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Student Engagement, No Learning without It

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Abstract

Engaged students are emotionally invested in their learning and sustain concentration on one task for long periods of time. They feel compelled to seek new learning opportunities to deepen their understanding. All students should have the opportunity to experience engaging school learning environments. However, falling high school graduation rates in many US states and fewer adolescents enrolling in postsecondary education after high school are evidence of declining student engagement. In the critical Science, Technology, Engineering, and Mathematics (STEM) disciplines, most students have reported low engagement. This article argues that the secondary STEM education system must prioritize student engagement which will result in improved student achievement and persistence in STEM college and career pathways. Existing literature indicates that youth engage deeply with STEM activities when they make meaningful connections to the material through strategies like project-based learning which blur the line between classroom and community. This article proposes systems changes to improve student engagement including new data systems to measure and track student engagement, supporting teachers in transforming their practice, and leveraging STEM community assets to create authentic learning experiences. Examples of these changes are used throughout the article demonstrate new possibilities to improve the student experience in high school STEM education.

Keywords

STEM Education, Student Engagement, Project-Based Learning, Community Engagement

"Once I was alerted to the concept of 'hard fun' I began listening for it and heard it over and over. It is expressed in many different ways, all of which all boil down to the conclusion that everyone likes hard challenging things to do. But they have to be the right things matched to the individual and to the culture of the times."—Seymour Papert, 2002[1]

1. Introduction

Seymour Papert's insight, that students are eager to engage in challenging tasks under the right conditions, is a call to action for school systems to take seriously their responsibility for student engagement. High school is a critical time for young people as they transition into college and career pathways, so it is the perfect time to engage students and the central focus of this paper. The short- and long-term consequences of disengagement come at great individual and societal cost. Disengaged students are more likely to drop out before high school graduation (Archambault et al., 2009) and less likely to enroll in postsecondary education (Fraysier et al., 2020). While the long-term effects of the Covid-19 pandemic remain uncertain, there is evidence suggesting that student engagement with school since 2020 is trending down. In 2021, high school graduation rates fell in at least 21 states (Barnum, 2022), and more young adults than ever are not enrolled in school and unemployed (Moss et al., 2020). These data are a warning sign to the education system which must address the student engagement issue.

Student engagement in secondary Science, Technology, Engineering, and Mathematics (STEM) subjects is especially important because, "[t]he success of the Nation demands a STEM-literate modern workforce and Americans adept at navigating an increasingly high-tech, digital, and connected world" (Committee on STEM Education, 2018: p. 2). Disengaged students in STEM classes will not be prepared for this future. Yet, there were signs before the 2020 pandemic that students were not engaged in high school STEM classrooms. Mathematics is often reported as the least engaging high school subject (Shernoff et al., 2003) and more than half of high school juniors are uninterested in required science classes (National Science Board & National Science Foundation, 2021). Failing to solve this engagement problem will have dire consequences for students and society.

In the following sections I argue that the high school STEM education system can be redesigned for student engagement and suggest approaches to carry out this work. While student engagement has a colloquial meaning, the technical definition presented grounds the discussion in a current understanding of the learning sciences and connects with existing literature about student engagement in STEM. The extant literature and examples demonstrate how stakeholders in the school system can support student engagement and inform specific recommendations for redesigning the STEM education system. While education reforms tend to concentrate on supply-side concerns like teacher quality or instructional materials, reorienting the system to focus on student engagement is a demand-side approach (Rhodes, 2007). The school system, not the students, can be transformed and lead to improved student outcomes in secondary STEM education.

[1]http://dailypapert.com/april-18-2011/.

2. Defining Student Engagement

Papert's conception of *hard fun* is closely related to definitions of student engagement in the educational psychology literature. Student engagement is characterized by a state of intense concentration in interesting and enjoyable tasks (Csikszentmihalyi, 2014). This concept is broken down into four constructs: affective states (interest and enjoyment), behavioral states (visible task engagement), cognitive engagement (concentration), and agentic states (future actions) (Sinatra et al., 2015).

Affective engagement captures the interest and enjoyability of a task which is influenced by prior experiences and socializers like peers, teachers, or family members (Fredricks et al., 2004). Engaging classroom tasks account for the heterogeneity of student prior experiences, interests, and aspirations. Behavioral engagement is the outward expression of engagement and easiest to observe in a classroom setting. Having fun is the embodiment of engaging in enjoyable tasks. However, an activity can be fun without deep concentration. Cognitive engagement describes the degree of concentration in a task. In the context of classroom learning, task difficulty is positively associated with cognitive engagement (Shernoff, 2013). Agentic engagement represents the degree to which students choose to engage in a topic or series of activities over time. Truly engaged students exercise their autonomy by going "above and beyond" assignment requirements and seek out opportunities to extend their learning (Reeve, 2013). Engagement exists when all four components are simultaneously present. For example, behavioral engagement in the absence of the other components is better described be as *compliance* (Anderson, 2021). Compliant students may behave well in class and achieve good grades, but their experiences with the subject fail to fully engage their interests and they will not be likely to persist when faced with competing choices later in life.

Student Engagement in Action

The complexities of student engagement are best demonstrated through analyzing an example case. Consider a recently published account of a middle-school child's learning experience (Larson, 2021). The father describes his son as so deeply engrossed in creating a computer animation for a school project that he stayed up all night working. The boy's refusal to put his work down overnight required sustained concentration to produce the final product which is evidence of cognitive and behavioral engagement. The affective component of engagement is captured in the father-son dialogue where the boy is excited to share the resulting product from an assignment he thoroughly enjoyed creating overnight. By choosing to learn and creatively apply new computer animation technology to create the final product which such depth and creativity, this boy displayed agentic engagement. Without a doubt, this project was *hard fun* for the boy in this story.

Engaging tasks in STEM classrooms, like the project was for the boy in this example, are the critical to supporting student development along STEM college and career pathways. A meta-analysis of sixty-nine student engagement studies indicates that affective, behavioral, and cognitive dimensions are all positively correlated with future academic achievement (Lei et al., 2018). Designing for student engagement in STEM classrooms will improve results on existing accountability measures like student achievement. It is not surprise, then, that the boy in this example was both highly engaged and a high achiever—going on to attain postsecondary degrees in STEM and becoming a STEM professional. This is an opportunity all youth should have.

3. Designing for Engagement in STEM Classrooms

Engaging students in high school STEM education is achieved by creating opportunities for students to connect their intrapersonal qualities like interests, cultural background, and future aspirations with classroom activities. It is the school system's responsibility to create opportunities for students to engage with classroom tasks. This section synthesizes prior literature and describes examples in the field of ways schools are already creating engaging experiences in STEM education.

Meaningful Work with Real Professionals

School projects that extend into the community are highly engaging. Students enjoy making public presentations of their learning where adult interactions reinforce their sense of being STEM-capable (Couch et al., 2019) and increase their motivation to pursue STEM projects which positively impact people they care about (Gale, 2022). The career academy model is effective at increasing school engagement by bringing community partners into schools to design and implement career-related activities (Fletcher Jr. et al., 2018). These results indicate that interactions with adults in the community are a strategy to engage students in STEM learning.

A national award-winning teacher exemplifies this principle as described in a recent interview with the United States Patent and Trademark Office[2]. He took students into the community to search for shipwrecks in local lakes using technology they built and collaborated with first responders to invent a system which improves safety during underwater search and rescue operations. Each semester, he invites local police and firefighters to bring problems they face at work for students in his classroom to solve. During these projects, local engineers visit the classroom to provide feedback and help troubleshoot technical problems. Students are deeply engaged in these projects because they are treated as capable adults by community members, motivated to see the real impact of their efforts beyond a grade on a test, and connect their learning career opportunities in their community.

Attending to Student Heterogeneity

Recent advances in the learning sciences remind educators that students are most engaged when they can connect the context and practices used in the

[2]https://www.uspto.gov/learning-and-resources/journeys-innovation/audio-stories/lets-do-real.

classroom to their personal life and prior experiences (de Royston et al., 2020). To create engaging STEM learning experiences, teachers must adapt their instruction to student interests, identities, and cultural experiences which vary greatly between communities, individuals, and even within the same person over time. This argument is not new. For example, one essay makes the case that including, "a dimension of engagement, equity and diversity [in the Next Generation Science Standards] could have illustrated how the science content could have been made more culturally and socially relevant" (Rodriguez, 2015: p. 1042). Designing and adapting instructional materials for the socio-cultural contexts and interests of students is the key to student engagement.

Consider a common topic in science classrooms: the water cycle. Teachers looking to create an engaging context for learning this topic should explore how water is experienced by students in their community. Students in Southern California have lived through extreme drought and can personally connect to the need for water conservation and connected issues like deadly wildfires. Current high school students in coastal Louisiana and Mississippi were born around the time of Hurricane Katrina and are old enough to remember the impact of the Deepwater Horizon oil spill. These events severely disrupted the infrastructure and local economy which are highly dependent on waterways and marine wildlife. Toxic levels of lead discovered in 2015 in Flint's drinking water caused a public health crisis and residents became dependent on bottled water for their everyday needs. These three examples represent a range of prior experiences with water and can be assets for learning about the topic and applying their knowledge to have a positive impact on locally relevant issues.

The contexts and opportunities to engage in STEM learning vary across the country. The landmark study on education opportunity in the United States found that White students and students from higher income families were more likely to attend schools with highly qualified teachers, challenging courses, and facilities for advanced math and science instruction compared to Black, Latino, and students from lower income families (Oakes, 1990). While students in tech-rich areas like the Route 128 corridor outside of Boston or Silicon Valley might have ample access to STEM mentorship, exposure to family members or neighbors working in high tech STEM fields, and well-resourced schools with many advanced courses, that is not the norm. STEM professionals might be willing to travel to urban high schools and meet with a class of students while rural communities may still face internet connectivity challenges limiting their ability to collaborate outside of the community. In these cases, the STEM education system must leverage existing community assets to develop engaging STEM education experiences for their students.

Classroom teachers use documented strategies to learn about their students and create bridges between home and classroom cultures that might not be visible to the teacher. In one school with students from diverse cultural and linguistic backgrounds, a science teacher created a homework assignment asking students to discuss how the concept of heat transfer connected to practices in the culture of an adult at home (Kim et al., 2021). Students described conversations with their families about Moroccan clay ovens, cooking over fire in Guatemala, and Italian brick ovens. The students were excited make connections between their home life and school projects and transferred the cultural knowledge from this assignment to strengthen their understanding of the core science content the project was designed to teach. Another approach deploys students as problem finders to survey and interview community members to discover important issues that can be addressed with an engineering design project (Schenkel et al., 2020). Even when a community connection to the course content may not be readily apparent to the teacher, they can use open-ended structures like this and empower students to collect evidence and create their own relevance.

Encouraging student choice in the classroom is another important strategy which allows students to connect with the lesson in ways they find meaningful (Parker et al., 2017). A teacher cannot know in advance all the possible ways a student might connect with a certain topic so they must create opportunities for students to make their own connections. For example, students with disabilities are often overlooked as potential STEM students and do not have opportunities to participate in engaging STEM activities like their classmates. A teacher in North Carolina created a program to address this issue and allow students with disabilities to choose STEM projects in a program that supported their differences. Participants describe the program as the first time they were given the opportunity to engage with STEM in a way meaningful to them and are inspired to pursue STEM careers after high school graduation[3]. In both examples, the teacher increases student engagement by creating opportunities for students to express their personal interests and identities in the context of STEM.

Project-Based Learning (PBL)

Project-based learning combines the previously discussed instructional strategies into one powerful, engaging experience. Results from a teacher-researcher partnership indicate that, with the right supports, teachers can learn to design engaging PBL in their classrooms (Juuti et al., 2021). Consider an example project from the MIT BLOSSOMS website where student teams are tasked with identifying a safety issue in their community like poor visibility at traffic intersections or unsafe playground equipment[4]. Students present a proposal to address this issue as their final product. The prospect of hosting a culminating event for community members to present their ideas and the chance to improve in their community immediately raises the stakes of the project and increases student engagement. Situating the investigation in the local community provides a context where all students in the class can connect to the issue at hand compared to a project that might investigate data from a fictional town. By allowing groups to choose the context they are most interested in, students have some autonomy and are more likely to be engaged. Older students might be more

[3]https://www.ednc.org/catalyst-inventeam-brings-high-level-stem-students-disabilities/.

[4]https://blossoms.mit.edu/projects/flaws_averages/home.

likely to look at traffic intersections because they are starting to drive. Students with younger siblings might choose the playground equipment context because they want to improve conditions for their family members. Regardless of the issue students choose, they will still learn and apply the same core mathematical concepts to investigate their topic. PBL is a powerful strategy to engage students in STEM.

4. Engagement with STEM Education Requires Collective Action

Engaging students in STEM education is the responsibility of the school system but the entire community has an important, supporting role to play. Collective action among stakeholders will have a large impact on student engagement by enhancing the high leverage classroom practices described in the previous section.

Higher Education

Many colleges and universities promote a mission of community engagement and seek to prepare students for success before they step foot on campus. This can lead to mutually beneficial relationships. For example, The University of Toronto's Discovery Program pairs high school classrooms with STEM graduate students to design and conduct authentic research in the university's cutting-edge facilities which a high school student would not otherwise have access to[5]. The number of students who choose to enroll in this course multiple times during high school is evidence of this program's efficacy to engagement students (Davenport Huyer et al., 2020). Colleges and universities have deep STEM expertise and specialized equipment that can be deployed to support local student engagement in STEM.

Local Industry

The next generation of STEM professionals is in today's high school classrooms. Many companies are active in supporting STEM education in their local communities because they recognize the impact they can have on inspiring their future workforce (Webber et al., 2020). Career-oriented instruction in STEM has a positive impact on high school student engagement—especially for students from low income families (Plasman et al., 2021). For example, all students in the Cristo Rey network attend school four days each week and participate in an off-site internship the fifth day. The long-term commitment of mentors and the opportunity to participate in real projects creates a highly engaging experience (Bempechat et al., 2014). One Cristo Rey student attributes his MITRE Corporation internship experience in computer science with developing college-level math skills during high school and being prepared for success in college[6] which is compelling evidence of agentic engagement. Microsoft created the TEALS program to pair industry professionals with teachers to accelerate the growth of

[5]https://www.uoftdiscovery.ca.

[6]https://www.mitre.org/careers/student-programs/student-voices/teenage-work-study-programmer-rises-to-cyber-challenge.

computer science (CS) coursework in high schools where no certified teachers were available and reaches students historically marginalized in STEM pathways. Last year, 44% of students in TEALS classes identify as underrepresented in STEM by race or ethnicity, 63% of the participating schools are Title 1 and nearly 20% rural[7]. The program creates immediate opportunities to take a CS class for thousands of students each year who otherwise would not have access to coursework in a topic many youth are interested in and the industry mentor supports the paired teacher to become skilled and confident in their ability to teach CS without support after three years in the program (Hubbard & D'Silva, 2018). These examples demonstrate how industry partners can create meaningful and sustained partnerships which enhance student engagement with STEM education.

Parents and Families

Parents and families are vested in their child's success and many express a desire for their children pursue a STEM career pathway (Milner-Bolotin & Marotto, 2018). While having a parent in a STEM occupation is strongly associated with increased likelihood of pursuing a similar STEM career pathway (Bell et al., 2019), simple experiences can have a large impact on a child's future engagement in STEM education regardless of a parent's current occupation or background. For example, talking about STEM with young children is universally accessible and positively associated with increased STEM engagement later in life (Dou & Cian, 2021). Walking outside at night and looking up to observe the sky can spark wonderful questions and inquiry between adults and children. Why do some objects appear to flicker? Do the stars appear in the same spot each night? What might the moon look tonight like for someone in the opposite hemisphere? Questions like these, and the ensuing conversation, can fuel a child's engagement with STEM for years to come. Parents and families do not need to be content experts to engage their children in STEM at an early age[8].

Students

Most importantly, when they are supported by the STEM education system, students are stakeholders in their own future and create engaging STEM experiences for themselves. When a group of young women in Los Angeles's San Fernando Valley researched the scope of the homeless problem in the city, they were moved to help by creating a self-sanitizing tent to keep homeless mothers and children safe. Their calculus teacher and a local STEM professional agreed help the team acquire the funding, technical expertise, and community by-in to make their idea into a real product. The adults stepped back and became facilitators so the students could step up and lead the way. In the end, the students raised over $30,000 to complete their project, presented their solution to local elected officials, and traveled across the country to showcase their project. They

[7]https://www.microsoft.com/en-us/teals.

[8]Richard Larson's new book "Everyday Life: Working Wonders with a Blank Sheet of Paper" (Dynamic Ideas publisher, Cambridge MA, to appear 2022) contains many examples of constructive parent-child STEM questions.

learned about material science, CAD modeling, and electronics to achieve their goals. After this experience, many pursued STEM pathways for the first time to further their knowledge and continue improving lives with STEM[9]. These students created deeply meaningful STEM experiences for themselves because they were empowered by caring adults.

5. Systems Changes to Improve Student Engagement in STEM

The examples above describe what student engagement looks like in high school STEM education, how classroom instruction can impact student engagement, and the role community stakeholders can play in supporting student engagement. The examples demonstrate possibilities, but systems change is needed to ensure all students have opportunities to engage with STEM in high school. This section describes an agenda for future practice, policy, and research which would advance student engagement in high school STEM education.

Measuring Student Engagement

The current K-12 STEM education system does not require schools to track or measure student engagement. As a result, there is no way to know how well the system is performing and no data teachers and schools can use to improve their practice. Federal and local education policies can raise the importance of student engagement in STEM by creating assessment systems to measure student engagement. The National Association of Independent Schools, for example, provides its members access to a student engagement survey which schools can use for school accreditation and improving student engagement in schools[10]. This approach can be adopted to the context of STEM education national data with common instruments that allow for between-school comparisons. In the same way that high-stakes testing environment has been an instrument to narrow curriculum to only the knowledge and skills on the assessments (Madaus & Russell, 2010), measuring and holding schools accountable for student engagement in STEM alongside existing measures would cause the system to redirect resources to improving the quality of this important attribute. Such as system would include multiple measures at the student, classroom, and school level. At the classroom level, teachers could create surveys which routinely monitor how well students have opportunities to engage with STEM instruction (Fincke et al., 2021). Educators do not need to wait for policy changes to incorporate these approaches will be the positive proof in their community that emphasizing student engagement makes a difference in student outcomes. The local approach in this example provides teachers real-time evidence to quickly respond to student needs and aligns with broader calls to improve the validity of school performance measures (Schneider & Gottlieb, 2021).

Cultivating Student Engagement through Classroom Practice

Teachers need more support to ensure all students have the opportunity for

[9]https://mashable.com/feature/diy-girls-solar-powered-tent-homeless.

[10]https://www.nais.org/analyze/student-engagement-surveys/.

engaging STEM instruction. The engaging instructional practices described above require a markedly different set of skills and knowledge than some teachers, especially novice teachers, currently possess. Teacher preparation programs must include experiences with these engaging practices early in the training program, like the popular UTeach model does[11], so they are confident and prepared to be engaging STEM teachers in their own classrooms as early as possible in their career. Schools must also devote considerable resources to continuous teacher professional development because, in the current system, teachers develop these skills in the timescale of years (Navy et al., 2021; Zhang et al., 2019). Teachers in the United States spend a relatively large portion of their day teaching students compared to other countries so little time is left for thorough planning, collaboration, or professional learning (Burns & Darling-Hammond, 2014). Schools must release teachers from some of their instructional time to participate in proven programs to shift teacher practice like instructional rounds (City et al., 2009) or lesson study (Hird et al., 2014; Lewis et al., 2012). Full-time staff members in schools, like instructional coaches, can provide feedback and individualized support for teacher growth. These shifts will increase school personnel costs, but the improved quality of teaching will create more engaging STEM learning experiences in formal school settings and pay off in student outcomes. Future research and evaluation can describe the degree to which these professional learning models lead to improved student engagement.

Incentivizing a Role for Local Stakeholders

The previous sections established that community members outside of the formal education system have a stake in creating more engaging students STEM opportunities. New policies can ensure all stakeholders do their part in improving student engagement in STEM. Local businesses and colleges have access to cutting edge technical facilities, STEM professional role models, and mentors from a variety of backgrounds and experiences who are committed to the success of students in their local community. Organizations must be incentivized to deploy these assets in support of high school STEM student engagement. The widespread adoption of video conferencing during the pandemic can bridge the gap for many schools who, previously, did not have access to these resources because of their location. For example, a high school in Chattanooga, Tennessee sends aquatics samples from their local river to scientists at the University of Southern California who return high resolution microscopy images in real-time with the students over the internet (Newcomb, 2020) in the same way professional scientists collaborate. Local partnerships should be the priority, but technology has broadened access so all students can have access to some form of authentic partnership with STEM professionals or researchers.

From an early age, parents and families can support their children engaging in STEM education and the systems must provide opportunities for engagement. STEM showcase and competitions allow for children to be seen and celebrated in

[11]https://institute.uteach.utexas.edu/.

the same way a sports game allows for athletic achievements. Some families, especially those who work in STEM or have STEM-based hobbies, are equipped with skills to engage their children in STEM but others may be unsure. Schools and organizations can regularly host intergenerational events to increase family awareness of STEM and model strategies for future STEM education engagement. The Society for Hispanic Engineers asks local chapters to host a Noche de Ciencias (science night) to achieve this goal and they include bilingual parent workshops[12] to ensure all attendees have access to the workshop resources. These events are critical support to ensure students have the access to the social capital needed to navigate STEM college and career pathways.

Finally, the system must position students as autonomous stakeholders within the STEM education system rather than passive consumers. Many of the proposed changes are designed for students or with students in mind, but agentic engagement requires that students are actively involved in creating their own pathways and the system design. Chief Science Officers is a successful and replicable program which program trains youth to be advocates for STEM and innovation and bring more opportunities to youth in their communities (Babendure et al., 2018). Programs like this are needed in every community because they directly engage the students involved and their efforts positively improve the STEM education experience for all students.

Carrying out these community-level activities may present a challenge in locations where there are not many existing STEM opportunities or examples of engaging STEM education. In these cases, intermediary organizations can convene local stakeholders as part of a formal STEM learning ecosystem (Baker, 2018) to disseminate best practices and organize collective action. Efforts in Oregon demonstrate some success and opportunities to refine a networked approach to increase student engagement with STEM (Dierking et al., 2021).

6. Conclusion

There has yet to be a national emphasis on student engagement in high school STEM education. I have argued that this approach has the potential to improve outcomes for students across the country. The opportunities for policy, practice, and research described in this article support the STEM education system's reorientation towards this goal. While investments are needed to shift learning practices in classrooms, local communities have a collective responsibility to improve the system for America's youth and have a stake in their success. Importantly, the approaches presented are descriptive rather than prescriptive allowing for local stakeholders to create and implement the changes in ways that make sense for them. A strength of the United States is its great diversity. Creating a system that is responsive to community and individual student needs will ensure that all students have access to engaging STEM education experiences which can propel them into future STEM pathways.

[12]https://www.shpe.org/about-shpe/our-programs/noche-de-ciencias.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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