Journal of Pre-College Engineering Education Research (J-PEER)

Volume 14 | Issue 1 Article 3

2024

Hands-On for Whom?

Isabella Stuopis
isabella_stuopis@brown.edu

Avneet Hira
Boston College, hiraa@bc.edu

Recommended Citation

Stuopis, I., & Hira, A. (2024). Hands-On for Whom?. *Journal of Pre-College Engineering Education Research (J-PEER), 14*(1), Article 3.
https://doi.org/10.7771/2157-9288.1419

Hands-On for Whom?

Abstract

Hands-on technology-enhanced pedagogies have been hailed as a panacea for engaging K–12 students in engineering. We unpack how the entanglement of the sociopolitical with the educational, namely how factors pertaining to resources and individual characteristics, impact engagement with such pedagogies. In particular, we expand upon how school funding, teacher preparation and support, access to out-of-school resources, and family background impact the in-and out-of- school resources students have access to. Further, we explain how characteristics such as a sense of belonging, pedagogical approaches, and assumptions and gatekeeping by adults impact students' ability to engage with hands-on engineering education. In doing so, we make a case for rethinking hands-on and technology-enhanced engineering learning for just and inclusive education.

Keywords

hands-on, technology, sociopolitical, makerspaces, equity

Document Type

Provocation

ARTICLE

Hands-On for Whom?

Isabella Stuopis and Avneet Hira, Boston College

Abstract Hands-on technology-enhanced pedagogies have been hailed as a panacea for engaging K–12 students in engineering. We unpack how the entanglement of the sociopolitical with the educational, namely how factors pertaining to resources and individual characteristics, impact engagement with such pedagogies. In particular, we expand upon how school funding, teacher preparation and support, access to out-of-school resources, and family background impact the in- and out-of-school resources students have access to. Further, we explain how characteristics such as a sense of belonging, pedagogical approaches, and assumptions and gatekeeping by adults impact students' ability to engage with hands-on engineering education. In doing so, we make a case for rethinking hands-on and technology-enhanced engineering learning for just and inclusive education.

Keywords hands-on, technology, sociopolitical, makerspaces, equity

For the last decade, since the release of the national-level Next Generation Science Standards (NGSS) in the United States (NGSS Lead States, 2013), school districts across the country have increasingly included engineering in their curriculum, with the number of high schools offering engineering courses of any kind almost being doubled between 2012 and 2018 (National Survey of Science & Mathematics Education, 2013, 2018). While not all schools in the country still have active engineering courses—especially those in underresourced districts—the adoption numbers are increasing. A primary vehicle for teaching engineering in schools is through engineering design, an "engineering approach to identifying and solving problems" (National Research Council, 2009, p. 4). The NGSS replaced the term "technology design" with "engineering design" to distinguish between engineering as a practice and technology as a result or a means. Often conceptualized as a process comprising divergent and convergent phases of problem discovery and solution testing, engineering design is a common framework used in informal engineering

https://doi.org/10.7771/2157-9288.1419

programs in after-school and summer/winter programs for students and is also a crucial aspect of several widely adopted engineering curricula, including Engineering Is Elementary (2020), Project Lead the Way (2023), and Teach Engineering (n.d.). Other aspects of engineering integration at the K–12 level include integration with other STEM disciplines and focusing on engineering habits of mind skills associated with engineering that many believe to be essential in the 21st century.

Even though there have been attempts to distance engineering from the technologies used in and created by engineering as in the NGSS, using low- and high-tech technologies in open-ended, project-based, hands-on settings is one of the more popular pedagogical approaches to teaching engineering in both formal and informal settings (Taylor, 2016; Weiner et al., 2018). Enactments of this can be seen in school, library, and museum makerspaces and more generally in engineering classes where students use various low- and high-tech technologies to work through the engineering design process. In this essay, we refer to using low- and high-tech technologies for engineering learning as *technology-enhanced pedagogies*. Our use of the term *hands-on learning* encompasses learning by doing and reflection with roots in constructionist pedagogy (Papert & Harel, 1991). In this short essay, we argue that for students to engage in such teaching and learning approaches, they need to not only be able to access such technologies but also have the ability to engage in open-ended project-based explorations. Such an ability is essentially a privilege for several groups of students, since they are impacted by both in- and out-of-school factors.

Hands-on technology-enhanced pedagogies have been hailed as a panacea for engaging K–12 students in engineering and have certainly helped engage more students. However, for us as a community of K–12 engineering education practitioners and researchers to make further progress, consideration of the sociopolitical in how students engage with such forms of teaching is a worthy exercise. While the adoption numbers of technology-enhanced pedagogies are increasing, there are also disparities in the distribution of school resources, availability of out-of-school resources, the utility of engineering pedagogies, and gatekeepers' perceptions of who can do engineering. In the next few sections, we briefly unpack how in- and out-of-school resources and characteristics such as students' sense of belonging, pedagogical practices, and gatekeeping behaviors of adults impact who gets to engineer.

RESOURCES

The resources that students have access to play a significant role in whether they can participate in hands-on engineering activities. This section focuses on how school funding, access to in- and out-of-school resources, and students' family backgrounds

https://doi.org/10.7771/2157-9288.1419

impact students' engagement with technology-enhanced pedagogies in in school and informal learning settings.

In-School Resources

School funding impacts what schools can do to incorporate technology-enhanced pedagogies. In the US, school funding is typically linked to local property taxes and state and federal funding, and schools with more significant funding tend to have better outcomes (Baker, 2019). Factors impacting these better outcomes include upgraded facilities, additional extracurricular activities and programs, and better rewarded and sometimes better-qualified school staff.

The lowest-income schools have the highest repair needs on the existing infrastructure (Jackson & Johnson, 2021). Sixty percent of the schools that serve 75% or more students who are eligible for free or reduced-price lunch are in fair or poor condition (Jackson & Johnson, 2021, Figure 2). These schools need upgrades to many systems, such as their HVAC, lighting, and plumbing systems. When schools need to use their infrastructure funding to upgrade these systems, few resources are left to invest in technology-enhanced facilities such as makerspaces and upgrading classrooms to support the incorporation of needed hardware. Even when they invest, fear of breaking the technology and lack of repair and maintenance resources often keep educators from engaging with such practices (Bingimlas, 2009). This digital divide impacts in-school resources that students have access to as well as out-of-school resources, as we will briefly describe in the next section.

In addition to funding the facilities, schools need to be able to fund the teachers and curriculum to support these technology-enhanced pedagogies. Professional development workshops and acquiring materials can be expensive. Additionally, there needs to be time in the curriculum to incorporate hands-on engineering experiences. The NGSS's incorporation of engineering design into the standards has helped incentivize districts to incorporate these experiences into their curriculum. However, teachers are significantly underprepared to teach engineering. Only 3%, 10%, and 13%, respectively, of elementary, middle, and high school science teachers (usually tasked with teaching engineering) have taken at least one engineering course in college (Banilower et al., 2018). Even when professional development opportunities are present, the recent report of the National Academies of Sciences, Engineering, and Medicine (2020) points to how it has not been possible to assess the effectiveness of such programs, and their reach is limited. For the report, the committee commissioned the Educational Development Center to survey pre- and in-service programs that offer such professional development. The center was able to identify 120 programs with an explicit focus on engineering design/practices, of

https://doi.org/10.7771/2157-9288.1419

which 50 completed the survey. The conclusion was that while a majority of the programs focused on only in-service or both pre- and in-service teachers, there was still no reasonable way to measure the effectiveness of the programs. Thus, the ability of schools to have access to upgraded facilities and the ability of teachers to attend and implement relevant professional development activities and feel confident and supported in maintaining and repairing technologies significantly impact students' long-term engagement in hands-on engineering learning.

Out-of-School Resources and Informal Learning

In-school activities are just one way for students to engage in hands-on technology-enhanced engineering learning. Many students engage with engineering practices outside the classroom through online resources, informal learning opportunities (i.e., technology camps), and extracurricular activities. Such low-stakes engagement significantly impacts who pursues engineering and experiences a sense of belonging in engineering. Below, we explain how the digital divide, students' family backgrounds, and having access to extracurricular programs impact students' engagement with engineering.

The digital divide has been documented over the past several decades; however, it became even more prominent as the COVID-19 pandemic moved classrooms online. Despite attempts at bridging the gap in student access to technology and the internet, the divide persists (Hetling et al., 2022). Even after federal and state funding attempts to provide all K–12 students with reliable access to the internet and use of a computer or a tablet at home in the wake of the pandemic, one in five students do not have access to high-speed internet, and one in four students from lower-income backgrounds do not have access to a computer at home (Rideout & Robb, 2021). Even students with a computer in their house are not guaranteed reliable access, especially if multiple family members need it. The digital divide, in tandem with how social and economic classes reproduce themselves in society (i.e., the economic prospects of a child are highly related to their parents' financial standing), further broadens the gap between individuals who have access to and participate in technology-related activities and those who do not.

Students from higher-income backgrounds can access more academic resources outside the home and school, such as tutors to support struggling students (Diaz, 2019). Families with a higher-income status are also more likely to have parents pursuing advanced degrees who can help their children with academic concepts (Kalil, 2014; Reardon, 2018). Additionally, these families can afford to send their children to summer camps that engage with these technologies. Further exacerbating this divide of resources, some low-income students' time outside of school might be spent on

https://doi.org/10.7771/2157-9288.1419

part-time jobs to help their families pay their bills. This takes away from time that students can spend doing homework as well as engaging in extracurricular activities. Further, family and community narratives of whether they see young people as doing STEM have an enormous impact on whether students think of themselves as people who do STEM or not (Avraamidou & Schwartz, 2021; Master & Meltzoff, 2020).

After school, districts are able to fund extracurricular activities such as FIRST and 4-H robotics, invention conventions, academic decathlon, and student clubs related to STEM (Ozis et al., 2018). Students' involvement in such programs is impacted by several of the factors we have discussed above, including but not limited to school resources, the ability of family units to provide support for students' involvement, and other priorities for students' out-of-school time such as taking care of a sibling or working. Thus, access to technology and reliable internet outside of the school, the ability to enroll in often expensive after-school and summer STEM camps, and parents' and guardians' educational attainment impact youth's current and long-term engagement with engineering.

INDIVIDUAL CHARACTERISTICS

In addition to the in- and out-of-school circumstances we briefly described above, individual characteristics of students and educators also impact how and if students engage in hands-on technology-enhanced engineering learning. These include how students think about themselves and the contexts they find themselves in, assumptions that educators make about all students thriving in interactive team-based settings, and often inadvertent but far-reaching impacts of gatekeeping behaviors of adults in technology-rich spaces.

Student Identity and Belonging

Another barrier to the effectiveness of pedagogical practices in engineering education is student belonging. It has been theorized that humans take most actions to support their sense of belonging (Baumeister & Leary, 1995), and a sense of belonging to a space and community, even if temporary, contributes to long-term beliefs of whether they belong in engineering or not (Dika & Singh, 2002). Students who believe in their ability to succeed with these technology-enhanced pedagogies are more likely to engage fully in the programs provided. Beyond just self-efficacy, community members can positively influence students' belonging by recognizing youths' engineering practices (Avraamidou & Schwartz, 2021). However, stereotypes of who are considered STEM people can negatively influence students' belonging if they come from minoritized backgrounds (Master & Meltzoff, 2020). Thus, whether

https://doi.org/10.7771/2157-9288.1419

students feel a sense of belonging to the space and community in which they are learning greatly impacts how they learn, and students from underserved groups are more likely not to feel as much of a sense of belonging to technology-rich and engineering spaces as students who are better served in their communities.

Assumptions about Pedagogical Approaches

Further, while hands-on learning in engineering education has positively impacted student learning, we need to acknowledge that the level of effectiveness might differ for different students. Similarly, active learning has been hailed as highly beneficial for student learning; however, students from minoritized backgrounds are more likely to experience higher levels of stress in active learning environments than students who come from privileged backgrounds (Hood et al., 2020). Hands-on learning in technology-rich settings comprises several aspects of active learning, including thinking and working in teams, which requires having one's voice heard and developing a rapport with one's teammates and classmates. We have known from decades of research and narratives from classrooms that race relations, gendered language and actions, and social and economic capital present themselves in classrooms and learning environments, impacting how young people work with each other (Leath et al., 2019; Vogler et al., 2018).

Impact of Those in Charge

Fueled by a combination of educators' self-efficacy of using technology and teaching engineering as well as flawed perceptions of who engineering is for (e.g., high performers in math and science), we as educators may also be gatekeeping students outside of engineering (Kjällander et al., 2018; Manfra & Hammond, 2008; Ring, 2021; Shinnick, 2019). Technological pedagogical content knowledge (Mishra & Koehler, 2006), which refers to teachers' knowledge for supporting the successful use of technology in teaching, is significantly affected by teachers' self-efficacy toward technology use and how easy they perceive it is to use technology (Joo et al., 2018). Consequently, teachers' technological pedagogical content knowledge impacts how they use technology in formal and informal engineering learning settings. Further, working with hands-on technologies, which often constitute the maker culture, has a long history of promoting exclusive behavior. Some of these behaviors include differentiating between those who make and those who do not (Chachra, 2015), exacerbating gender stereotypes (Quattrocchi, 2013), and using technology as capital to build rifts between those who have access to it and those who do not (Morozov, 2014).

https://doi.org/10.7771/2157-9288.1419

Thus, beyond access to resources in and out of school, factors such as students not experiencing a sense of belonging, assumptions about the efficacy of pedagogical practices especially for minoritized students, and gatekeeping by adults with whom students engage all adversely impact students' engagement with engineering.

CONCLUSION

When promoting hands-on engineering pedagogies, careful consideration of who is being served needs to be taken into account. While there is an appeal to think of technology as the great equalizer wherein access to technology can itself promote liberatory engineering learning in K–12 settings, in this short essay we argue that student learning cannot be separated from sociopolitical context. It is our hope that this essay starts to shed light on some aspects that are often hidden in the creation and use of learning materials for K–12 engineering education. Considering these and other factors in the design and development of educational programs may help us consider context not just in how we frame engineering problems but also in the contexts in which learning takes place.

At the beginning of this essay, we asked *hands-on for whom*? Unfortunately, our current response would be hands-on for students with high economic and social capital. This is often attributable to familial background, and while there are ways to support students from minoritized groups by appropriate pedagogies, supportive mentoring, and creating spaces for students to develop a sense of belonging, such work requires systemic change beyond pedagogy.

ACKNOWLEDGMENTS AND FUNDING

This manuscript is motivated by extensive work in the field of sociology of education. We would like to express gratitude to all the individuals and communities who have done work to help expand our understanding of educational systems.

This work was supported by the National Science Foundation (CAREER-EEC-2237371).

AUTHOR BIOS

Isabella Stuopis is a postdoctoral research associate in the Human-Centered Engineering Program at Boston College. Email: stuopis@bc.edu.

Avneet Hira is an assistant professor in the Human-Centered Engineering Program and the Department of Teaching, Curriculum & Society (by courtesy) at Boston

https://doi.org/10.7771/2157-9288.1419

College. She is also an affiliate faculty of the Schiller Institute for Integrated Science and Society. Email: hiraa@bc.edu.

REFERENCES

Avraamidou, L., & Schwartz, R. (2021). Who aspires to be a scientist/who is allowed in science? Science identity as a lens to exploring the political dimension of the nature of science. *Cultural Studies of Science Education, 16*(2), 337–344. https://doi.org/10.1007/s11422-021-10059-3

Baker, B. (2019). *Does money matter in education?* (2nd ed.). Shanker Institute. https://www.shankerinstitute.org/resource/does-money-matter-education-second-edition

Banilower, E. R., Smith, P. S., Malzahn, K. A., Plumley, C. L., Gordon, E. M., & Hayes, M. L. (2018). *Report of the 2018 NSSME+*. Horizon Research, Inc. https://eric.ed.gov/?id=ED598121

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin, 117*(3), 497–529. https://doi.org/10.1037/0033-2909.117.3.497

Bingimlas, K. A. (2009). Barriers to the successful integration of ICT in teaching and learning environments: A review of the literature. *Eurasia Journal of Mathematics, Science and Technology Education, 5*(3), 235–245. https://doi.org/10.12973/ejmste/75275

Chachra, D. (2015, January 23). Why I am not a maker. *The Atlantic*. https://www.theatlantic.com/technology/archive/2015/01/why-i-am-not-a-maker/384767/

Diaz, A. (2019). *Tutoring as a form of cultural capital: A qualitative study* [Doctoral dissertation]. California State University, Fullerton. ProQuest 27548774.

Dika, S. L., & Singh, K. (2002). Applications of social capital in educational literature: A critical synthesis. *Review of Educational Research, 72*(1), 31–60. https://doi.org/10.3102/00346543072001031

Engineering Is Elementary. (2020). *EiE® Curricula for Grades PreK–8*. https://www.eie.org/stem-curricula/engineering-grades-prek-8

Hetling, A., Porumbescu, G., Holcomb, S., & Trehan, V. (2022, January 19). *State efforts to close the K–12 digital divide may come up short*. The Conversation. http://theconversation.com/state-efforts-to-close-the-k-12-digital-divide-may-come-up-short-173977

Hood, S., Barrickman, N., Djerdjian, N., Farr, M., Gerrits, R. J., Lawford, H., Magner, S., Ott, B., Ross, K., Roychowdury, H., Page, O., Stowe, S., Jensen, M., & Hull, K. (2020). Some believe, not all achieve: The role of active learning practices in anxiety and academic self-efficacy in first-generation college students. *Journal of Microbiology & Biology Education, 21*(1), Article 28. https://doi.org/10.1128/jmbe.v21i1.2075

https://doi.org/10.7771/2157-9288.1419

Jackson, V., & Johnson, N. (2021). *America's school infrastructure needs a major investment of federal funds to advance an equitable recovery.* Center on Budget and Policy Priorities. https://www.cbpp.org/research/state-budget-and-tax/americas-school-infrastructure-needs-a-major-investment-of-federal

Joo, Y. J., Park, S., & Lim, E. (2018). Factors influencing preservice teachers' intention to use technology: TPACK, teacher self-efficacy, and technology acceptance model. *Journal of Educational Technology & Society, 21*(3), 48–59. http://www.jstor.org/stable/26458506

Kalil, A. (2014). Inequality begins at home: The role of parenting in the diverging destinies of rich and poor children. In P. Amato, A. Booth, S. McHale, & J. Van Hook (Eds.), *Families in an era of increasing inequality: Diverging destinies* (pp. 63–82). Springer International Publishing. https://doi.org/10.1007/978-3-319-08308-7_5

Kjällander, S., Åkerfeldt, A., Mannila, L., & Parnes, P. (2018). Makerspaces across settings: Didactic design for programming in formal and informal teacher education in the Nordic countries. *Journal of Digital Learning in Teacher Education, 34*(1), 18–30. https://doi.org/10.1080/21532974.2017.1387831

Leath, S., Mathews, C., Harrison, A., & Chavous, T. (2019). Racial identity, racial discrimination, and classroom engagement outcomes among Black girls and boys in predominantly Black and predominantly White school districts. *American Educational Research Journal, 56*(4), 1318–1352. https://doi.org/10.3102/0002831218816955

Manfra, M. M., & Hammond, T. C. (2008). Teachers' instructional choices with student-created digital documentaries: Case studies. *Journal of Research on Technology in Education, 41*(2), 223–245. https://doi.org/10.1080/15391523.2008.10782530

Master, A., & Meltzoff, A. N. (2020). Cultural stereotypes and sense of belonging contribute to gender gaps in STEM. *International Journal of Gender, Science and Technology, 12*(1), Article 1. https://genderandset.open.ac.uk/index.php/genderandset/article/view/674

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Morozov, E. (2014). Making it. *New Yorker*. http://www.newyorker.com/magazine/2014/01/13/making-it-2

National Academies of Sciences, Engineering, and Medicine. (2020). *Building capacity for teaching engineering in K–12 education*. National Academies Press.

National Research Council. (2009). *Engineering in K–12 education: Understanding the status and improving the prospects*. National Academies Press.

National Survey of Science & Mathematics Education. (2013). *2012 NSSME*. Horizon Research. https://horizon-research.com/NSSME/2012-nssme

National Survey of Science & Mathematics Education. (2018). *2018 NSSME+*. Horizon Research. https://horizon-research.com/NSSME/2018-nssme

https://doi.org/10.7771/2157-9288.1419

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* https://scholar.google.com/scholar?q=next+generation+science+standards&btnG=&hl=en&as_sdt=0%2C15#3

Ozis, F., Pektas, A., Akca, M., & DeVoss, D. A. (2018). How to shape attitudes toward STEM careers: The search for the most impactful extracurricular clubs. *Journal of Pre-College Engineering Education Research (J-PEER), 8*(1), Article 3. https://doi.org/10.7771/2157-9288.1192

Papert, S., & Harel, I. (1991). Situating constructionism. *Constructionism, 36*(2), 1–11. https://web.media.mit.edu/~calla/web_comunidad/Reading-En/situating_constructionism.pdf

Project Lead the Way. (2023). *High school engineering curriculum grades 9–12.* Project Lead the Way. https://www.pltw.org/curriculum/pltw-engineering

Quattrocchi, C. (2013). *MAKE'ing more diverse makers*. Ed Surge. https://www.edsurge.com/news/2013-10-29-make-ing-more-diverse-makers

Reardon, S. F. (2018). The widening academic achievement gap between the rich and the poor. In D. B. Grusky (Ed.), *Social stratification* (4th ed., pp. 536–550). Routledge. https://doi.org/10.4324/9780429494642

Rideout, V. J., & Robb, M. B. (2021). *The Common Sense Census presents: Research brief; Remote learning and digital equity during the pandemic*. Common Sense Media. https://www.commonsensemedia.org/sites/default/files/research/report/final_release_digital_equity_research_brief_fact_sheet.pdf

Ring, J. (2021). *Re-tooling the sisterhood: Conceptualizing "meaningful making" through maker culture, makerspace politics, and feminist "little m" making-as-activism* [Doctoral dissertation]. Carleton University. https://doi.org/10.22215/etd/2021-14845

Shinnick, S. (2019). *Stories in the making: A phenomenological study of persistent women tech-makers in co-ed community makerspaces* [Doctoral dissertation]. Pepperdine University. https://digitalcommons.pepperdine.edu/etd/1060/

Taylor, B. (2016). Evaluating the benefit of the maker movement in K–12 STEM education. *Electronic International Journal of Education, Arts, and Science (EIJEAS), 2*, 1–22. http://www.eijeas.com/index.php/EIJEAS/article/view/72/85

Teach Engineering. (n.d.). *What is engineering?* Retrieved September 25, 2023, from https://www.teachengineering.org/k12engineering/what

Vogler, A.-M., Prediger, S., Quasthoff, U., & Heller, V. (2018). Students' and teachers' focus of attention in classroom interaction: Subtle sources for the reproduction of social disparities. *Mathematics Education Research Journal, 30*(3), 299–323. https://doi.org/10.1007/s13394-017-0234-2

Weiner, S., Lande, M., & Jordan, S. S. (2018, June 24–27). *What have we "learned" from maker education research? A learning sciences-base review of ASEE literature on the maker movement* [Paper presentation]. 2018 ASEE Annual Conference & Exposition, Salt Lake City, Utah. https://peer.asee.org/31235

https://doi.org/10.7771/2157-9288.1419