Impacting Teacher and Counselor Practices as They Support Traditionally Underrepresented Students to Pursue STEM Majors and Careers

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Abstract — **This Innovative Practice Work in Progress paper presents Catalyzing Inclusive STEM Experiences All Year Round (CISTEME365), a multi-year project funded by the National Science Foundation. We designed a networked community of middle/high school teachers, counselors, and administrators focused on improved understanding and promoting practices that increase students' motivations and capacities to pursue science, engineering, technology, and mathematics (STEM) careers. We also collaborated with them to implement out-of-school-time STEM clubs that provide engineering design, project-based, and other hands-on experiences to students throughout the school year. We investigated the experiences of K-12 students, educators, and administrators during a year-round engineering and technology-rich informal learning environment. Single-person interviews, focus groups, and surveys provided initial findings on how CISTEME365 programming influenced STEM content knowledge, career awareness, awareness of micro-messaging and equitable access, and persistence in STEM endeavors. School teachers, counselors, and administrators reported significant changes in their asset-based learning, self-efficacy knowledge, STEM career awareness, micro-messaging awareness, equitable access awareness, and culturally-responsive instruction. This study highlights the importance of establishing a networked community of school educators to better support and develop traditionally underrepresented students' interest in STEM and, subsequently, improve the diversity of the technical workforce.**

Keywords — STEM, access, school educator practices

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I. STEM FOR ALL THROUGH INFORMAL LEARNING

In the United States (U.S.), Black, Latino, first-generation, woman, and low-income persons constitute historically underrepresented students who enroll in STEM (URSs) majors and careers disproportionately as compared to their peers [1]. From 2015-2016, engineering bachelor's degrees grew by 6%, while the percentage of degrees to Hispanic students remained stagnant at 10.7%, and those to African-American students decreased from 4.0 to 3.9% [2]. As the U.S. job market continues to evolve, educators and policymakers need to effectively respond to issues of underrepresentation in postsecondary institutions as well as STEM-related majors and careers [3].

Many researchers and practitioners have recommended or initiated strategies and interventions to lessen these barriers to STEM. One approach has included making STEM learning more accessible through informal learning opportunities. Banks and colleagues (2007) credit the majority of learning across a lifespan to informal spaces. When used effectively, these spaces are essential avenues for increasing knowledge intake and addressing STEM career inequities, which in turn, broadens participation in STEM long-term [4], [5]. Informal STEM opportunities are broadly defined as any STEM learning outside of school (i.e., visiting learning centers like museums or libraries, consuming digital media like watching tv or surfing the web, playing outside, participating in summer camps, or attending public-held events) [6]. Recent research on informal STEM learning opportunities has focused on the importance of improving assessments for informal STEM learning opportunities [7]–

[9]. Additional research has identified the importance of STEM identity formation [5], [10], hands-on STEM activities [11], extending STEM content learning in authentic STEM spaces, and traditional teachers as gatekeepers for students' interest in STEM [5], [12]. Given the role that educators play in developing URSs' academic and career interest in STEM, we believe it is imperative for all K-12 educators to have knowledge, attitude, and behaviors (KAB) that effectively contribute to closing the gap.

Self-efficacy refers to an individual's "belief about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives" [13]. Previous research has identified science self-efficacy as a critical factor in the success of URSs in STEM majors [14]–[17]. Specifically, this research suggests healthy science self-efficacy as a vital connector between student interest in STEM careers and academic achievement in STEM coursework. However, research also indicates that STEM self-efficacy is not linear, and students interested in STEM may experience fluctuations in self-efficacy, in particular when transitioning into postsecondary education systems. Developing STEM self-efficacy among MS/HS student participants through informal STEM learning opportunities begins with K-12 educators.

The Next Generation Science Standards (NGSS) have asked for teachers in the U.S. to integrate engineering principles and practices throughout science curriculum, but embedding these design and problem-based skills in the middle- and high- school curriculum has been slow, particularly in under-resourced schools that serve high proportions of URSs [18]–[20]. Compounding this problem of in-school opportunity divide, students with fewer financial resources are less likely to have access to out-of-school enrichment opportunities, such as after-school STEM activities, maker spaces, or summer STEM camps [21], [22]. In recent years, teacher training and standards-based reform have been the overwhelming focus for generating increased student awareness in STEM.

Still, considering the pivotal role that school guidance counselors play as gatekeepers of opportunity, a tremendous impact on student trajectories into STEM majors and careers could be achieved if counselors also integrate effective STEM initiatives into their work [23]. Counselors may be influential in affecting educational inequities caused by demographic variables, gender, and socioeconomic status [24]–[26], but counselors are often underutilized in efforts toward increasing student awareness of and interest in STEM. According to counselor-based standards set by the American School Counselor Association (ASCA), K-12 counselors have the responsibility to introduce students to all types of careers and aid students in planning for these types of careers [27]. However, the overall American population, including counselors and educators, have little understanding of STEM careers, specifically what the field of engineering is and what engineers do [28], [29]. Research also supports that counselors with a lack of engineering knowledge affect their engineering career guidance with students [30]. Therefore, it is necessary to prepare more counselors to discuss these high-demand, high-wage, and high-skill jobs, particularly in ways that challenge stereotypes that have consistently excluded women and people of color. Given the already documented significant disparity of URSs entering STEM occupations, our work considers ways to engage meaningfully and challenge purposely all K-12 educators, including school counselors, through professional development rooted in research-based practices.

II. DEVELOPING AN EQUITABLE MINDSET OF SCHOOL EDUCATORS THROUGH PROFESSIONAL DEVELOPMENT

Though educators' professional learning often focuses on their practices, it is rare for knowledge to spread across classroom, role, school, or district boundaries [31]. When educators' practice is collaborative, inquiry-based, sustained over time, and content-focused, professional learning has been shown to impact student achievement positively [32], [33]. Improvement science is the learning-by-doing process of focused and repeated cycles of plan, do, study, and communication (or act) for addressing and improving a problem. Improvement science has roots in science, and educators have adopted this model in the field of education [34].

A network improvement community (NIC) is grounded in improvement science, and it brings together multiple individuals or teams across contexts and roles to engage in a plan, do, study, and act processes to address a shared problem [35]. In a NIC, it is essential to consider the diversity of expertise, participation expectations, and to align NIC efforts to initiatives or work that is already occurring. Members of a NIC come together regularly to report progress toward addressing the joint problem or to jointly troubleshoot issues experienced by one or more members of the NIC. By doing this work jointly, moving the needle on the sticky issue is more efficient, and progress is accelerated. Middle and high school NICs can provide a space to: (1) explore ways to promote technology-rich experiences for students, (2) increase student awareness of STEM careers and educational pathways to STEM majors/occupations, and (3) become culturally competent by learning about topics such as implicit bias and stereotype threat that could affect their interactions with students. Research into the impact of NIC initiatives in education is limited despite broad interest in implementation, and this work will contribute to this developing body of knowledge.

III. CATALYZING INCLUSIVE STEM EXPERIENCES ALL YEAR ROUND (CISTEME365)

CISTEME365 is a synergistic, 3-pronged strategy for addressing informal STEM learning opportunities for K-

12 URSs living throughout the state of Illinois. For our first targeted programming, we designed and offered a 10-day (80 hours) summer Institute for Inclusion, Diversity, Equity, and Access (IDEA) teams of counselors, teachers, and other relevant stakeholders. Over the summer, these teams learn foundational materials for engineering content knowledge. These teams also develop action research projects for improving STEM equity (AREP) within their schools and for providing STEM-enrichment opportunities for their students facilitated by a nationally-recognized STEM equity expert. Following the summer Institute as our second targeted programming, IDEA teams meet virtually (20-60 hours) as a NIC to discuss the implementation of their AREPs and further develop their engineering content knowledge. Participants left the Institute having developed an action research plan to work toward more equitable practices in their schools. Additionally, they formed a NIC with four other IDEA teams who were working toward similar goals during the academic year. This NIC would reconvene monthly to discuss progress, ask questions, and learn more from project leaders and from one another.

In conjunction with the AREP, we work with teams to build, launch, fund, and sustain out-of-school-time STEM clubs at each school site. Each STEM club receives enough materials to support up to 50 students with unique, technology-rich experiences during the school year; the IDEA team members facilitate these clubs. For our third targeted programming, we provide up to 228 scholarships (76 per academic year) for students to attend an immersive STEM summer camp at the University of Illinois Urbana-Champaign. IDEA teams recruit and nominate students for this scholarship process, but any student can apply. The summer camp, as a second informal STEM learning environment, along with the STEM clubs provide core competencies that are aligned with NGSS and prevalent in the STEM workplaces, namely engineering design, applying technical knowledge to solve problems, multidisciplinary team projects, design of experiment, data acquisition/analysis, hardware/software integration, and evaluating a hypothesis.

Our equity work is based on a curriculum designed by the National Alliance for Partnerships in Equity (NAPE). Part of curricular programming, Micromessaging to Reach and Teach Every Student™, is a research-based, strategy-driven, practical-application-focused professional development curriculum designed by NAPE that equips educators with tools to address specific school needs, addressing gender and culturally-based bias that can limit students entering into and succeeding in STEM pathways. The micro-messaging curriculum has been successful in increasing educators' belief in student STEM ability and their ability to create equity in their classrooms [36]. Recently, a large urban school in TX increased its 8th-grade math and science state assessment scores by six percentage points in one year after implementing the micro-messaging curriculum. The summer Institute addressed the following topic questions: what is educational equity and how can I influence and realize change within my school's classrooms, my practice, and myself; what are specific strategies for providing intentional positive micro-affirmations that build student belief in their capacity to accomplish challenging tasks, particularly those related to STEM; in what ways can I create equitable access to STEM, and provide an inclusive and welcoming space that supports every students' success; how can I increase student awareness of the breadth of opportunities and pathways in STEM careers; and how can I become a STEM ambassador and put these strategies into action?

During our first year, we worked with 13 active K-12 educators during the summer to provide STEM equity knowledge and STEM enrichment content, addressing the following research questions:

- How does participation in the IDEA team (i.e., Institute) (1) improve educator and counselor understanding of STEM careers and paths; (2) improve educator and counselor attitudes on who belongs in STEM and motivate action to advocate; and (3) affect educators' and counselors' efficacy in implementing practices to address inclusion, diversity, equity, and access in STEM?

IV. STUDY DESIGN AND METHODS

To examine these connections, we worked with 13 individuals in a preliminary study to better understand how our program affects the IDEA team's understanding of STEM careers and paths, attitudes on who belongs in STEM, and efficacy in implementing practices. We designed survey instruments to evaluate the impact of the summer Institute on educators' KAB in addressing STEM inclusion, diversity, equity, and access as well as educators' technical engineering skills. Because this study is a work in progress, we will only present the survey data collected from our summer Institute, addressing the first and second research questions. Projected outcomes include a statistically significant pre/post-survey improvement in KAB of IDEA team members to act as STEM advocates. Additional details about our data collection, recruiting techniques, participants, and analysis approach follow.

A. Data Collection

Data collection occurred from April 2019 through August 2019. We conducted pre- and post-surveys with each participant that included questions about their understanding of STEM careers and paths, attitudes on who belongs in STEM, and self-efficacy in implementing practices to address inclusion, diversity, equity, and access in STEM. Additional questions included information about their educational background, race/ethnicity, gender, and education professional experience. The survey was created with the Webtools. The survey questions were developed using group expertise about intended outcomes for IDEA teams. Many of the questions required scale responses (i.e., *Strongly Disagree* = 0 to *Strongly Agree* = 5; *No Knowledge* = 0 to *Expert* = 4), though some of our questions were open-ended.

Each participant was compensated with a $1200 stipend as well as housing and traveling costs for the duration of the summer Institute. Each IDEA team also received a $3000 set of kits with engineering materials and equipment for the STEM clubs to use throughout the school year, and the school teams received an additional $1500 for additional spending for more equipment or materials (e.g., a 3D printer, desktop milling machine) and other STEM-related kits or (e.g., build your own drone or virtual reality headset). The research design was approved by an ethics review board and consented to by participants.

B. Recruiting

We recruited IDEA teams from the schools that serve a diverse population of over 20,000 inner-city, rural, and/or low-income students in the state of Illinois. We also identified several partnerships at the time of our submitted proposal. Some of these schools decided to defer the start of their participation to a future summer. Ultimately, we worked with five school partnerships for the summer of 2019. Only one of these schools was a partner at the time of proposal submission. To be accepted, IDEA teams must apply to the summer Institute, draft a letter of support from a school administrator, and agree in advance to assist in nominating students for summer camps and to help to launch or expand STEM clubs within their schools. We acknowledge that neighboring schools outside of the state of Illinois can contribute valuable research and scholarship. Still, we wanted to begin our work in this area with a defined group of dedicated participants.

V. RESULTS

We performed descriptive statistics for demographic data and t-test analysis on pre- and post-survey responses using R Studio [37]. The pre-survey was 40 questions, and the post-survey was 114 questions. Additional questions were asked on the post-survey for internal evaluation purposes.

A. Demographics

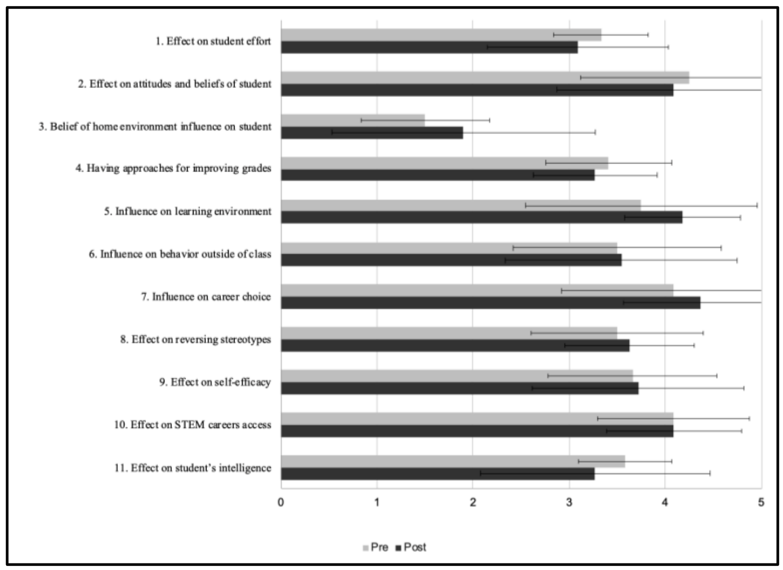
Thirteen participants completed our surveys for this paper, with one person who did not complete the pre-survey (*n* = 12) and two people who did not complete the post-survey (*n* = 11). Seven participants identified as male and six as female. The mean number of years doing education work was 15 years (SD = 9.3). Participants came from various positions across schools, with teachers (*n* = 8), counselors (*n* = 2), and other school personnel (*n* = 3). All participants earned postsecondary degrees and were currently working in a school. Participants identified as Native American (*n* = 1), Asian American (*n* = 1), African American (*n* = 5), and White (*n* = 4). Of these thirteen participants, one person identified as Hispanic (*n* = 1).

B. Equitable Mindset and Practices of School Educators

Of the survey questions in the pre- and post-survey, 26 responses were comparable. Refer to Figure I and II for the mean, standard deviation, and t-test analysis. Questions 1-2 and 4-11 explore whether the educator believes in their own impact, or their self-efficacy, on the stated outcome. Question 3 explores the educators' belief of whether home environments are outside their control. Questions 12-26 explore educators' understanding or knowledge of a skill.

FIGURE I. T-TEST ANALYSES FOR PRE- AND POST-INSTITUTE VARIABLES OF SCHOOL EDUCATORS' SELF-EFFICACY

Fig. 1. *$p<0.05$; **$p<0.01$; Variable Responses 1 through 11 range from 0



(Strongly Disagree) to 5 (Strongly Agree).

FIGURE 2. T-TEST ANALYSES OF SCHOOL EDUCATORS' SHIFTING KNOWLEDGE FROM PRE- TO POST-INSTITUTE

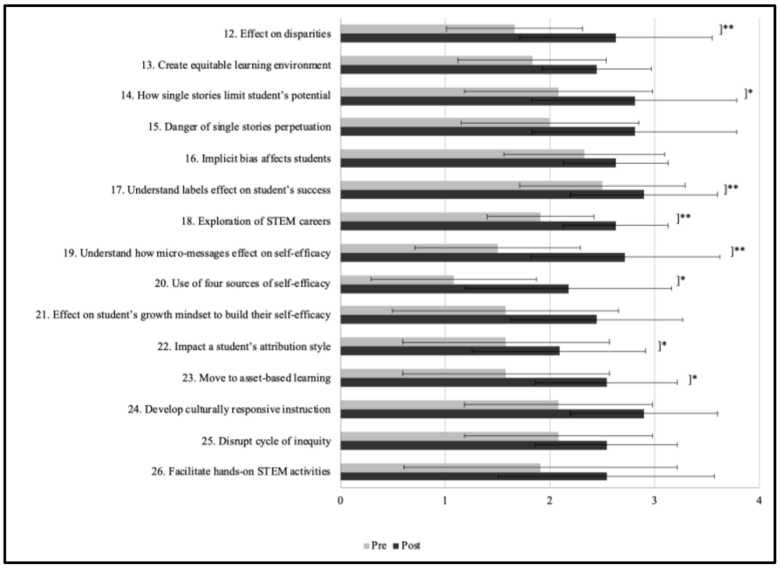


Fig. 2. *$p<0.05$; **$p<0.01$; Variable Responses 12 through 26 range from 0 (No Knowledge) to 4 (Expert).

VI. CONCLUSION

This study explored our summer Institute programming effects on school educators' understanding of STEM careers, biases, and attitudes on who belongs in STEM, and educators' efficacy in implementing practices to address STEM inclusion, diversity, equity, and access. We hypothesized that our summer Institute programming would result in statistically significant improvement in pre/post responses for the KAB of IDEA team members to act as STEM advocates.

To address our first research question on improving school educators' understanding of STEM careers and paths, our summer Institute programming statistically improved educators' KAB on exploring STEM careers and disparities. To address our second research question on improving attitudes on who belongs in STEM and motivate action to advocate, our summer Institute programming statistically improved educators' KAB on the danger of single stories perpetuation, micro-messaging effects on self-efficacy, four sources of self-efficacy, affecting student's growth mindset to build self-efficacy, asset-based learning, creating equitable learning, and culturally responsive instruction. Additionally, it is worth noting that the KAB items exhibited a larger rating change than the self-efficacy items. Therefore, our programming at the summer Institute somewhat impacted participants' mindsets and knowledge about STEM careers and engagement, and like other researchers have noted, including school counselors in-school professional development efforts to address issues of STEM inclusion, diversity, equity, and access is critical [23], [24], [30], [38].

From our pre/post-surveys, we were unable to find statistically improving results for educators' KAB on students, student's intelligence, student effort, reversing stereotypes, self-efficacy, STEM careers access, learning environment, behavior outside of class, having effective approaches for improving student's grades, home environment, and student's career choice. Additionally, we were unable to find statistically improving results for educators' KAB of how single stories limit student's potential, implicit bias affects students, and labels effect on student's success as well as educators' KAB on how to impact a student's attribution style, disrupt the cycle of inequity, and facilitate hands-on STEM activities. Our results show how shifting and non-linear self-efficacy can be in practice, and though these results speak to our summer Institute intervention, we hope to statistically improve these outcomes throughout the school year in our NIC sessions and AREP implementation follow-ups.

This work shows the possibility of changing school educators' practices using an innovative, collaborative professional network. In CISTEME365, we plan to continue pursuing novel ways to influence and diversify the STEM pipeline meaningfully. Though we do not have data on how these results, in turn, affect educators' practices throughout the school year, we look forward to observing these effects in future observations, interviews, focus groups, and surveys.

VII. FUTURE WORK AND LIMITATIONS

Though our work shows some effects on school educators' knowledge, attitudes, and behaviors, we plan to use this data to inform future iterations of our summer Institute and overall CISTEME365 efforts. Since we have only presented information on our summer Institute data, we look forward to sharing ongoing learning from our NIC sessions and AREP implementation throughout the school year, which would ultimately address our third research question. Lastly, we also plan to include qualitative data from our focus groups to provide further insight into the experiences of school educators.

This study does include limitations. This small sample of participants limited statistical power for our study, and as aforementioned, we plan to substantiate these findings with data from future iterations of our summer Institute. To add on, in our work, we do not mean to suggest that school educators' practices directly impacted underrepresented students' pursuit of STEM majors and careers. Instead, we offer results that reflect some effects on school educators' knowledge, attitudes, and behaviors, and in future reporting, we hope to share more about how their practices affect underrepresented students' STEM interests and participation. Another limitation is that this work does not include a full discussion of our entire survey data. Given the breadth of evaluation and assessment from our summer Institute survey data, we wanted to spend more time reviewing this survey data to improve our programing services for future participating schools and school educators.

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