STEM indicate girls lack interest, not ability [5], and that interest may have a larger influence than academic achievement on choice of STEM as an educational or career aspiration. Girls and women remain under-represented among students and within the workforce of STEM [6]. Minority women still make up a very small percentage of those receiving degrees and jobs in computing fields, with African American women representing only 3% of computing professionals [7] - [9]. During the Computer Science for All initiative (January, 2016) President Obama cited access to computer science education, especially for girls and minorities, as a "critical step for ensuring that our nation remains competitive in the global economy." This is even more critical in urban regions where there are both low-income areas and employer demand for computer science expertise. [10].

Most STEM research is focused on a single STEM area [11]. How to link the four areas continues to be a challenge. However, infusing CT into STEM as a mutual way of thinking, and infusing student voice through iterative design cycles could be that link, fostering improved knowledge and interest while understanding a commonality among the content areas.

Research Questions. Our exploration of the interplay of CT and STEM content will be guided by the research questions: (a) What aspects of the integration of CT and STEM increase the likelihood of girls acquiring CT skills? (b) What aspects of the integration of CT and STEM increase the likelihood of girls acquiring STEM content knowledge? and © How does the

integration of CT and STEM affect minority girls' self-perception as future technologists?

Conceptual Framework. The study uses mixed methods. However, the initial phase of the study is highly explorative, and dependent on interpretation of qualitative data. The extant research on women and girls in STEM fields indicates that low participation is based on gender-socialization (societal norms, gender stereotyping and media portrayal) [12], [13] which leads to lower interest. Additionally, minority populations are challenged with access to computers [8], [14] and resultant low self-efficacy [15]. This program will follow a design protocol and a curriculum based on constructivism (drawing on learners' existing beliefs, knowledge and skills) [16] and real-world experiential, project-based applications which have been shown to support STEM and computing interest and success for minorities [17], [18].

Computational thinking practices in STEM will focus on students gaining experience in practices for data management, computational problem solving, modeling and simulations and systems thinking. One of the controversial topics in the study of CT is a lack of consensus on a definition. The popular definition, espoused by Jeanette Wing [19], is paraphrased as a way of thinking to prepare a machine to solve a problem. However, others suggest that computational thinking is separate from the "machine" and is a way of deconstructing, analyzing and reconstructing data, similar to how algorithms are created in algebra. Others state that the importance of a definition is secondary to the challenge of agreeing on the instructional methodology for teaching CT [20].

Methodology. This is an exploratory, longitudinal, 2-year, mixed methods study. The initial phase will focus on unveiling areas of challenge in student perception, CT thinking practices, and STEM +CT integration, by optimizing student voice to help refine and evolve both the CT-integrated activities and the research instruments for the most effective curriculum design. The curriculum will follow design principles and inclusive engineering experiences from Cunningham and Lachapell [21] and follow a 5-E constructivist model of engage, explore, explain, elaborate and evaluate [22]. CT thinking practices were pulled by the university research team from Weintrop et al.'s Taxonomy of CT [23] for integration with STEM. Those practices include Data Collection, Data Creation, Understanding a System as a Whole, Understanding the Relationship Between Parts of a System, Preparing Problems for Computational Solutions, a bit of Programming, and Using Computational Models to Solve a Problem. Data Practices (Collecting, creating, manipulating, analyzing and visualizing data) were integrated with iBio Institute's STEM units, "Feeding the World" and "Healing the World." The activities evolved from understanding the science to incorporating data practices.

Participants. The participants for this study attend an after-school community center in an urban area with a predominantly low-income minority population. Grades 3 and 4 students experience significant declines in academic achievement and interest in science [24]. Thirty-six girls were recruited by the community center from grades 2-6. The center has one educator for this program. Two additional educators were recruited by the center-one from the community, and another, who is currently elementary science teacher in the near-by district. This school district has a student population of 97.5% African- American and 98.8% low-income [25].

Methods This mixed methods study will include the following data collection instruments:

quantitative surveys, and qualitative interviews (pre-, during, and post-intervention), observations, open-ended surveys, think-aloud interviews (Harvard's Project Zero) both audio and video recorded and written interest, engagement surveys and content learning assessments, and student artifacts (notebooks/products). The first segment began 11/20/18. The curriculum is an integration of the science and CT activities and learning goals (TABLE I).

TABLE I
SCIENCE AND CT LEARNING GOALS

Sunscreen and Skin Cancer: Limiting UV Light Exposure			
Science Goal	Science Activity	CT Goal	CT Activity
Explain the importance of using sunscreen and that the amount of UV radiation varies in differing conditions of sun and shade.	Experiment with UV sensitive beads and place in different environments with different types of sunscreen.	Collect Data/Visualize Data Programming Assessing Computational Models	Create a table of experimental results. Learnt the format and meaning of conditionals, then use them to make computational models. Make computational models of an experiment in Scratch.

Data Analysis. All data will be transcribed by *Nvivo* Transcription software [26], read and open coded, then *a priori* coded by *Nvivo* Coding software [26] using thematic analysis [27]. A constant comparison method [28] will code the data to find patterns and themes. Initial analysis of qualitative data will be viewed, transcribed and coded by, minimally, the primary researcher and graduate student and, on occasion, the curriculum development specialist for interrater reliability. In addition to interrater reliability assurance, multiple modes of data collection are exercised to provide triangulation of methods, data and investigators. The research team meets at least weekly to discuss the events of the week, including comparing observations, field notes, and needs for member checking.

Results. Results are limited and preliminary. Initial evaluations of student perception and learning was analyzed from engagement surveys and pre-, post, and think-aloud interviews, observations, and member checking (educators) for the lessons on Sugary Surprises (a subsection of Feeding the World) and for Sunscreen and Cancer (a subsection of Healing the World). Below are some interview and survey findings from three of the girls (TABLE II). Interviews suggested all three girls improved their understanding of what was nutritious and healthy and their ability to utilize data. Interest improved for all three girls in the engagement surveys. However, two of the three girls indicated they were less engaged (daydreaming) in the Sunscreen and Skin Cancer lesson than in Sugary Surprises. Observations and review of student work indicate CT skills are not yet transferring into programming. For example, in the science section of the SSC lesson students discussed and created if-then statements. However, they did not connect that thinking to the creation of the computational model.

TABLE II
STUDENT INTERVIEW AND ENGAGEMENT SURVEY PRELIMINARY RESULTS

Student (Pseudonym)	Pre-, Post Lesson, and Think Aloud Interviews Trendy Traits (TT) and Sunscreen and Cancer (SSC)	Pre- and Post Engagement Surveys (12/04/2018 TT, 04/09/2018 SSC)
Katie	**Pre-Intervention** (10/22/2018) – Showed interest in learning new things and excited to begin the course. Able to list healthy foods (i.e. broccoli) but unable to explain why these are healthy. **Post Sugary Surprises Interview** (02/10/2019) – Thoroughly enjoyed all activities but mostly the online activities. Increased knowledge on why certain foods and drinks are healthy to consume. Able to explain the nutrition label with some struggle to locate serving size. Sufficient skill in utilizing data tables. **Post Sunscreen and Skin Cancer Scratch Think Aloud** (04/23/2019) – Was able to explain what she chose to create the computational model and show the interviewer what her model does. Did not connect this model to her previous experiment with sunscreen.	Showed increase in 5 of 8 questions and decrease in 1 of 8. She showed an increased amount of boredom. Her score remained low in happiness and high in not talking to others about unrelated topics.
Johnna	**Pre-Intervention** (10/23/2018) – Grasped what STEM stands for completely. Stated that she does enjoy math but was concerned about the technology portion due to the possibility of being hacked. Was shocked that she and the interviewers (females) could be scientists. Able to list healthy foods (i.e. strawberries and oranges) and explain that they are healthy because they are natural and from the earth. **Post Sugary Surprises Interview** (02/10/2019) – Thoroughly enjoyed all activities but mostly data collection. Increased knowledge on why certain foods and drinks are healthy to consume and able to compare to other foods and drinks. Able to explain the nutrition label with slight confusion of percentages and grams. Sufficient skill in utilizing data tables. **Post Sunscreen and Skin Cancer Scratch Think Aloud** (04/23/2019) – No data due to lack of attendance.	Has been interested and engaged since her first survey, all questions remained at the same increased rating as latest survey.
Kassidy	**Pre-Intervention** (10/22/2018) – Initially unsure about starting the program but thought it may be fun. Able to list healthy foods (i.e. broccoli) and that she likes to eat them. Did not hold an understanding of why food is healthy, what energy is, and other basic science concepts. **Post Sugary Surprises Interview** (02/10/2019) – No data due to lack of attendance. **Post Sunscreen and Skin Cancer Scratch Think Aloud** (04/23/2019) – Understood that this computer task related to her previous experiment with sunscreen. Was able to slightly explain what was happening in the model she created.	Showed increased engagement on 2 of 8 questions, decreased engagement in 3 of 8, while three stayed the same. Happiness and excitement increased but daydreaming and focus decreased.

Discussion

A key finding from observations, think-aloud interviews, student artifacts/products, and member checking indicated both students and teachers were focused on correct results instead of the

critical thinking process. Teachers would not allow students to fail and own their own decision-making. This interference in cognitive disruption hampered computational thinking. A reason for this behavior may be rooted in deficit thinking and critical race theory. Operationally, we continue to revise the curriculum to be more student-centered, enabling student inquiry, curiosity and risk-taking.

A central component of this project is the feedback from program participants. Student feedback has played a key role in the curriculum design and CT integration, and is an integral component in its design cycle. We continue to focus on engagement surveys, interspersed by follow-up and think-aloud interviews and reviews of student work during segments combined with observation. This opportunity to catch student learning in the moment, or soon after, has been most beneficial to understanding how the girls are conceptualizing computational thinking. We have found that the younger (grades 2 and 3) girls struggle with synthesizing their thoughts but are fully capable of verbalizing what they are thinking and demonstrating their learning. This has led to key realizations for the curriculum design team, including the structuring of our integrated STEM and CT learning cycle. We were able to determine, through observation and questioning during activities, where girls were learning each type of content and have since formalized this learning process in subsequent curriculum units.

In addition to student feedback providing insight into the curriculum, it also sheds light on needs. We began recognizing the need for and soliciting feedback from the educators. Educator feedback has provided insight on girls' skills development. The value of feedback has also led us to making the educators integral to the activity design team. Educator feedback is directly responsible for changes in how CT is integrated into the STEM activities. One example of activity design improvement is the shift from activities that have a more set "correct answer" to those that are more open-ended. This includes the inclusion of creating a commercial in the Punnett Square activity (prior to Sugar Surprises) that has not one but a range of possible answers.

Limitations
The limitations of the program are somewhat unknown at this exploratory stage. We project that our primary limitation is socio-economic and cultural. Regular attendance by the girls was expected, and continues, to be a challenge, absent family support.

Implications
The implications of the limited findings are that we need to further study the integration of the STEM and CT curricula, agree to a definition of CT that helps scaffold teaching of CT. The definition defines and bounds what is evidence and what to assess. In order to do so, researchers must member check with the educators and include student voice rigorously while continuously assessing both learning and perception.

The implications of the project are broad in that there is little extant literature on the topic of integrating STEM and computational thinking for elementary-aged minority girls on how to improve their content knowledge and CT skills, if an integrated CT curriculum improves their self-perceptions as future technologists and ultimately increases the representation of minority women in computing fields.

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