Program for Minority Girls (Research to Practice-Diversity)

Ms. Henriette D Burns, Southern Illinois University, Edwardsville

Henriette is a STEM Fellow at Southern Illinois University Edwardsville. 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, a MiT and a Ph.D. in Math/Science Education from Washington State University. 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.

Prof. Mark McKenney, Southern Illinois University Edwardsville

Mark McKenney is an Associate Professor at Southern University Edwardsville with interests in spatiotemporal databases and high performance computing. He earned his Ph.D. in Computer Engineering from the University of Florida, and his MS and BS in Computer Science from Tulane University. He has received awards for research and teaching.

Matt Johnson
Prof. Sharon Locke
Ms. Ann Vogel, iBIO Institute

Ann Vogel is Senior Vice President EDUCATE Center at 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 twice been elected to serve on the Executive Committee and the Education Subcommittee of the national Coalition of State Bioscience Institutes, 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.

Colin Wilson, Southern Illinois University

Colin Wilson works as a faculty instructor, curriculum writer, and outreach specialist at Southern Illinois University in Edwardsville, IL. His focus is STEM topics, especially earth and space sciences, and inquiry-based projects for authentic learning.

Dr. Georgia Bracey, Southern Illinois University Edwardsville

Georgia Bracey is a research assistant professor in the Center for STEM Research, Education, and Outreach at Southern Illinois University Edwardsville. She has a BA in elementary education and spent thirteen years teaching in public schools. She has an MS in physics and a PhD in science education. Her research interests include physics/astronomy education, citizen science, and the integration of technology in teaching and learning.

Mitigating the Fear of Failure in a STEM + Computational Thinking Program for Minority Girls (Work-in-Progress-Diversity)

Introduction

This is a work-in-progress study. The purpose of the paper is to present research on an intervention informed by the first year of the study. We are conducting an after-school program, studying an integrated STEM +Computational Thinking curriculum, in an urban, low-income neighborhood. Our program's broader intention is to influence how minority girls think about STEM and to unveil careers in STEM, especially engineering, they might not have otherwise considered. The framework of our mixed-methods study is socio-cultural and critical race theory with a feminist perspective. Most of the data analysis tools are qualitative but some surveys are also conducted. In its first year, we saw what we believe to be a fear response from the girls in grades 4-5. During both the in-class and the staged interviews the teachers and coordinators influenced students to give the "right answers." We believe this behavior has the same roots as that of the girls: a fear of failure. In this case the teachers are trying to mitigate the girls' failure. Because our second-year curriculum has a strong engineering design process focus, it is especially important for the girls to provide their own answers, to recognize the value of failure in the iterative design process, and to learn to embrace it. Consequently, we changed our community involvement with the venue, and urban activity center, and with women of color in STEM in the area. The instructional methodology and our data collection methods became more in-class, collaborative, and spontaneous. Our purpose is to mitigate the influence of the fear of failure (and boost self-efficacy) for underrepresented students, especially minority girls, and their teachers.

Background

Girls and women remain under-represented among students and within the workforce of STEM [1]. 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 professions [2], [3]. During the Computer Science for All intuitive (January, 2016) President Obama cited access to computer science education, especially to girls and minorities, as a critical step for ensuring that our nation remains competitive in the global economy. This is even critical in urban areas that consist of both low-income areas and employer demand for computer science expertise. [4]. Could participation of minority women and their self-efficacy in STEM improve by mitigating the fear girls feel about failure in STEM?

Research Questions

Although this research is part of a larger study, our exploration of how to mitigate student fear of failure is guided by the following questions:

1. How does the inclusion of instructional methodology meant to mitigate fear influence student response behavior in class and perception of taking risks?

2. How does interactions with females-of-color in STEM influence student response behavior in class and perception of taking risks?

Conceptual Framework

The initial phase of the study was highly explorative, and dependent on interpretivism of qualitative data. Or to say that the intent is to "study things" within their context and consider the subjective meanings that people bring to their situation [5] through observation and discourse.

The extant research on women and girls in STEM fields that indicated low participation was based on gender-socialization (societal norms, gender stereotyping and media portrayal) [6], [7] which led to lower interest. Additionally, minority populations are challenged with access to computers [8], [9] and resultant low self-efficacy [10]. This program will follow a design protocol and a curriculum based on constructivism (drawing on learner's existing beliefs, knowledge and skills [11] a real-world experiential, project-based applications which have been shown to support STEM and computing interest and success for minorities [12], [13].

Computational thinking practices in STEM will focus on students gaining experience in practices for data, computational problem solving, modeling and simulations and systems thinking based partly upon the definition of CT by Jenette Wing [14], paraphrased as a way of thinking to prepare a machine to solve a problem. Also applied is the suggestion by others, such as Weintrop et al. [15], that computational thinking is separate from the machine and a way of deconstructing, analyzing and reconstructing data, similar to how algorithms are created in algebra.

The preliminary results from year one, from both observations and interviews, suggested students we hesitant to respond because of a fear of failure. Fear of failure has been studied for many years. Fear in children has been described as an "adaptive reaction to a real or imagined threat" [16]. Fear increases during the middle school years [17], with girls reporting more fears than boys [18]. In 2009, Burnham and Lomax [19] reported little extant literature on fear existed across African American, Hispanic and White youth. Their study of 1030 children indicated differences in fear intensity and prevalence by race/culture, school level, and gender. Another study by Nelson, Newman, McDaniel, and Buboltz [20] on fear of failure amongst engineering students, reported a similar gender difference. Additionally, research suggests a strong connection between fear of failure and self-efficacy [21], [22]. Self-efficacy has long been a predictor of engagement [23], [24] and achievement motivation [25], [26]. Additionally, the program community was purposefully expanded to include center and university, parents and women of color in STEM to further improve the self-efficacy of the girls [27], [28].

Methodology

This research is part of a larger exploratory, longitudinal, 2-year mixed methods study. The initial phase was focused on unveiling areas of challenge in student perception, CT thinking practices, and STEM +CT integration. Student voice was optimized to help refine and evolve the integration of STEM and the CT activities. CT thinking practices were pulled by the university research team from Weintrop et al.'s Taxonomy of CT [15]. 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 the educational institute's STEM lessons. The lessons were organized under topics, which were then organized under one of four larger umbrella. The four umbrellas were "Feeding the World," "Healing the World," "Fueling the World," and "Saving the World." The activities evolved from understanding the science to incorporating data practices (see Fig. 1).

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Year one process:

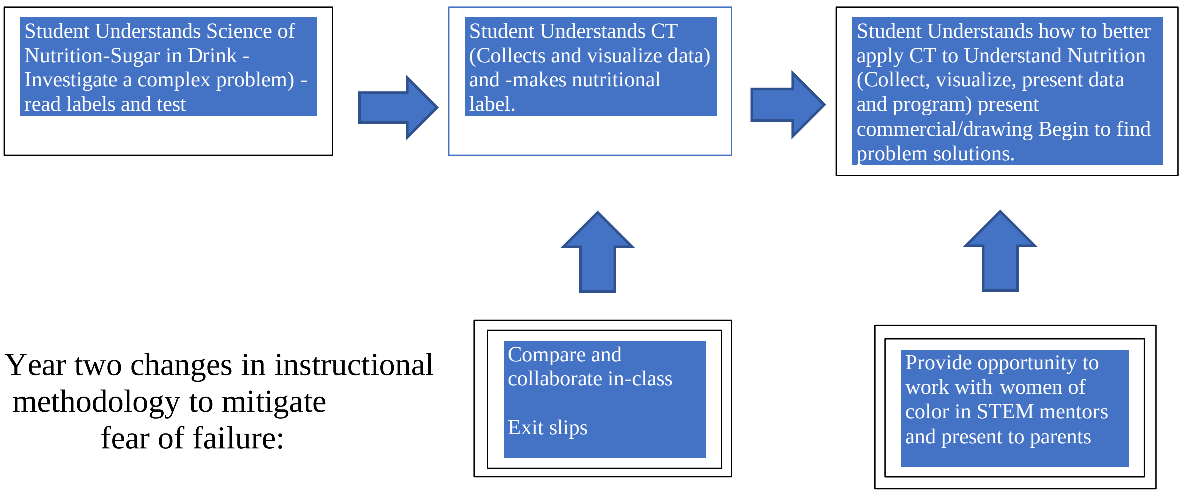

Fig. 1. Evolution of Learning in STEM +CT with Instructional Changes in 2019-2020

Participants. The participants for this study attended an after-school community center in an urban low-income underrepresented area. The first-year program was attended by grades two thru six, recruited by the center. The educators were also recruited by the center, one a current employee, and the other two from the community. The third educator was a current elementary science teacher in the district. This school district has a student population of 97.5% African-American and 98.8% low-income [29].

In year two only grades four and five girls were recruited to attend because preliminary results indicated an influence of the wide range of girls' grade levels (grades 2-6). Additionally, the educators were changed to improved our efficiency and focus on instructional methodology geared to an after-school program. One current employee was kept. A new educator with extensive after-school science outreach was assigned as the teacher. Although attendance was mandatory, approximately 10-13 girls came to the weekly Monday/Wednesday class which was shifted from a 90 to a 60-minute class to better accommodate the schedule at the center.

Methods. Year one included the following data collection instruments: quantitative surveys, and qualitative interviews (pre-, during, and post), observations, open-ended surveys, think-aloud interviews, (Harvard Project Zero) both audio and video recorded, written engagement surveys and content learning assessments, and student artifacts (notebooks/products).

Description of Data Collected During the Program (11/20/18 start)
The following data collection processes were employed in year one of the study:

1. Seventy-six engagement surveys from 30 girls.
2. Thirty-three pre-interview recordings from 33 girls (estimated total time of 495 minutes).
3. Nine post-interview recordings from nine girls (estimated time of 135 minutes).
4. Thirty-six think-aloud recordings from twenty-two girls.
5. Twenty-eight lessons days with classroom video collected as an additional source of qualitative data for triangulation (estimated time of 80 hours).
6. Twenty-nine lessons-days with still images collected.
7. Ninety-four student notebooks scanned from thirty-seven girls.
8. Thirty lessons-days with observation protocols.
9. Twenty-eight lessons-days with field notes.

Based upon preliminary results from year one, the instructional methodology for year two was adjusted to help mitigate fear-of-failure. The adjustments to instruction, and consequent data collection methods, included the following:

1. Increase real-time focus on the engineering design process, especially on the requisite failure at the start of an iterative process.
2. Increase real-time in-class opportunities for the girls to share through spontaneous presentation and compare differing results in a "what works versus what did not work" model, at least once per topic.
3. Provide an experience for girls to improve presentation skills.
4. Increase the girls' exposure to connect with women of color in STEM from the area by creating regular meet and greet events at the center for the girls and their parents. The girls will study the biography of each women and create relevant questions about their careers and how they came to be women in STEM.
5. Increase real-time formative assessments and think-aloud interviews during lessons.
6. Expand data collection tools and analysis rubrics to include more visual and kinesthetic expression, including Draw-a-Technologist [30], [31] and sequencing exercises such as explaining how to put on a coat verbally to another girl.
7. Expand data collection to include reflection, usually in the form of exit slips at the end of class.
8. Design tools specifically targeted at the CT skills and practices relevant in the lesson of the day.
9. Add real-time in-class data collection hardware, such as *Swivl* video systems to capture conversations at multiple locations in the classroom.

Data Analysis. Quantitative data, such as the engagement surveys, will continue to be analyzed by descriptive analysis. The small participant size excludes the application of popular methods for affective construct analysis. All qualitative data will continue to be transcribed by NVivo Transcription software [32], read and open coded, then a priori coded by NVivo Coding software [32] using thematic analysis [33] in a constant comparison method [34] to find patterns and themes. Initial analysis of qualitative data will be viewed, transcribed and coded by, minimally, the primary researcher and either another educator such as the program manager and/or a graduate student 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 will continue to meet at least weekly to discuss the events of the week, including comparing observations, field notes, and needs for member checking.

Preliminary Results

The content of the seventeen questions in the original interview protocol addressed foci of the research question, i.e., STEM and Computation Thinking topic and career understanding, proficiency, experience, interest and engagement. Each time an umbrella concept changed, for example from “Feeding the World” to “Fueling the World” we changed from food to renewable resource questions on the interview protocol. When assessing CT skills and practices, for example, we changed from organizing data to sequencing and describing systems.

Preliminary Results from 2018-2019. Analysis is ongoing. However, preliminary qualitative results for 2018-2019 suggest girls are improving their ability to mention “data” and “data collection” but could not yet verbalize what “computational thinking” meant. Additionally, the girls appeared to have more fun, positive attitudes, and curiosity with less discouragement (Figure 2, Figure 3).

Nodes

Name	Description	Files	References
Attitudes	Overall attitudes expressed by students	5	15
Confusion		0	0
Curiosity		2	4
Discouragement		2	3
Disgust		0	0
Engagement		0	0
Frustration		0	0
Fun		2	2
Helping Others		0	0
Positive Attitude		1	3
Teaching Others		1	2
Computational Thinking	Any suggestions of understanding or using CT	1	1
Data	Mentions of data whether correct or incorrect, mentions of data collection	8	14
Data Collection		0	0
Incorrect Data		6	7

Figure 2. Section of Pre-Interview Codebook from *NVivo* software.

Nodes

Name	Description	Files	References
Attitudes	Overall attitudes expressed by students	7	36
Confusion		1	1
Curiosity		2	3
Discouragement		1	1
Disgust		1	1
Engagement		1	2
Frustration		2	3
Fun		4	8
Helping Others		2	2
Positive Attitude		4	7
Teaching Others		0	0
Computational Thinking	Any suggestions of understanding or using CT	0	0
Data	Mentions of data whether correct or incorrect, mentions of data collection	7	24
Data Collection		4	8
Incorrect Data		2	2

Figure 3. Section of Post-Interview Coding from *NVivo* software.

Preliminary Results 2019-2020. All the names in this paper are pseudonyms. Data collection to assess fear of failure, and improvement in CT skills and practices began September 2019 and will continue through June of 2020. What follows is a snapshot of the preliminary results:

Observations: Girls were observed from September 2019 to date under the same protocol as year one. One of the behaviors most noticed was the increased competition amongst the girls to participate and present. That behavior was especially noticeable during one of the meet and greet events. Every girl insisted on asking their questions to the visitors, extending the one-hour event by twenty minutes.

Teacher comments:

> The girls have become more comfortable taking risks, they've become more willing to give answers, make suggestions, support their answers, and generally participate. Thus, they are better engaged with the material and willing to practice the CT skills in personalized ways (email, 02/03/20).

Teacher's aide comments:

> Over the past year I have seen a significant increase in the girls' interest and confidence in STEM. They have learned to think more independently and develop better problem-solving skills. I personally feel great knowing that my students will be much more likely to succeed in future STEM programs and potential careers because of this program with SIUE (email, 02/03/20).

Student One: Why do you like presenting?(interview, 3/18/20)

- I like presenting because they like—some—you could be thinking of something, but the other person don't think of it and once they see what you did to your house, maybe they can add some things that you said and other people said to their house to make it better.

Student Two: Why do you like presenting?(interview, 3/18/20)

- Because I'm just telling people what—the ways I think it can make my house more warmer, so we won't be cold. I liked it because presenting itself is telling them based on what—how it went, and did it do good and stuff? Maybe next time they can use some of them strategies.

Exit slips and other questionnaires:

However, we still have work to do. In a recent exit slip, six out of nine girls still worry. Denise, Ava, and Victoria, three of the more outspoken girls, still said they worry about saying something wrong when presenting to parents and other students. One of the seemingly more mature girls, Lili, wrote that she worries about people laughing at her. Another (Danielle) wrote she worries about people being mean (01/29/20).

Interviews: The third set of interviews for this school year are in process now. A definite change is evident in the girls' sense of belongingness in STEM and self-efficacy related to a career in STEM. Their responses to what they want to be in a future career were more STEM related in recent interviews than before the women of color in STEM meet and greet events. Some of the girls said their minds were changed from being policeman, mechanic, working at Wal-Mart, and even teaching, after meeting the women of color in STEM. When asked, "What do you want to do when you grow up?" Jaclyn replied, "I want to be a scientist, an experimental scientist." "Why? Did the ladies who visited us motivate you? " Jaclyn replied, "Yes" (12/10/19). Another girl, Lili, was asked the same question and replied, "I want to do something with engineering" (12/10/19).

Discussion

Implementation of changes began in September and are constantly being updated, and analysis completion far away. Some new results are in this paper, but all of our data collection and analysis cannot be completed until schools reopen after the pandemic. At that time, we will add a richer discussion in the paper.

Although we cannot predict the final results, our preliminary results suggest exposure to, discourse with, and support from the expanded community of other students, teachers, parents and young women of color in STEM role-model mentors may mitigate fear of failure, and improve confidence and self-efficacy. Our strategy of introducing "what worked/what does not work" in the instructional methods, and adding more real-time, increased student voice data collection tools, spending time with STEM Women of Color seems to have a positive influence on their comfort level sharing their work (recently they were competing to be heard) and understanding the reason for failure/iteration in design (girls were often explaining what they learned from failure to each other). This improved outlook may influence girls to participate in STEM programs, especially those following the engineering design process which highlights the critical value of failure in an iterative way.

Additionally, in the intervention teachers who were more comfortable with "learning" were assigned to this program and often reminded why the girls should find their own answers. Interestingly, the teacher's aide was most receptive and usually participated in the lessons with the girls. This behavior helped the girls think of the program as a "safe place."

Limitations. We project that our primary limitations will be socio-economic and cultural. However, to reduce related effects, the collaborative nature of our program allowed for member checking with the activity center and teachers to ensure cultural relevance. Limiting factors included inconsistent attendance in an already small number of participants for a case study, competing activities at the venue, and a shortened class time. From a research prospective, because of the nature of studying affects like frustration and fear (either self-reported or difficult to observe), it is difficult to attribute behavior, attitudes and even academic improvements to a specific instructional methodology. The reason for improvement might very well be other factors such as grade-level or age, or positive changes in a student's home life.

We hope to mitigate the influence of some of these limitations by expanding the girls' community to parents, professional STEM women at more social gatherings, changing the structure and time of the classes, and adding teachers experienced in after-school teaching. Regular attendance by the girls was expected, and continues, to be a challenge. Some families do not have the time, means to transport, or proclivity to send their girls twice-a-week, for 10 weeks at-a-time or participate in after-school activities.

Implications. 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, how to improve their content knowledge and CT skills, and how to determine if the integrated curriculum improves their self-perceptions as future technologists and to ultimately increase the representation of minority women in computing fields.

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