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Critical Technology Integration in Pursuit of a Liberatory Engineering Education

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Abstract

When designing an engineering curriculum for K-12 or higher education students, it is important for us to continuously ask two questions. When does technology integration enhance or hinder our students' ability to thrive as humans and potential future engineers? What does it take to balance technology with authenticity? The purpose of this paper is to provide readers with a front row seat to one educators' reflection on her evolving understanding of the nuances of determining when technology in engineering education can be liberatory and enhance human flourishing using current literature as well as her positionality and diverse experiences in the field of education. Readers should be able to engage with key questions for reflecting on the relationship between human flourishing and technology integration, consider how to support engineering educators' development of judgment for technology integration, and take an opportunity to reflect on their own context and evolving understanding of a liberatory engineering education.

Introduction

Educational scholar Dr. Bettina Love relentlessly advocates for the urgent need for abolitionist teachers who can design curriculum and educational experiences for our students that are liberatory in nature.[1] A liberatory engineering education has the potential to empower our historically underrepresented and racially minoritized students to be the kind of engineers who will collaboratively strive for a just world and solve humanity's most pressing problems.[2] Technology integration in engineering curriculum can either aid or hinder students' ability to thrive as humans as well as potential future engineers. After years of seeing the ways technology can be integrated into contexts of all shapes and sizes in K-12, it is clear that engineering educators need to critically evaluate the potential impact of classroom technology integration.

Engineering education can look vastly different from one school district to another. For example, some schools may have designated engineering classes while others incorporate engineering concepts and practices into computer science, technology education, STEM, and/or STEAM (science, technology, engineering, the arts, and mathematics) pathways. Others focus on integrating engineering practices into core subjects like science. Regardless of the grade level, course name, or area of expertise; engineering educators must carefully consider the tradeoffs and synergies of technology integration through the lens of broad, liberatory student outcomes that move beyond academic achievement alone.

Author positionality

Education is political, and it can never be objective or neutral.[3] Educational researchers in particular need to interrogate our positionality[4] by asking three questions. Why this? Why now? Why me? My unique identity constellation, my experiences, my values, and my context are all relevant to this work. I am a woman with a privileged racial identity who is a graduate student at a predominantly white institution. I approach this paper from the perspective of a former middle school science teacher, department chair, instructional coach, science content facilitator, and school leader. My introduction to engineering education outside of STEM integration and incorporating engineering practices from the Next Generation Science Standards occurred during my first year as a classroom teacher. In an effort to increase engineering occupational identity in our feeder pattern, my school administration recruited me to partner with a city-wide STEM alliance to build an after school engineering club as well as to pilot engineering-specific curriculum in my science classroom.

As I transition to educational research and teacher education in higher education, I have worked on state and federal grants that support STEAM, computer science, and engineering education in third through eighth grade classrooms. I also incorporate critical technology integration and engineering education practices for preservice teachers in my master's level science methods courses. I ground my work in my commitment to continuously grow, learn, and unlearn in pursuit of the opportunity for a liberatory education for all students. Liberatory educational scholars including but not limited to bell hooks, Paulo Friere, and Bettina Love provide the blueprint for my own pedagogical practice.

Engineers of 2030 need the tools to achieve academically as well as to communicate effectively, grow personally, critically evaluate tradeoffs and synergies, and gain access to pathways of opportunity in the field.[5,6] One step towards a liberatory engineering education is for us as educators to realign our philosophy of technology integration in "pursuit of educational freedom."[1] All students deserve to thrive, not just survive.[1]

What is a liberatory education?

Practitioners and scholars of liberation have used different language to describe the concept of liberation praxis and theory in education. Brazilian educator and philosopher Paulo Friere in *Pedagogy of the Oppressed* defines "the oppressed" as people working together to fight for their own freedom.[7] Friere argues that a liberating education leads to freedom while rejecting education that is dominating and views children as empty vessels to be filled with knowledge by expert educators.[7] Instead, a liberatory education encourages learners to construct their knowledge.[7] "Authentic liberation- the process of humanization- is not another deposit to be made in men. Liberation is a praxis: the action and reflection of [people] upon their world in order to transform it".[7]

For feminist, anticolonial, critical, and liberatory educational scholar bell hooks, learning can be both a "practice of freedom" and a tool for liberation.[3] hooks insists that "the classroom remains the most radical space of possibility in the academy."[3] In *Teaching to Transgress,* she encourages educators to pay attention, ask questions, and push boundaries in the struggle for freedom and liberation.[3]

The works of Barbara Love and Keith Edwards contribute to the literature on liberatory education by offering frameworks for educators who want to develop a liberatory consciousness and aspire to allyship.[8,9] Edwards describes a conceptual model that can be used as a tool to move through the identity development of an aspiring social justice ally from "self-interest" to "altruism" to "social justice" while grappling with tensions between intent and impact, self-identification, and the non-linear path of allyship.[9] Love, on the other hand, defines liberation in the context of liberation workers like educators. Educators who are liberation workers are those who are, "...committed to changing systems and institutions characterized by oppression to create greater equity and social justice- a crucial step in the development of a liberatory consciousness."[8] Love's conceptual model of liberatory consciousness includes four elements: awareness, analysis, action, and accountability/allyship.[8]

Jalali and Matheis argue that liberatory praxis and theory are directly connected in the process of fostering critical thinking in engineering education.[10] Engineering educators can also use liberatory praxis and theory to design an educational experience that is liberating. A critical lens must be used to evaluate the tradeoffs and synergies of technology integration in the K-12 and higher education engineering classrooms.

Underrepresented and racially minoritized students in engineering

Koh and Rossmann trace some of the history of the role of engineers in enacting violence against minoritized populations in particular.[11] It is clear that there has always been a relationship between systems of domination and engineering education.[11] Engineering educators are preparing future leaders who will have the knowledge and power to create technology that can be used to enact violence or dismantle systems of oppression.

Practitioners and researchers with intentions of improving the STEM "pipeline" for underrepresented and racially minoritized students often fall into the trap of focusing on providing additional support or resources for students rather than dismantling the structural racism and systemic inequities perpetuated by institutions.[2]

A better analogy to the pipeline is the popular cartoon by Craig Froehle often used to contrast different definitions of equality. The modern Internet went to work adapting the image to explain the difference between equality and equity using people of different heights trying to view a baseball game over a fence barrier.[12] Other artists have since modified the original cartoon to illustrate liberation (tearing the fence down altogether), or a more accurate presentation of reality that situates uneven ground as the problem rather than pathologizing the shorter baseball fan as a problem simply needing more resources. The analogy of representing underrepresented and racially minoritized students on uneven ground rather than shorter than their peers disrupts deficit-based thinking in education.[4]

The point is that simply throwing resources at underrepresented and racially minoritized students in engineering does not equate to liberation. Liberation involves understanding structural racism and other isms are the problem (in this analogy, the uneven ground) and barriers (the fence) like cultural stereotypes[13] need to be dismantled.

Underrepresentation is often intersectional.[14] Students with dis/abilities are often underrepresented in STEM and engineering.[15] Universal Design for Learning (UDL) is a framework that can be applied to technology integration in order to embrace learner variability and dismantle barriers for learning.[15] UDL calls for multiple means of engagement, representation, action and expression.[16] Early critiques of the UDL framework highlighted a weak connection to social justice and liberation.[16,17] When UDL is used in combination with Vygotsky's idea of funds of knowledge and the work of the aforementioned liberatory education scholars, it has the potential to transform technology integration into a tool for liberation.[18, 7,1,3]

Moving beyond technology integration frameworks to critical technology integration

Like education, technology is never objective or neutral. In fact, it is often political, and context matters.[11] For example, algorithms used for the latest technology in facial recognition and predictive software can reproduce and reinforce inequities.[19,20] Despite the growing criticism of algorithms used to reinforce systems of oppression,[19,20] algorithms and computational thinking practices can also be tools for liberation. Coding literacy is considered a critical literacy for all students.[21] The International Society for Technology in Education released standards intended to be a roadmap for educators to move from "teaching with technology to using technology to empower learners."[22] Standards for instructional design are also organized into competencies.[23] However, critical technology integration is not solely based on competencies but honing judgment and knowing which lens to use to analyze one's purpose for integration.

There are a number of practical frameworks educators can use as tools to overcome common challenges to technology integration in engineering education,[24] classify active learning methods,[25] build teachers' capacity to integrate content and technology,[26] and determine the level of technology needed to improve various student outcomes.[27] However, these tools are often aimed towards student academic achievement outcomes alone.[28]

Two frameworks often cited by educational technology researchers include the technological pedagogical content knowledge (TPCK) and substitution, augmentation, modification, and redefinition (SAMR) frameworks.[29,26] TPCK is a theoretical framework for educator knowledge originally developed by Punya Mishra and Matthew Koehler.[30] Their framework describes the type of complex and situated knowledge needed for educators to effectively integrate technology.[30] Mishra and Koehler describe a point of intersection between three types of complex knowledge; pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge. The intersection is technological pedagogical content knowledge or TPCK which is a necessary relationship between content, pedagogy, and technology for educational technology integration to lead to student understanding.[30] Practically, the researchers argue that this framework accounts for the "rapid rate of technology change" as well as "the situated nature of learning."[30]

Ruben Puentedura's SAMR framework can be used as a tool for engineering educators to analyze the function of current technology integration as well as apply the framework to emerging technologies. The first strategies in the framework are considered technology "enhancements". Substitution describes technology that can act as a direct replacement for another way of doing something that does not change the functionality.[29] The most common example of substitution in an engineering education setting is swapping out pen and paper for technology like typing. In my classroom, this looked like using Chromebooks to type up reflections after engaging in engineering design challenges rather than writing them with pen and paper. A Chromebook can be used for so much more than word processing, but educators are only using this technology at the level of substitution if the task remains unchanged. This is not inherently harmful for students if the goal is efficiency or familiarizing them with word processing software. The technology integration, however, does not enhance engineering learning objectives.

Augmentation is also an "enhancement" element of the SAMR framework. Unlike substitution, augmentation provides some kind of improvement in functionality.[29] In engineering education, augmentation strategies may allow for a task to become more student centered. In my classroom, I often designed scavenger hunts that guided students through the process of safely using search engines to understand a topic rather than listening to a teacher-centered lecture on new material from me. This technology integration encourages students to do the "heavy lifting" of learning without drastically changing the level of rigor due to the amount of scaffolded guidance.

The remaining strategies of the SAMR framework involve increased sophistication and the possibility of transformation.[29] Modification is a technology integration strategy that allows the instructional designer to significantly redesign the task at hand.[29] A common example of modification in the engineering education context is using technology to make an abstract concept more tangible whether it be a window into the microscopic world or zooming out to a world larger than we can imagine in the universe. In my classroom, I often used technology to connect engineering ideas with content students were learning in their English Language Arts, Mathematics, Art, and Social Studies classes.

Finally, redefinition is a technology integration strategy that "allows for the creation of new tasks previously inconceivable."[29] Creation is the highest level on Bloom's taxonomy of educational objectives. [31] While there are less "common" examples of redefinition in the engineering education field, an example might be the use of multimodal elements to engage in digital storytelling. In my classroom, I encouraged my students to use digital storytelling to communicate their findings and seek feedback on their engineering designs. The process of redesigning curriculum gives engineering educators a space to critically reflect on how the task positions students in relation to their teacher and interrogate whether this snapshot of the learning environment and instructional planning is conducive to a liberatory education.

Using a technology integration tool like a Google Document (Google Doc) can fall anywhere from substitution to redefinition on the SAMR framework. One way to determine whether it is a substitution, augmentation, modification, or redefinition is to decide the level of Bloom's taxonomy of educational objectives[31] students will use.[29] A Google Doc that is used as a substitution for pen/paper does not move students beyond the "remember" level of Bloom's taxonomy[31]. When a Google Doc is used for augmentation, students may use it to increase their understanding and apply their knowledge. I used Google Docs in my classroom to provide quick, real time feedback to students. They can also respond to my feedback and comments in a way that increases their ownership in their learning. A Google Doc can also be a modification in the SAMR framework. For example, my students used the Google Suite including Google Docs to engage in aspects of the engineering process collaboratively. In this process, they move to analyzing and evaluating each other's ideas as they define the problem, develop models, plan investigations, analyze and visualize data, use computational thinking, design solutions, iterate, and communicate their findings.

Rather than looking at a specific technology integration tool like a Google Doc, it is also helpful to analyze a common engineering task using SAMR. All students need to be able to analyze, interpret, and visualize data as part of the engineering process. At the substitution level, this might look like using Microsoft Excel or Google Sheets to transform a handwritten table and graph into a digital one. This might even move to the level of augmentation if the software is used to make calculations or visualize the data three dimensionally. Technology integration for this task, in my classroom, moved to modification when students were able to use tools like EarthTime to analyze and evaluate data about issues of environmental justice and climate change on a larger scale in multiple regions in the world. At this level of technology integration, there is room for even more content integration like engineering, Earth Science, and data science in this example. In my classroom, redefinition for engineering data science skills looked like students engaging in citizen science initiatives where they collaboratively collected, analyzed, and visualized data with other students and scientists outside of the confines of our classroom.

There is room for substitution, augmentation, modification, and redefinition in engineering education. The SAMR framework can be used to build the judgment of educators. It is not limited to the instructional design process. SAMR provides an opportunity for engineering educators to make their thinking visible for students when it comes to making choices about technology integration. This level of transparency with students from early childhood to higher education models critical technology integration and sets the stage for a liberatory education where students and teachers are constructing knowledge together.

While the SAMR framework focuses on educational technology integration, the framework can be used by engineering students when engaged in the design process. SAMR provides a framework for students to consider the function and possible impacts of their creation. Technology integration in engineering can transform accessibility and the meaning making process for engineering students.

The Next Generation Science Standards (NGSS) includes engineering practices that can be integrated into standards and curriculum transdisciplinarily[32] or as needed to solve a problem or complete a task.[33,34] A body of research seeks to understand how to overcome barriers to integration.[35] While these barriers are significant, professional development alone will not lead to critical technology integration.

Integrating technology for technology's sake or a sense of obligation will not promote learning, or worse, it can cause unintended harm for students. Just because technology exists, does not mean it will add value for students. In K-12 education, there is often a push for one-to-one technology without considering how the technology will be used and supporting teachers to integrate it with a critical lens. During my first year in the classroom, our school received a grant that allowed us to purchase one iPad for each student in our building. I saw firsthand the way those iPads could both enhance and hinder student learning. For example, students may not be pushed to engage in dialogue with their peers or leverage their creativity when they can rely on iPads for answers. This is just one way technology integration can actually disempower students. On the other hand, iPads can be used to facilitate authentic collaboration with peers, connect students with experts in the field, expose them to applications and programs that mimic real world engineering skills, etc.

In order to move into critical technology integration rather than informed technology integration or creation, it is important to build awareness of historical context, examine possibilities for synergies and trade-offs,[36] interrogate positionality, apply a critical lens in the design and evaluation process, act with empathy,[37] and use creativity and design for liberation through technology integration. This process moves beyond theories and ethics into liberation praxis of reflection and action.[7] A liberatory education means students are flourishing and thriving, not just surviving.

Implications for Engineering Education

In order to begin the ongoing process of pursuing a liberatory engineering education, I am committing to and suggest the following for fellow engineering educators:

1. **Prioritize self-reflection:** we need to make interrogating our positionality and assumptions part of our ongoing practice. Praxis is both reflection and action. Self reflection is the first step towards transformative action. Anti-oppression work is ongoing. There is no checklist. There is no arrival. We need to check ourselves with questions like- Why this? Why now? Why me?

2. **Pay attention:** when we are in the room where decisions are being made, we need to pay attention to who has the decision making power. Who is being heard? Who is missing? How are tools of domination used to maintain the system (even if the intention is liberation)? After building awareness and engaging in analysis, move to action and aspiring allyship.

3. **Involve students in the reflective and analytic process:** our students are more than capable of metacognition. We can be transparent about our own thinking and empower them to co-construct a liberatory engineering education with us. Our students are the most powerful tool in interrogating whether our pedagogical practices lead to learning as a practice of freedom. Students can easily identify potential barriers and work collaboratively to solve problems.

4. **Technology integration frameworks can be helpful, but they are not enough:** we

need to consider holistic student outcomes beyond academic achievement that work towards the ultimate goal of a liberatory engineering education. Other objectives may include: critical thinking, creativity, personal growth, access to opportunities, social and political consciousness, etc. Historical and contemporary context matter. Consider aligning engineering standards with standards for social justice like Learning for Justice's Social Justice Standards from The Teaching Tolerance Anti-Bias Framework. [38]

5. **Balance technology with authenticity:** when we prioritize our own growth as humans and educators, our students can reap the benefits. Engineering curriculum at any level is essentially a combination of vision, goals, pedagogical practices, learning tools, and assessments of understanding. There is no reason why students should not take an active role in designing aspects of their learning experience and classroom culture. This process disrupts power structures and makes room for authenticity and transformative technology integration.

6. **Consider what it means to thrive, not just survive**: we need to understand what it means for our students to flourish as humans. What does it mean for us to flourish? Our students, like us, deserve to thrive and align their learning with their values.

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