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Recruiting and Mentoring the Mentors: Practices from the STEM+C MentorCorps Project

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Introduction

Computing has become integral to the practice of science, technology, engineering, and mathematics (STEM). Integrating coding and physical computing with Arduino and electrical components into STEM classes has been attracting more and more attraction in STEM education. One of our NSF-funded projects, Science Modeling through Physical Computing, the STEM + Computing (STEM+C) program, applies integration of computational thinking and computing activities within STEM teaching and learning in early childhood education through high school (preK-12). In this STEM+C project, the 5^{th}- and 6^{th}-grade students use science models to learn science and computing. The project investigates how introducing elements of practice may support both the learning of STEM subjects and the development of self-identity in children as STEM-capable and STEM-interested individuals. We advance a "Computational Thinking" model to enhance STEM engagement and accomplishment at the grade school level. This model combines Making with programming to explore STEM concepts in the established 5^{th}- and 6^{th}-grade science curriculum.

To support teaching computational content, we develop a Mentor Corps of college students to collaborate with intermediate school teachers in the classroom. This paper aims to report the practices and processes performed to recruit, mentor, and evaluate student mentors. After recruitment, student mentors receive professional development using multiple science models, language, and pedagogy that highlight the representational power of models. Since computational modeling activities are integrated into the regular intermediate school science classes, we highlight how we mentor student mentors on computational modeling and science. In addition, we mentor the college student mentors so that they learn pedagogical methods to teach in the classes so that kids' passion and enthusiasm for engineering and science are triggered or enhanced. Further, as a research project, an array of data sources is gathered from student mentors. Technical knowledge about data-collecting tools is conveyed to mentors so they can assist the research team in collecting data in an ideal way.

Mentoring

A skilled mentor can significantly impact what students learn about science and technology [1]. To develop a mentor, the process might encompass a long-term maturation, growth, and development of an individual at the trainee level into an innovative and productive mentor who can accept expanding leadership roles in his or her chosen field [2]. In the literature, mentoring is defined as collaborative professional learning characterized by an egalitarian approach of sharing knowledge, working together, and nurturing the whole person to improve practice [3-5]. Although mentors and mentees share a learning experience over time, mentoring is traditionally a one-way learning activity. Mentors act as a teacher to counsel, listen, and encourage mentees (a learner) to enhance their self-confidence, whereas less experienced mentees gain from mentors' wisdom, knowledge, and experience [6]. While traditional mentoring still carries weight, its scope and function are expanding [7]. A contemporary view defines this practice as "a form of socially established cooperative human activity that involves characteristic forms of understanding (sayings), modes of action (doings), and ways in which people relate to one another and the world (relatings), that 'hang together' in a distinctive project" [8]. Thus, the practice of mentoring should encourage both mentors and mentees to share power for the "purpose of empowerment" [4]. In this paper, we adopt this contemporary view and believe mentors and mentees are co-learners who can build a reciprocal relationship, trusting rapport, and mutual affection to ensure the success of the mentorship.

Mentoring is classified in to nine types: formal mentoring, informal mentoring, diverse mentoring, electronic mentoring, co-mentoring/collaborative mentoring, group mentoring, peer mentoring, multilevel mentoring, and cultural mentoring [6]. While our MentorCorps project may include all types of mentoring, we mainly focus on group and peer mentoring in this report.

Recruiting and Mentoring the Mentors: Practices

Background information

Our MentorCorps program sends STEM majors to local ISD schools so they can share their passion for STEM with kids who might not otherwise have access to a strong STEM program. We look for excited, dedicated student mentors who could commit time each week to the MentorCorps. Mentors work with the in-classroom teachers to provide technical expertise. A mentor also acts as a role model and aspirational example to the kids they work with. Our goal is to help these students visualize themselves as future STEM professionals. We know that student mentors will only be experts in some areas. Therefore, we provide training/mentoring in the technical subjects the mentors will assist classrooms with and training/mentoring in classroom management and pedagogy. What we expect from our mentors is enthusiasm for STEM subjects, reliability in supporting schools at scheduled times, and a willingness to work with kids (ages 8-18). Mentors perform three to six weeks of in-classroom work throughout a semester. They must be available for all scheduled classroom work. This in-classroom work entails working with the school science teachers in a local ISD classroom. Usually, a class period lasts 1½ hours in local ISD schools. School science teachers teach science in the first 40 minutes, then our mentors step in for another 40 minutes, acting as the STEM instructor. The classes they teach are in the 5^{th} and 6^{th} grades.

Weekly training (usually every Tuesday from 6:30 pm-7:30 pm) is provided throughout the semester to prepare for upcoming interventions. Mentors are trained to mentor kids in the experience of Making, which means teaching them how to complete tasks such as connecting simple circuits, using a 3D printer, and performing other simple Maker tasks to enhance their STEM learning.

In addition to recruiting and mentoring practices, we report the reflections and suggestions from student mentors to illustrate how they learn and progress. We also utilize descriptive data and conduct t-tests regarding training and mentoring outcomes to determine whether student mentors master the knowledge and pedagogy, therefore, are confident to teach the 5th and 6th-grade kids.

Recruiting

Our mentors are mostly recruited from engineering and science students at a large research university in Texas, USA. The recruitment started in June 2022 and ended in September 2022. We distributed our weekly application ads through university bulk emails during these times. Four types of information were collected. The first is demographic information, while the second information is work-related questions. For example, "Would you be willing to commit to more than one semester with the MentorCorps." The third is about their skills, abilities, and experience, such as teaching, experience, experience with kids, computer programming, Arduinos, "making" (using soldering irons, glue guns, 3D printers, and others), online profile (GitHub, YouTube channel, Instagram, Vimeo, Stack Overflow, and others) that highlights their passion for STEM. One sample question includes "How much experience do you have with "making" (using soldering irons, glue guns, 3D printers, and others)?" However, these questions are not the main criteria for selecting our mentors. As clearly stated in our ads, the essential qualities expected from them are dedication, passion, and commitment. "What we expect from our mentors is enthusiasm for STEM subjects, reliability in supporting schools at scheduled times, and a willingness to work with young students." This information is collected to determine how we train and mentor our recruited mentors. As previously mentioned, our project supports the learning of STEM subjects and the development of self-identity in children as STEM-capable and STEM-interested individuals. Therefore, we are willing to teach skills they do not have. "A mentor is not expected to have these skills in advance, just a love of STEM and a willingness to mentor young students". The last information we need is their CV and college class schedule. We asked applicants to upload their CVs and schedules to the application system.

Altogether, 119 students applied, and 68 were invited to an interview. A total of 40 students were selected. However, five students opted out for different reasons, ending up with 35 mentors. Twenty-one students are female students, while 14 are male. Altogether, 25 mentors major in engineering, while only one mentor majors in biology, math, health, economics, oceanography, business, bioinformatics, respectively. Most students (11) are seniors, whereas two are master students. As for ethnicity, most mentors are Caucasian (11) and Hispanic students (11), and only one is black. The demographic information of mentors is presented in Table 1.

Table 1 Demographic information of mentors

Demographics	Classification	Number	Percentage
Gender	Male	14	40%
	Female	21	60%
Major	Engineering	25	71.43%
	Biology	1	2.86%
	Mathematics	1	2.86%
	Oceanography	1	2.86%

	Applied Health	1	2.86%
	Economics	1	2.86%
	Business	1	2.86%
	Bioinformatics	1	2.86%
	Technology Management	2	5.71%
Year	Freshman	9	25.71%
	Sophomore	8	22.86%
	Junior	5	14.26%
	Senior	11	31.43%
	Master	2	5.71%
Ethnicity	Asian	7	20%
	Black/African	1	2.86%
	Caucasian	12	34.26%
	Hispanic/Latinx	13	37.14%
	Pacific Islander	1	2.86%
	Caucasian/Asian	1	2.86%

Onboarding and group mentoring

After accepting the mentor position offer, they have to go through onboarding processes, such as filling out the student's worker form, submitting it to the business office, and filling out the I-9 form. They must also complete the University background check and local independent school district background check. Further, as they participate in NSF-funded project, they must complete the RCR CITI training. After onboarding, they will attend the training/mentoring session. As aforementioned, we provide group training/mentoring in the technical subjects the mentors will assist classrooms with and training/mentoring in classroom management and pedagogy. The group mentoring session occurs every Tuesday from 6:30 pm to 7:30 pm. In this formal mentoring session, all mentors are required to attend. The mentoring team comprises professors, the director of MentorCorps, school science teachers, fabricators, and Ph.D. students.

Our mentors go to local ISD intermediate schools to conduct interventions. There are altogether five-unit interventions for each grade. Take fifth grade for an example. The units include force and motion, fossil fuels, the water cycle, adaptation, inherited traits, and learned behavior. As we incorporate computing into intermediate School STEM education in this project, we teach our mentors basic knowledge of electronics, circuits, and CASSM programming. We also teach them technical skills such as how to use code in computing programming, how to connect the bus, Arduinos, and LED. During our first week of training, we refresh the mentors on what is Arduino, what is the circuit and its components, what are Incandescence and Luminescence.

We use a Push Pull Machine model to teach students in the Force and Motion unit. Table 2 provides what knowledge and skills our mentors need to possess, and accordingly, we train them.

Table 2 Knowledge and skills

1	2	3	4	5
Push-Pull Machine with Switch	Push-Pull Machine with Arduino	Push-Pull with Timing Code	Push-Pull Machine to Lift (Gravity)	Push-Pull Machine with Friction
What is Electricity (Circuit = circle of electricity)	What is a computer?	Assemble Push-Pull Machine with Arduino using Table Circuit Chart	Assemble Push-Pull Machine with Arduino using Table Circuit Chart with Rubber band and Cup	Assemble Push-Pull Machine with Arduino using Table Circuit Chart with Rubber band and Cup (shorter string, lower cup attachment)
Electricity Safety	Computer as a switch? (Enactment)	Enact Timing Code: Run; Count; Stop; Wait forever	Students pull the rubber band assembly: What happens if you pull harder? Make a point that rubber band stretch measures the force	Students will pull the cup over 3 surfaces: Table, Fine Sandpaper, Coarse paper. They will place two different number of marbles into the cup for different pulls and estimate the extension of the rubber band when the cup begins to

				move
Basic circuit: power, load (motor), conductor, switch How to read a circuit table chart (Arduino, 5V, GND) 3D construction Simple Rack & Pinion machine	Introduction to visual programming: Show CASMM screen and run a switch-on, switch-off (Disengage the shaft, show class the one-line code "Set Pin 2 to HIGH", "Set Pin 2 to LOW")	Show Timing Code on screen and explain the code instructions. A Program is a sequence of instructions to do a specific task. Discuss washing machine steps	Students use the Pull machine to lift cup from the ground with different number of marbles in the cup. Observe how GRAVITY works on different weights and need more force to lift.	Teacher creates a table of stretches on the board. Students learn the experiential process, and that results can vary.
Rack & Pinion machine: Simple machine that converts rotational action to linear motion. Where do you find rack and pinion? (Car steering)	Introduction to CASMM: Walk class through login process	Class login to CASMM and run the code. Experiment with changing the timing	Students lift different weights and measure the rubber band extension. Teacher creates a table of stretches on the board. Students learn the experimental process, and that results can vary.	
Build Machine with a DC motor; Run the Machine with switch; Measure how long to press switch	Computer Instruction: Disengage the Push-Pull Machine and run the motor with the "Set Pin 2 to HIGH/LOW" instruction. Show how to upload the program	Do Push-Pull experiment: Push the Pumpkin from Start X to End X. Draw the direction of push on the Table Circuit Chart with Arrow. Where did they have to place the push machine?	Discuss why the results varied: Different strength of the rubber bands	
About DC motors: Polarity determines direction of rotation	Explain the relationship between the Chrome Book and the Arduino	Pull the Pumpkin from Start X to End. Draw the direction of push on the Table Circuit Chart with Arrow. Where did they have to place the pull machine?		
		Discuss the Push Pull Machine as an experimental model		

In addition to technical knowledge, we teach our mentors pedagogy- how to teach in a school classroom. One of our team members is a science education Ph.D. student and college professor. She taught science at K-12 schools for many years and thus is the best instructor to train mentors regarding pedagogy. While passion and enthusiasm are essential for our mentors, they must still be armed with teaching skills to ignite or enhance students' passion for STEM and increase their self-efficacy in STEM and programming.

We utilize GoPro cameras to catch students' interactions and learning behaviors in the classroom. Further, as an NSF-funded project, we conduct research and collect data. Therefore, during the training, technical knowledge about data-collecting tools is conveyed to mentors so that they can assist the research team in collecting data in an ideal way. These include how and where to place the camera, set up camera time, and determine when to recharge the battery.

The second form of group mentoring is through social media-GroupMe in which all student mentors and our mentoring team join as a member. All members can post questions, messages, and concerns. Others who know the answers can respond. In addition, while our mentors teach students in the actual class, school science teachers support them, providing professionalism and assisting in class control.

Peer mentoring

Although peer mentoring may involve informal developmental learning, we only discuss formal mentoring. We assign two mentors to teach in one class: primary and secondary mentors. Primary mentors are usually experienced, more senior, or engineering/science-major students. In school classes, primary mentors most often assume teaching responsibility, while secondary mentors take on an assistant role as classes go on. They can rotate as secondary mentors gain more experience. This way, both mentors can learn from each other, especially the less experienced mentors. More importantly, this peer-to-peer relationship supports student mentors' persistence, success, and "sense of belonging"[9], fostering engagement, collaboration, communication, and mutual support. Also, as school science teachers take on the first 40 minutes of the class, student mentors observe how to teach students and learn pedagogy in different scenarios.

Evaluating

We create pre and post-surveys for each training session to assess whether mentors understand the knowledge and technical skills conveyed during the training or how to teach this knowledge in the upcoming school intervention. The questions are usually the same for pre and post-surveys, only that mentors complete these questions before and after the training. For example, one of the questions in our second week (October 4, 2022) training is "I know how a Ballista works" (0 represents "totally disagree" while six is "totally agree"). Figures 1 and 2 present how mentors respond to this question pre and post-surveys.

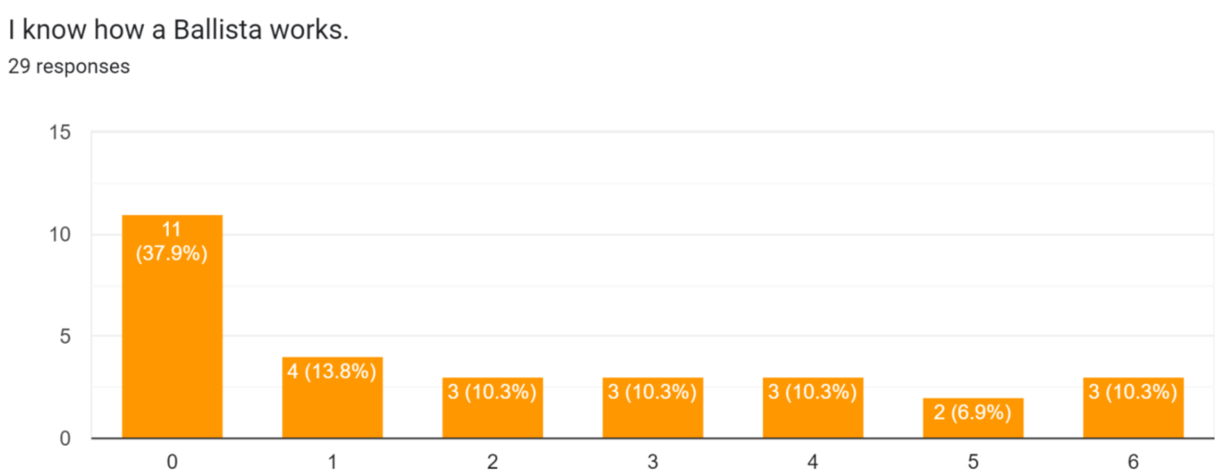

Figure 1 Pre-survey result

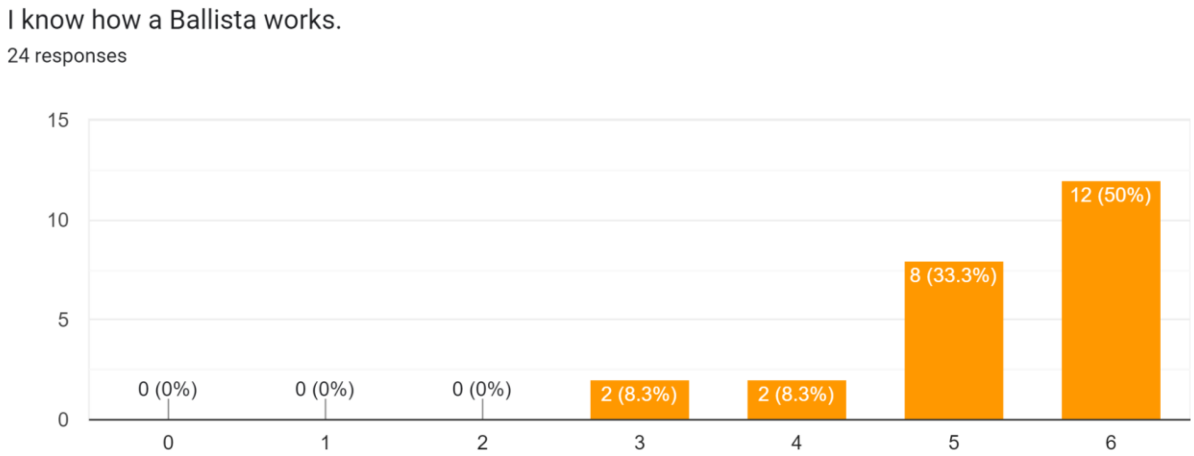

Figure 2 Post-survey result

t-test showed that the difference between post and pre-results is statistically significant [t (23) = 9.099, $p < 0.001$]. Almost all survey questions showed the same results. Pre and post-surveys help us detect mentors' understanding of the training contents. For those who cannot attend the training or those who attend but for some reason cannot fully understand the contents, we schedule make-up training for them to make sure they are ready to go to schools to conduct the intervention.

Reflections, Challenges, and Suggested Solutions

We collected student mentors' feedback and reflections on the challenges during our training/mentoring sessions regarding recruiting and mentoring student mentors. Firstly, most mentors mentioned that there is only one Black student mentor. She has recently emigrated from an African country. No native Black Americans applied for the position. To recruit more Black student mentors, they suggested providing more incentives to attract the Black student population to participate. In addition, we might need to create a network with Black student organizations campus-wide.

Secondly, although we distributed our application ads to the entire student population, most applicants are from engineering majors (25), such as mechanical engineering, aerospace engineering, and chemical engineering. To our surprise, only a few mentors major in science (3), math (1), and technology (2). Again, we need to create a link with science, technology, and math student organizations to attract more mentors in these fields. As we moved to the School of Education in the fall semester of 2022, we should have more opportunities to recruit these students as the school offers science and math education degrees.

Third, we expect that more sophomore and junior students will apply for the STEM+C project. They are more experienced than first-year students and have less pressure to find a job than senior students. However, most students are seniors. One of the possible reasons might be they have more free time to work with us.

Fourth, our project teaches intermediate school students STEM and computing programming. However, our mentors come from different backgrounds and knowledge levels, posing a challenge to mentor them. While some are experienced in programming languages, electronics, circuits, or LED, some student mentors need to gain basic knowledge of these skills. We need to provide individualized mentoring. Fortunately, our peer mentoring works for these to some extent, and it is between student mentors to student mentors. We also encourage student mentors to reach out to those who can help them, such as faculty members, science teachers, Ph.D. students, other mentors, and fabricators.

Fifth, most mentors are excited to teach in intermediate school classrooms. Not only do they get more experience teaching kids, but they also know that kids love to get creative with our science models. They are also aware of kids' emotions and behaviors in the class. "Kids are difficult to keep on task" and "They are easily distracted." However, "the kids are really excited to learn though, and they are ready to learn and eager to hear more about what we have to teach."

Sixth, mentors raise some concerns. For example, we use CASMM to do programming in the classroom. While the kids like building the code with us on CASMM, mentors mention CASMM does not work well in the class; sometimes, it does not allow kids to log in when they use their accounts and passwords. In this case, mentors have to use a sandbox to log in. As one mentor said, "......coding takes a long time, and it would be quicker if CASMM already had all the code". They suggest that, in mentoring, we need to make sure to "......really put these complex STEM concepts into easier, more relatable terms that 10-12-year-old kids can grasp." Also, we need to make sure that the student mentors "......understand the codes and give them more time to practice with CASMM."

Lastly, we expect that mentors can not only teach kids scientific knowledge but also teach how to develop kids' good character. Our mentors learn how to respect their students and value kids' input and participation through peer mentoring by observing science teachers' classes. "To gain respect from kids, you almost have to be a kid. Although they can be talkative and make ill-advised jokes, the kids will find you a fun person if you run along with them instead of always discouraging them. Kids like and respect fun people, which helps them pay attention to you more as a mentor." An increase in scientific knowledge and development of character boost kids' self-efficacy in STEM and computing, which is the main purpose of this NSF-funded project.

Conclusion

Our Mentor Corps program was developed to support teaching computational content for college student mentors to collaborate with intermediate schoolteachers in the classroom. This paper reported the practices and processes to recruit, mentor, and evaluate student mentors. This paper also presented challenges in mentoring our mentors and provided possible solutions. This report has several practical implications. Firstly, it provides a roadmap for practitioners to follow regarding how to mentor engineering and science majors participating in STEM research projects. Secondly, researchers and practitioners in the engineering field benefit from the practices and challenges faced in interacting with engineering and science-major students. Thirdly, this report assists researchers in cooperating with students and capitalizing on the resources to conduct research, as instructional materials and resources will be freely accessible.

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