Collaborative partnership: helping adolescents to develop a STEM mindset

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Abstract

Purpose – Studies have shown that science, technology, engineering and mathematics (STEM) careers remain to be one of the areas where there is considerable job growth (Lacey & Wright, 2009; National Science Board, 2010; Singh et al., 2002). However, in many rural regions, science teachers still find it challenging to motivate adolescents to develop an interest in these fields or pursue opportunities in STEM at their schools or in their communities. In exploring a distinctive way to motivate students from rural regions to develop and maintain a STEM mindset, the authors provided students opportunities to participate in programs within their communities to increase their interests in STEM. The authentic STEM learning experiences, "at no cost" for the high school students, helped them focus on cognitive and social abilities as they engaged in experiences developing identities as pre-STEM professionals. This paper reports on how the authors were able to develop research through the support of the professional development system at the university.

Design/methodology/approach – The authors explored the experiences of the high school students and parents as they engaged in the Science Olympiad events, community volunteering and mentoring projects over three years in the southeastern United States. A total of 50 high school students participated from the Science Olympiad team from ethnic backgrounds: Hispanic/Latino Americans (55%), African Americans (10%) and White Americans/Caucasians (35%) participated. The high school students and parents were asked to participate by completing required permissions and also completing pre- and post-surveys to help understand their reasons for participating in the activities. At the end of the semester, an interview was conducted with participants to better understand their experiences with working on the team and their STEM perspectives. Parents and guardians of the high school students were also asked to share their thoughts about their children participating in these activities through indirect conversations. The school partnership teacher, also Science

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The following Nine Essentials are highlighted in this article:
Essential 2: Clinical Preparation
Essential 3: Professional Learning and Leading
Essential 4: Reflection and Innovation
Essential 8: Boundary-Spanning Roles

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Olympiad co-coach, invited high school students to participate in additional STEM activities throughout the school year through the university partnership.

Findings – The pre- and post-survey responses provided insight to researchers about the "lived experiences" of the students as they developed a STEM mindset. Analysis of data indicates students' interests in STEM and working with youth increased as a result of the STEM opportunities. To help in increasing their interests, additional opportunities are needed for these youth to engage in STEM tasks and mentoring. The professional development system (PDS) creates the space for these opportunities to take place, leading to new knowledge for learning and "boundary-spanning roles" for school-university faculty to discover and experiment new ideas that "transcend institutional settings" (National Association for Professional Development Schools, 2021).

Research limitations/implications – Additional research is needed in helping high school students develop a STEM mindset as they participate in volunteer STEM experiences. The survey tools should be revised to address the specific STEM activities that the students participate in during the year. In addition to feedback from the youth and parents using focus group interviews or other defined survey instruments.

Practical implications – The school-university partners continue to explore the successes and challenges of the collaborative effort. Disruptions in the collaborative effort such as school closures due to severe weather and the pandemic have resulted in cancellations of STEM opportunities for high school students. Despite challenges, this collaborative effort continues with an additional focus on STEM learning.

Social implications – Suggested research may involve investigating parental involvement strategies that increase the likelihood of actual high school student attendance during out-of-school time activities, such as community STEM fairs, competitions and summer STEM camps. Use of focus group interviews provided students setting to talk freely.

Originality/value – Through a new initiative established by the PDS at the university, "PDS Master Teachers," the school-university faculty were invited to participate and engage in purposeful, intentional professional learning and leading to enhance the quality of the experiences for teacher candidates (Professional Development System, Watson College of Education at the University of North Carolina Wilmington, 2022). This innovative program inspired the school-university faculty to reflect on practice and create new approaches to expand STEM learning in the school and community. Through this collaborative effort, the following National Association for Professional Development Schools (NAPDS) Nine Essentials were addressed: Essential 2: Clinical Preparation; Essential 3: Professional Learning and Leading; Essential 4: Reflection and Innovation; Essential 5: Research and Results; and Essential 8: Boundary-Spanning Roles (National Association for Professional Development Schools, 2021). The University's PDS comprehensive approach to professional learning and its dedication to providing a space for all to engage in reflective practices for professional growth provided the required support for this project.

Keywords Mentoring- youth, STEM mindset, Collaborative partners

Paper type Practitioner paper

Studies have shown that science, technology, engineering and mathematics (STEM) careers remain to be one of the areas where there is considerable job growth (Lacey & Wright, 2009; National Science Board, 2010; Singh *et al.*, 2002). However, in many rural regions, science teachers still find it challenging to motivate adolescents to develop an interest in these fields or pursue opportunities in STEM at their schools or in their communities. In exploring a distinctive way to motivate students from rural regions to develop and maintain a STEM mindset, the authors provided students opportunities to participate in programs within their communities to increase their interests in STEM. The authentic STEM learning experiences, "at no cost" for the high school students, helped them focus on cognitive and social abilities as they engaged in experiences developing identities as pre-STEM professionals. This paper reports on how the authors were able to develop research through the support of the professional development system at the university. The authors were able to create authentic STEM learning opportunities for high school students to be motivated to study STEM content and to visualize themselves working in STEM careers.

The well-established school-university faculty partnership provided a continuum for the authors to further their professional learning by not only engaging in research to improve STEM learning but also supporting teacher candidates to improve teacher quality. This school-university faculty partnership was able to address several of the NAPDS Nine Essentials

through the collaborative efforts described. Through a new initiative established by the PDS at the university, "PDS Master Teachers," the school-university faculty were invited to participate and engage in purposeful, intentional professional learning and leading to enhance the quality of the experiences for teacher candidates (Professional Development System, Watson College of Education at the University of North Carolina Wilmington, 2022). This innovative program inspired the school-university faculty to reflect on practice and create new approaches to expand STEM learning in the school and community. Through this collaborative effort, the following NAPDS Nine Essentials were addressed: Essential 2: Clinical Preparation; Essential 3: Professional Learning and Leading; Essential 4: Reflection and Innovation; Essential 5: Research and Results; and Essential 8: Boundary-Spanning Roles (National Association for Professional Development Schools, 2021). The University's PDS comprehensive approach to professional learning and its dedication to providing a space for all to engage in reflective practices for professional growth provided the required support for this project.

Context

It is no secret that many students in the United States fall behind students from other countries in studying and pursuing STEM careers. In the *Washington Post* report by Heim (2016), there was a remarkable lag in performance by US high school students on the 2015 Program for International Student Assessment (PISA). This international tool is administered to fifteen-year-old children in US schools to measure their knowledge of reading, science and mathematics. According to 2018 PISA results, the mean performance remained similar to 2015, with still a low performance from US students (OECD, 2019). STEM educators continue to face challenges with motivating adolescents to develop an interest in these fields or even participate in opportunities involving STEM (science, technology, engineering mathematics) at their schools or communities. While most high school students come to school with some knowledge of STEM and how it influences the world in which they live, however, underrepresented, disadvantaged students must deal with additional challenges to help in their understanding of STEM and see themselves as future STEM professionals. Minority students that pursue studies in these areas are likely to experience stereotype threat, change in interests and a high rate of attrition (Sparks, 2018; Steele, 1997). These students have limited resources to participate in authentic STEM learning experiences and support to pursue studies in STEM.

Even though high school students come to school with some knowledge of STEM and its influence on their role in their communities, many of the minority, disadvantaged high school students attending the high school explored in this paper face additional challenges such as limited resources and support that prevents them from pursuing STEM career paths. The high school students do not participate in out-of-school activities, such as clubs or competitions, and fail to enroll in advanced STEM courses to better prepare them for STEM career paths. Increasing investments in STEM in a diverse environment remains a challenge. The overarching goal of motivating and preparing poor and underrepresented minorities in the field of STEM is attempted by working with high school students in the eastern region of the United States. The geographic location of the high school is rural, as it is surrounded by agricultural fields and population of fewer than 2,000 residents. Through the PDS Master Teachers' initiative, the school-university faculty decided to explore the reasons that motivated high school students from diverse backgrounds to participate in the high school's Science Olympiad team and other STEM activities at the school and community. Research questions for this study were as follows:

RQ1. How can we continue to increase interest in the Science Olympiad team/STEM school activities?

RQ2. How can mentoring increase students' interests and motivation?

By addressing the questions, the authors sought to increase high school students' STEM interests to engage in STEM mentorship within their communities by engaging teacher candidates in the community STEM activities. The school-university faculty consisted of the high school STEM teacher (PDS Master Teacher), who also works as the co-coach for the high school Science Olympiad team, and the College of Education STEM faculty. The teacher candidates assisted with the management of STEM community activities for the participating high school students. Through the PDS teacher, candidates were able to fully embrace responsibilities for teaching youth about STEM mentoring concepts during out-of-school times. The authentic STEM learning settings provided teacher candidates more experience to make decisions and be responsible for students' learning outside of traditional school settings (National Association for Professional Development Schools, 2021). College of Education STEM faculty served as a mentor and worked collaboratively with PDS Master Teacher on instruments to collect data on the high school student's interests in STEM and parental influence on their investments.

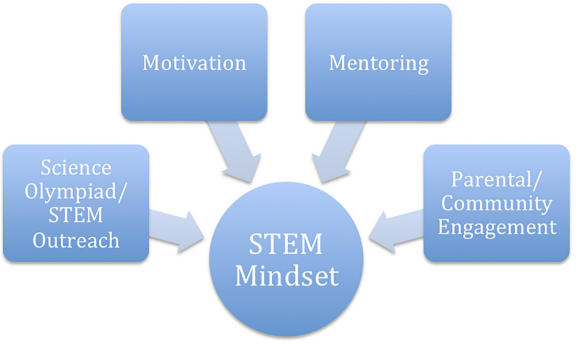
According to research studies by Johnson, Showalter, Klein, and Lester (2014) and Subramaniam, Asim, Lee, and Koo (2018), informal learning opportunities help increase students' interests in STEM while providing real-world, authentic experiences that help students view themselves in these fields. While there remains a gap in the interests of minorities, underrepresented students in STEM versus majority students, or white students, the informal learning opportunities in communities, specifically rural, have increased in the minority, underrepresented students entering postsecondary institutions and majoring in STEM areas. Students participated in volunteer community STEM-related activities throughout the academic school year while also serving on the competitive Science Olympiad team. The events involved managing the county-wide elementary Science Olympiad competitions, mentoring school youth, hosting Community STEAM nights and volunteering in a week-long STEM program for middle school youth sponsored by the local university. Each opportunity afforded students the chance to mentor and assist younger students in STEM topics and activities, build on their interests in STEM and connect them with other STEM professionals and opportunities to engage in STEM. Youth displayed a sustained interest and commitment toward STEM and pursued self-motivation for exploring and engaging in activities outside of the traditional school context. This participation led to an ongoing approach to improving and enhancing the exploration of knowledge and understandings to which they were already devoted (Basu & Barton, 2007, p. 469).

STEM mindset

In addition to the benefits arising from collective efficacy among youth, the importance of nurturing environments that foster spaces that promote a growth mindset cannot be overlooked. The top scholar in the STEM field of research among youth, Dweck (2015) comments that "students who believed their intelligence could be developed (a growth mindset) outperformed those who believed their intelligence was fixed (a fixed mindset)." The idea here is that teachers and educators should respond to students' errors with positive feedback that encourages learning as a process rather than as a final destination. Promoting negative (fixed) feedback that limits the learner has been accepted in past environments, although this adds a limitation to the student, resulting from his/her specific environment. In Murphy's article, "What STEM Mindset Is. . . and Why Everyone Should Have One," she underlines the importance of manifesting a growth mindset rather than the previously accepted fixed mindset approach. She defines the growth mindset as one that encompasses the idea that "your intelligence isn't fixed and you can get smarter by putting in effort" (Murphy, 2019). To promote positive growth-oriented mindset, educators and mentors must create environments in afterschool and summer STEM programs where youth are encouraged that they can succeed in whatever they put their minds to.

Smith and Bradshaw (2017) direct our attention to the importance of promoting nurturing environments in afterschool settings as a means of minimizing toxic social and biological conditions, reinforcing diverse pro-social behaviors, limiting possibilities of problem behavior and promoting psychological flexibility in pursuit of one's values and goals. Regarding mindset, the researchers explain to us the importance of the last concept, psychological flexibility, which they define as, "being clear about one's values and mindful of one's thoughts and feelings, and acting in service of one's values, even when thoughts and feelings discourage taking valued action" (2017). The two key areas of psychological flexibility addressed by Smith and Bradshaw (2017) are emotions and social values. They explain to us that this framework has been used in areas with high crime and poverty rates, and places a focus on "civic engagement and character." Biglan, Flay, Embry, and Sandler (2012) define nurturing environments as "environments that foster successful development and prevent the development of psychological and behavioral problems." A focus is put on prevention regarding the framework of the nurturing environment where these environments not only promote positive youth development but also promote long-term social capital gains concerning overall well-being among youth. STEM afterschool and summer programs are an essential aspect of positive youth development in middle and high school youth. Collective efficacy and mindset are two key aspects that aid in positive youth development that eventually will benefit our society as a whole, resulting in positive social capital gains. If students can develop positive dispositions toward STEM, they can gain an increase in social capital by engaging in learning activities modeling STEM professionals. By providing the opportunities, the high school students should be able to see themselves as STEM professionals through their volunteering, mentoring and training of young children in the community.

The social learning theory of change that focused on situated learning set forth by Lave and Wenger's (1991) concept of community of practice was well suited to address the social and personal transformations of knowledge that occurs in the STEM opportunities provided for the students. The authentic experiences provided for the high school students to serve as STEM leaders through volunteering and mentoring children, supporting the contextual framework of situated learning by having them see themselves in this role. Situated learning enables learners the ability to transfer skills and apply knowledge to new situations (Guerrero-Gutierrez, 2017). The aspects of the community of practice that is addressed are developed by the students working together in support of STEM learning and collaborative partnering of school-university faculty. Figure 1 demonstrates the practices for providing a healthy STEM mindset for high school students.



Source(s): Reid-Griffin and Croson (2017)

Figure 1.
Positive STEM mindset model

Benefits of mentoring in STEM mindset

Mentoring is a favorable strategy for the positive and career pathway development of youth (Jekielek, Moore, Hair, & Scarupa, 2002). Youth receive a multitude of benefits from participating in a mentor relationship. Academic benefits include increased high school graduation rates, decreased rates of dropping out of high school, better overall attitudes about school and increased rates of university enrollment. Personal benefits include improved self-esteem and self-confidence, better overall behavior, enhanced interpersonal skills and better relationships with their friends, family and teachers (Lee & Cramond, 1999). Health-related benefits include participating in healthier relationships, making better lifestyle choices and a decreased rate of substance abuse (Youth.gov, n.d.). When the relationships formed are strong, the benefits that are associated with mentoring are enhanced significantly (DuBois, Holloway, Valentine, & Cooper, 2002). Throughout the school year, students are encouraged to participate in STEM events in which they act as mentees and mentors.

The participation in mentoring enabled the high school students to strive to reach other youth in their communities and help to direct them toward a positive path for learning about STEM concepts and STEM career pathways. STEM mindset was enhanced by these opportunities, leading to positive youth development (PYD). Fostering PYD is an intentional process, in which youth are engaged and encouraged to recognize and enhance their strengths. Research regarding PYD is limited; however, evidence suggests that the skills and opportunities are provided to youth that participate in programs that encourage PYD to lead to better educational and social outcomes (Youth gov, n.d.; Youth Power, n.d.). Dworkin, Larson, and Hansen's (2003) study revealed that youth involved in extracurricular programs are active participants in their development. Youth involved in opportunities involving mentoring and sharing their knowledge are not afraid to try new things and learn their limits. They develop initiative by learning to set realistic goals and take responsibility for their actions, as well as time management skills. The high school students also explore and learn how to manage their emotions, develop relationships with their peers outside of their normal networks, as well as develop their leadership, team building and communication skills (Dworkin *et al.*, 2003).

Through participation in mentoring opportunities within the community, students can acquire social capital through PYD processes. Three categories contribute to social capital: interconnected social relationships, the trust that exists within these relationships and the resources and benefits that are gained and exchanged within these relationships (Poteyeva, 2018). Students participating in volunteer community STEM-related activities throughout the academic school year while also serving on the competitive Science Olympiad team bolstered students' confidence and mindset toward STEM learning.

The cross-age mentoring model is rooted in the idea of PYD, with older mentors working with youth toward the desired outcome. Through this relationship, the potential of all individuals involved is maximized. Youth can develop foundational academic and career-related skills, as well as the social skills needed to be successful. Additionally, "mentors also acquire lifelong leadership skills and develop a greater commitment to community stewardship" (Besnoy & McDaniel, 2016, p. 19). Conclusively, students that foster a STEM mindset are also able to increase their confidence and awareness of STEM.

We explored the experiences of the high school students and parents as they engaged in the Science Olympiad events, community volunteering and mentoring projects over three years in the southeastern United States. A total of 50 high school students from the Science Olympiad team from ethnic backgrounds participated: Hispanic/Latino Americans (55%), African Americans (10%) and White Americans/Caucasians (35%). The high school students and parents were asked to participate by completing required permissions and also completing pre- and post-surveys to help understand their reasons for participating in the activities. At the end of the semester, an interview was conducted with participants to better

understand their experiences with working on the team and their STEM perspectives. Parents and guardians of the high school students were also asked to share their thoughts about their children participating in these activities through indirect conversations. The school partnership teacher, also Science Olympiad co-coach, invited high school students to participate in additional STEM activities throughout the school year through the university partnership.

Lessons learned

STEM needs

The pre- and post-survey responses provided insight to researchers about the "lived experiences" of the students as they developed a STEM mindset. Analysis of data indicate students' interests in STEM, and working with youth increased as a result of the STEM opportunities. To help in increasing their interests, additional opportunities are needed for these youth to engage in STEM tasks and mentoring. The PDS creates the space for these opportunities to take place, leading to new knowledge for learning, and "boundary-spanning roles" for school-university faculty to discover and experiment new ideas that "transcend institutional settings" (National Association for Professional Development Schools, 2021).

STEM motivation

In the responses to the questions by high school students concerning the motivation for participating on the team, 61% indicated they joined to help prepare for college. Thirty-nine percent of the students indicated they joined to spend time with their friends, while 11% decided to join because of input from parents/guardians. Overall survey responses indicated high school students' reason for participating in Science Olympiad team and STEM activities was due to their personal interests, opportunities and friends.

STEM mentoring and STEM mindset

Mentoring serves as a key focus for the team activities and service to the community and local youth; the high school students indicated that it serves as an important aspect of the team. Many of the students indicated other opportunities where they served their community. Over 87% indicated confidence in working and talking with others about STEM and having a mentor, and 50% indicated an interest in serving as a mentor to others. Overall, the social capital gained from the experience was positive, and the relationships established as the students worked together and with community youth increased their confidence and awareness of opportunities in STEM career paths. While the opportunities occurred in both formal and informal settings, participants were able to further enter career options, therefore fostering PYD and STEM mindset.

At the end of the last mentoring event, high school students were asked to share with the researchers their comments about their experiences. Table 1 highlights some of the comments from the high school students. Overall, comments indicated satisfaction with the activities and participating with the team as they found the activities helpful in guiding other children and developing leadership skills. The high school students felt the learning experiences contributed to increasing their confidence in STEM and motivation toward a STEM mindset.

Parental support

Parents and guardians of the high school students indicated they were happy with the new activities to engage the students in mentoring. They noted they felt more welcomed to take part in the students' activities and volunteered to share their expertise and resources to

Question	Student comments
Q 1. What aspect of mentoring with younger children during coaching elementary/middle school science teams or the out-of-school time program did you enjoy?	Student 26: . . .. What I liked was working with the kids, working with robots... Student 27: I would be willing to participate in this camp as a mentor again. . .. very interesting and very fun to interact with and help. . . Student 29: . . .. What I liked was the one-on-one teaching. And the people coming there to teach the kids different things about life and careers and college and everything Student 31: . . .. What I liked was working with the kids and doing a whole bunch of different activities. I might be willing to participate again. . .
Q 2. What are your future plans?	Student 26: I would consider taking a career in STEM, like engineering. . . Student 27: I would consider studying for a career in STEM or teacher education. . . Student 29: I would be willing to participate in this again. . . Student 31: I would consider starting a career in STEM. . .

Table 1.
Focus group comments from high school students

support mentoring and volunteer efforts of the team. They commented that having their children engaged in these experiences can improve their academic skills, as well as the social skills needed to be successful in the future.

Discussion

While the study portrays a beginning effort of increasing high school student's interests and involvement in STEM through various community activities, it was able to indicate an increase in STEM mindset by participants. The findings indicated agreement and satisfaction with engaging in community and mentoring experiences. The students' interests and awareness of STEM career options and motivation were positively influenced along with the development of better overall attitudes about school and university applications. As a result of the learning experience, many of the students developed positive dispositions toward STEM and gained an increase in social capital by engaging in learning activities modeling STEM professionals. By providing the opportunities, the high school students were able to see themselves as STEM professionals through their volunteering, mentoring and training of young children in the community (Reid-Griffin & Croson, 2017). They were able to foster a STEM mindset as they had increased confidence and awareness of STEM career paths. STEM out-of-school-time programs are an essential aspect of positive youth development in middle and high school youth. Collective efficacy and mindset are two key aspects that aid in positive youth development that eventually will benefit our society as a whole, resulting in positive social capital gains and motivation toward STEM as a career path.

Limitations

Additional research is needed in helping high school students develop a STEM mindset as they participate in volunteer STEM experiences. Suggested research may involve investigating parental involvement strategies that increase the likelihood of actual high school student attendance during out-of-school time activities, such as community STEM fairs, competitions and summer STEM camps. The school-university partners continue to

explore the successes and challenges of the collaborative effort. Disruptions in the collaborative effort such as school closures due to severe weather and the pandemic have resulted in cancellations of STEM opportunities for high school students. Despite challenges, this collaborative effort continues with an additional focus on STEM learning.

Next steps

Mentoring is extremely beneficial for all students. They can gain academic, personal and health-related benefits from participating in a mentoring relationship. Mentoring can be used to aid positive youth development, an increase in social capital and career pathway development. Each of these is important in shaping the futures of the youth and positively impacting their lives.

The authors credit the success of this collaborative research effort to the school-faculty partnership and its comprehensive approach to professional learning. The University's PDS Master Teacher initiative enabled an extension of the ongoing collaborations among school-faculty partners. Additional collaborative efforts to explore the successes and challenges of the STEM mindset are ongoing. The PDS school-university partnership increased professional learning and scholarship opportunities for faculty and schools throughout the academic year with special initiatives – PDS Master Teachers, First Years of Teaching, Educators of Color to support and sustain the collaborative nature of the partnership. By providing these opportunities and resources, the PDS continues to explore space for these opportunities to grow. With the support of the PDS at the university, school-faculty partners seek additional resources to help extend the research and share findings while exploring ways to improve the STEM mindset in youth.

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