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Exploring how Digital Technologies Can Support Co-Construction of Equitable Curricular Resources in STEM

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Abstract

The recent emphasis on engineering practices provides an opportunity for K-12 science and mathematics teachers to apply STEM concepts to real-world engineering design challenges (EDCs) for students (Next Generation Science Standards, 2013). We argue that engineering practices are more equitable when they are relatable to students and rooted in local experiences and social justice connections. There is promise in connecting middle school STEM teachers with minoritized engineers to achieve this goal. Digital technologies accessed through tablets can support teachers and engineers to form a community of practice (CoP; Lave & Wenger, 1991) and to collaborate, research, illustrate, and implement plans for equitable EDCs. We use a case study analysis to describe how two middle school STEM teachers and collaborating engineers use digital technologies within a blended community of practice to plan equitable EDCs using online collaboration and presentation tools. Teachers Kevin and Tania visually map their process of planning an EDC with professional engineers, creating connections between their middle school students, social justice issues, their own experiences, and content standards to create an EDC in which students were invested and motivated to devise solutions. The cases highlight how teachers adapted digital technologies to their needs to facilitate the co-construction of lesson plans with engineers.

Introduction

Society relies on individuals with expertise in science, technology, engineering, and mathematics (STEM) to situate challenges that affect human lives and devise innovative solutions to address them (Gutiérrez & Dixon-Roman, 2011). Innovations are more likely to be sustainable when challenges are addressed from multiple perspectives including those from diverse racial and cultural backgrounds, educational levels, and socioeconomic statuses (Hira, 2010; Gutiérrez, 2017). In the United States, there is a prevalent narrative of whom can be successful in STEM. Particularly in engineering, white males dominate the workforce, and racially minoritized students (i.e., Black, Indigenous, and Latinx students in economically disadvantaged urban or rural areas) report having difficulty seeing themselves in STEM because the content, processes, and professionals within STEM careers do not represent or relate to their own lived experiences (Joseph et al, 2017; Syed, Goza, Chemers, & Zurbriggen, 2012; Williams, 2013). Researchers have identified middle school as a time when students begin to form interests in careers, thus middle school teachers play a critical role in identifying ways to make STEM subjects more inclusive and personalized to diverse learners (Kier, 2013). One way that middle school STEM teachers can make engineering more inclusive is to connect their curriculum and their learners to diverse engineers who use STEM to design socially-just solutions for local communities. By creating a partnership with STEM professionals, teachers help reduce barriers for students by exposing them to professionals who they can identify with in terms of race, ethnicity, and gender. Further, STEM professionals can connect with minoritized students by sharing their own personal experiences and potentially serve as role models or mentors (American Association for University Women, 2010; Joseph, Hailu & Boston, 2017).

In addition to serving as role models, minoritized engineers are promising resources for supporting STEM teachers to design skills around students' real-world problems and craft contextualized career-related engineering design challenges (EDCs; National Research Council [NRC], 2012). An EDC is an open-ended problem posed to students that has multiple solutions (Wheeler, Whitworth, & Gonczi, 2014). The NRC (2009) asserted that engineering is a natural vehicle to teach important mathematics and science concepts, skills, and habits of the mind. EDCs have been introduced in K-12 education as practical methods for applying science and mathematics content (Next Generation Science Standards [NGSS], 2013). When designing personalized EDCs for students to explore and solve, teachers must purposefully connect their curriculum to their students and community-specific issues when designing open-ended engineering tasks for students to explore and solve (Barton & Tan, 2009; Esteban-Guitart & Moll, 2014). Berry and colleagues (2010) puts forth that when students engage in the practices of engineering design to solve relevant and applied problems, they are motivated to engage in producing solutions that represent the true nature of scientific inquiry. EDCs can encourage students to apply science and mathematics concepts in innovative ways to design solutions (Berry, Bull, Browing, Thomas, Starkweather & Aylor, 2010; Slaton, 2010). While EDCs are readily available online, teachers often lack the flexibility and time to meaningfully connect the community and students' interest to them (Bacow, Bowen, Guthrie, Lack & Long, 2012; Baker & Digiovanni, 2005; Christie & Jurado, 2009; Zyngier, 2003). Thus, teachers need support with developing EDCs that connect to their curriculum and motivate their students.

Given time constraints and locational distance between teachers and practicing engineers, a blended or virtual community of practice (CoP) is a promising structure for teachers and professional stakeholders to brainstorm, share ideas, reflect and improve upon practices (Hibbert, 2008; Lave & Wenger, 1991; Steeg & Lambson, 2015). Digital technologies that are flexible and accessed through tablets and mobile devices offer promise for teachers to collaborate with others and personalize curricular resources for students (Cook, Pachler, & Bachmair, 2011). Digital technologies have socio-material affordances that hold promise for liberating and transforming educational contexts as they provide users easy access to instant information and collaborations (Johri, 2011). Teachers, students, and committed professionals can access a myriad of representational materials (e.g., videos, blogs, and TED talks) that can shift the dominant narrative of STEM from white ethnocentrism to one that is more grounded in students' experiences or funds of knowledge (Aguirre, Turner, Bartell, Kalinec-Craig, Foot, Roth McDuffie, & Drake, 2012; Moll, Amanti, Neff, & Gonzalez, 1992; Powell & Frankenstein, 1997). For example, digital technologies can provide users with opportunities to ideate and share inspirations though visual mediators, concept mapping, and storyboarding as visual, non-verbal aids to learning that create equity in the classroom (Moazzen, Hansen, Miller, Wild, Hadwin, & Jackson, 2013; Poirier & Remsen, 2017; Schnittka, 2012; Silk, Schunn, & Cary, 2009). Teachers have used Google maps and virtual tours to engage students in more contextually-specific experiences that may better relate to their histories, values, and challenges than textbook-based instruction (Lamb & Johnson, 2010; Trautmann & MaKinster, 2010). Not only can digital technologies empower learners by allowing them to personalize their knowledge acquisition but they also enable students to find representations that reflect their own experiences regardless of perceived ability and normativity (Radford, 2003). It is perhaps these affordances that has tablet technologies labeled as *cultural resources* (Cook et al., 2011).

In addition to the affirming representational affordances digital technologies accessed through tablets may provide, their relational affordances illuminate their liberating power. Access to collaborative and interpersonal technologies, in addition to social network technologies, can facilitate processes that allow teachers and STEM professionals to co-construct opportunities that include students' perspectives when adapting curricula (Danielsson, Berge, & Lidar, 2017). Collaborative cloud-based tools support collective sense-making and discourses through discussions, storytelling, and ideations (Sfard, 2008). Digital technologies have semiotic potential of being a mediator between social justice and STEM, as current events, opinion editorials, persuasive essays and other curricular resources can support teachers in contextualizing student tasks and showing how STEM can be used to advocate for injustice in urban communities (Grant & Gillette, 2006; Gutstein, 2003; Khalil & Brown, 2015).

This case study expands the current knowledge base that is focused on how digital technologies are used within CoPs to personalize EDCs for minoritized students in STEM classes. Thus, this paper responds to the questions: How do teachers and engineers participate in a CoP using digital technologies found on tablets to plan engineering experiences that are personalized for students in STEM classes? We also inquire: How do teachers' online collaborations with engineers influence their perception of planning more inclusive engineering experiences for students? Through these two questions, we seek to describe how teachers developed their sophistication in sharing and how they developed their understanding of context, content, and pedagogy through cloud-based digital technologies featured on iPads.

An Equity-Focused Community Shaped by 'Place-Based' Technologies

This study is part of a three-year U.S. federally funded teacher professional development grant to bring a community of teachers, engineers, students, and university educators together to design equitable engineering opportunities for minoritized students in underresourced schools. Critical Race Design (CRD; Khalil & Kier

2017) provided the theoretical and methodological framework behind the professional development. The goal of CRD is to critically design equitable learning spaces for minoritized students. The guiding tenets of CRD include: 1) Empowering minoritized students by situating their everyday experiences and narratives as epistemological resources for solving culturally specific societal problems, 2) Attending to sociopolitical histories of minoritized students by taking a race-conscious approach to recruiting stakeholders who will serve as collaborators, 3) Iteratively re-directing and re-converging the interests of educational stakeholders with students' interests to design equitable STEM learning ecologies. For example, Hernandez, Morales, and Shroyer (2013) describe strategies that include connecting students' experiences to multiple representations of content, providing opportunities for students to use what they know to solve real world problems, fostering a positive collaborative climate between students, and using a variety of methods to support all students' individual success. When minoritized teachers believe in and practice strategies such as these, they are committing to grounding instruction in ways that are socioculturally and sociopolitically specific (Frank, Khalil, Scates & Odom, 2018; Gutiérrez, 2013)

CoPs have become prevalent in educational settings, as teachers can convene to share different interests and opinions around curricula and collaborate across schools and districts (Ardichvili, 2008; Barab, 2003; Lin, Lin, & Huang, 2008; Sailor & Roger, 2005). CoPs rely on the experiences of participants and a commitment to a common goal or outcome (Lave & Wenger, 1991). In the context of this study, teachers, engineers, and university STEM teacher educators were part of the community committed to planning inclusive, culturally responsive resources that broadened students' awareness and identification with engineering (Gay, 2002; Wenger, 1998). A CoP is defined by a group of individuals who have a shared domain of interest and who interact and engage in shared activities to achieve mutually agreed upon outcomes (Lave & Wenger, 1991). Community interactions develop over time and result in the creation of a shared repository of resources that they can utilize in their practice (Wenger-Trayner & Wenger-Trayner, 2015). CoPs may take different forms as participants may meet in person, online, and in a blended format (partially online and partially in person), and have the potential to extend teachers' knowledge and serve as transformative, sustainable professional development when the participants have purposeful goals and a commitment to outcomes (Fishman, Konstantopoulos, Kubitskey, Vath, Park, Johnson & Edelson, 2013; Lock, 2006; Vavasseur & MacGregor, 2008). CoPs facilitate the sharing of solutions to contextual problems, knowledge of best practices, and informative resources quickly and effectively (Wenger & Snyder, 2000). CoPs depend upon the engagement and practices of its community members and the values placed the shared activities and outcomes (Roberts, 2006).

Our study is part of a larger professional development CoP called *E-Communities*, funded through the National Science Foundation (Award #1510347). In this CoP, digital technologies accessed by tablets are integral to the professional development of all members. Collaborative and conceptual mapping technologies facilitate teachers' opportunities to co-design equitable EDCs in their lessons. The digital technologies that are introduced in CoPs are place-based, meaning they are shaped by social contexts entrenched with power dynamics and resource affordances (Prinsloo, 2005). While technologies enter a community (e.g., a school) with an intended use (e.g., to improve learning outcomes), users (e.g., teachers, engineers, and students) will shape the practices of the technology in different ways to meet unique contextual needs (Chao, Chen, Star, & Dede, 2016; Prinsloo, 2005). In the context of our study, teachers, engineers, and STEM educators joined *E-Communities* where the STEM educators selected digital tools that they believed would be most beneficial to collaborating and sharing knowledge between participants that facilitated collaboration. The unique population *E-Communities* lends itself to an exploration of how the technology was adapted between engineers and teachers to address the sociocultural needs of students (Prinsloo & Roswell, 2012).

Study Design

This study explored how two middle school teachers, two collaborating engineers, and STEM teacher educators communicated, ideated, and produced equitable EDCs in a blended CoP using selected digital technologies accessed by tablets and mobile devices (Hibbert, 2008). These teachers joined a professional development initiative developed by a university mathematics, science, and engineering teacher educator which facilitated the formation of the CoP with minoritized and engineers and middle school teachers. Participating teachers took part in a 12-hour synchronous online course with STEM teacher educators focused on creating inclusive EDCs and participated in asynchronous online reflections about the process (Teamy, 2016). Following this, teachers, engineers, and STEM educators came together to plan resources and lessons around four EDCs that they wanted to implement throughout the school year. Then, the community met synchronously online each month to share ideas, plan for their next EDC, and discuss successful implementations and challenges. Following each synchronous online meeting, teachers reflected through online discussion boards.

The development of equitable EDCs required teachers and engineers to use digital technologies to communicate and create together. Digital technologies included Zoom, Prezi©, Canvas discussion boards, and Google Docs which were frequently accessed by laptops, tablets, and cell phones. Teachers and engineers learned how to create resource maps that connected stories of the engineers to students' interests, social justice issues, and science and/or mathematics content (Teamey, 2016). Digital technologies can provide users with opportunities to ideate and share inspirations though visual mediators, concept mapping, and storyboarding as visual, non-verbal aids to learning that create equity in the classroom (Moazzen et al.,2013; Poirier & Remsen, 2017; Schnittka, 2012; Silk et al., 2009). All members of the community used Prezi© to create their maps, as all participants shared that they had used the tool before. Prezi allows for multiple participants (up to 10) to collaborate on the same platform to share visual ideas and build connections. Teachers selected engineers to create personalized connective maps that contained resources, questions, and images that students would use to consider problems and create solutions through engineering. The outcome of the experience was for each of the teachers to have completed Prezi© maps that featured all of the connections and resources for each EDC. The following sections elaborate on the intention behind teachers' resource maps to inspire equitable EDCs.

To begin the process of collaborative planning and resource mapping on Prezi, we (teacher educators along with STEM educator Paige Teamey) asked teachers to engage their students in activities and discussions that probe them to verbally reflect upon what they hope, fear, value, and how they see the world, inside and outside of school. We asked teachers to also engage in these discussions, share their personal experiences with their students, and openly reflect upon their own inspirations with students. We modeled this process using teacher questioning techniques, and examples of how to use current events to explore core values held by students. We created worldview surveys that they could use in their classes that elicited students' lived experiences and interests. We modeled how teachers could use asynchronous forums and survey sites to gather information from their students to understand their perspective on social justice issues and learn more about their interests and values. Teachers then used Prezi© to showcase and archive memorable connections that were made during these conversations with students.

Teachers were then asked to review their standards, curriculum and pacing guides to develop explicit connections between other concepts on their maps. We asked teachers to incorporate definitions, websites, embedded videos, and pictures into their maps. Teachers intentionally developed these connections to make challenges interdisciplinary and relevant to real-world events (Murata, 2002). Engineers created resource maps, storyboards, and videos about their careers and lived experiences and communicated these to teachers. Together they developed career-related connections to content and students. Teachers added all engineering concepts and student questions in the Prezi© and highlighted them with blue backgrounds. We then asked teachers to connect their resources to concepts that related to local, social justice issues that occurred in their students' community or that their students had discussed in class. CRD calls for educators to be committed to social justice issues, as it develops minoritized students' critical consciousness, particularly as it relates to systemic oppression within a community. By providing students the opportunity to learn more about community-based social injustices, and empowering them with the tools to design solutions, students' interests in solving social injustices can connect STEM content more closely to their lives and the broader minoritized communities (Leonard, 2008; Tate, 2001). Teachers proposed possible social justice connections based on either student worldviews or their knowledge of the local and broader community's issues. They used pictures and visual metaphors of place-based injustices to depict these connections on their maps.

Case Study Methods

We use case study methods (Yin, 1994) coupled with ethnographic approaches to study the way in which teachers and engineers worked together to plan teaching within and around equitable EDCs. We used comparative cases (Yin, 1994) of teachers who planned and enacted complete lessons with collaborating engineers using their students' interests. These teachers Kevin and Tania (both pseudonyms) enacted different practices and modes of participation to achieve their outcomes. Kevin, an eighth grade interdisciplinary STEM teacher, and Tania, an eighth-grade science teacher who co-constructed EDCs with engineers (a biomedical engineering and a medical physicist) in the larger CoP. We detail how teachers and engineers use digital technologies to facilitate the goals of the CoP and how they perceived the experience of using digital technologies to ideate, communicate, and create equitable student resources.

Data Sources/Analysis

Multiple data sources were drawn upon to construct the cases that describe the collaboration and products of teachers, engineers, and STEM educators. The mathematics and science educator and two graduate assistants took descriptive notes from each recorded synchronous online discussion between the teachers and engineers. The STEM educators captured each stage of Prezi© development and conducted follow-up interviews with Kevin and Tania to discuss their thinking behind each component of the resource map (Garrison, 2003). We also drew upon field notes during in-person professional development, asynchronous discussion forums around the development of each aspect of the Prezi©, and teacher and student artifacts from blog posts and handouts. Throughout the process, we were in constant communication with teachers as supporters and facilitators of the process and as researchers formatively assessing the outcomes in order to understand the meaning of some of the options taken (Lieberman, 1995; Schensul, 2008). We used this data to describe the tools and communication in co-constructing the EDC and to inform why Kevin and Tania made the decisions that they did in their task design (Swan, 2003). These sources were triangulated to depict the two descriptive cases (Yin, 1994), and then discussed in relation to how digital technologies were adapted by members of the community to accomplish outcomes for students.

Exemplary Case Studies

Kevin

Kevin is a 40-year-old Black male who taught an eighth-grade interdisciplinary STEM course, where students learn about the principles of engineering through experiences with robotics, computer science, and aerospace engineering. Kevin was a biomedical engineer for 1.5 years, and transitioned into the teaching profession through an alternative certification program offered by the county. He began his teaching career as a mathematics teacher before becoming an integrated STEM teacher. Kevin showed a passion for students that extended to other community activities including supporting his school's sports teams and teaching Sunday school for 2nd and 3rd graders. Kevin attended all face to face professional development meetings and all synchronous online meetings with teachers and engineers. He actively participated in both environments by communicating frequently and sharing his experiences and ideas about EDCs. While Kevin had exemplary ideas and inspirations on projects, he was provided extensive support by one of the STEM educators to share his resources and connections on Prezi© to the entirety of the community. Below describes how Kevin used digital technology to plan for and implement his lesson in the CoP, and how his collaboration with a STEM teacher educator allowed him to share these ideas via Prezi©. Kevin worked closely with Nancy (a pseudonym) a biomedical engineer and his students to develop his EDC: "Students will apply knowledge of mathematics, science, and engineering to design and build mechanisms that will carry water long distances."

Eliciting the Perspectives/Voices of Students

Kevin used a virtual discussion board in his class to learn more about his students and provide engineers with insight into his students' culture and worldviews. He asked students to share who/what was important to them and what they could not live without. Kevin submitted his students' interests in an asynchronous reflection on Canvas but was contacted by a STEM educator to map them onto Prezi© so that other members of the community could ideate with him.

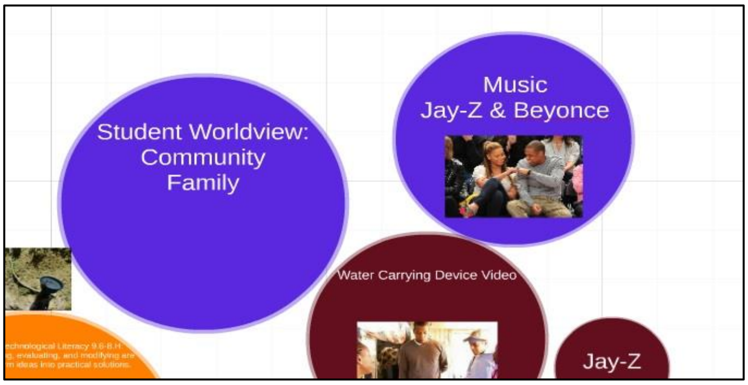

Figure 1. Kevin's worldview connections to students

The STEM educator supported Kevin to organize students' interests within Prezi©. Kevin's students shared that they "could not live without" family, friends, Jay-Z (popular rap musical artist), food, clothing and water. The student inspirations for Kevin's EDC is found in Figure 1.

Connections to Social Justice

During a virtual online meeting, Kevin shared with the community that he used his personal experiences to connect to his students' interests and values. Kevin explained in an online discussion post that he recalled seeing a video of Jay-Z interviewing people in Rwanda about their experiences living without access to clean water. To further support Kevin, the STEM educator emailed Kevin and helped him find the video on Youtube, which he then added to his Prezi© map. Also in a synchronous online session, Kevin discussed another event to help students understand why a community could lack access to clean water and how this would affect the people living there. He described how he could connect Rwanda to a more local water crisis in Flint, Michigan. Kevin told STEM educators that he would use infographics to show students the severity of the water crisis and to illustrate comparisons between a U.S. crises and other developing nations like Rwanda. In an online discussion board, Kevin shared his personal connection to Flint, Michigan and explained that his brother visited Flint, Michigan during the height of their water crisis, when high levels of lead and other toxins in the water that he experienced. Following this process of brainstorming, Kevin reflected via online discussion board:

> My brother is a pastor and took a trip to Flint, Michigan a couple of years ago, and his stories had a big impact on me. One of the things that I wanted to get across to the students is that not everyone is as fortunate as you all are. When I started showing the video about the water issue in Flint and Rwanda, many of them made connections with where their family members live in Central and South America in terms of their access to clean water and what they have to do to get to clean water. It was interesting to hear their conversations about political structures and questions like, 'Why do we have access to clean water and these people don't?

A STEM educator followed up with Kevin to brainstorm images that connected to his brother's stories of Flint. Kevin used online research and STEM educators supported him to place images of contaminated water on Prezi© and instructed students to use their iPads to find images that they related to Flint. Kevin's social justice connections are depicted in Figure 2.

Figure 2. Kevin's social justice connections to students' worldviews

Connections to Community-based Engineers

Kevin met biomedical engineer Nancy at an in-person professional development meeting when she shared her commitment to designing devices that help people. This commitment was also a passion for Kevin who previously served as a biomedical engineer. Nancy shared pictures with Kevin that showed her engineering prosthetics and designs of feeding devices for unborn babies. The engineer added her pictures to Kevin's Prezi©. Kevin followed up with Nancy in an online virtual meeting to discuss how economics plays in accessibility of materials. This discussion inspired their ideation of low-cost materials that students could use to prototype devices that could help transport water to underserved populations. This conversation influenced Kevin's pedagogical decisions to later emphasize the process of design through prototype development and creating clear connections to how engineers can address public health issues. Kevin's Prezi© that highlights his connection to his engineer is found in Figure 3.

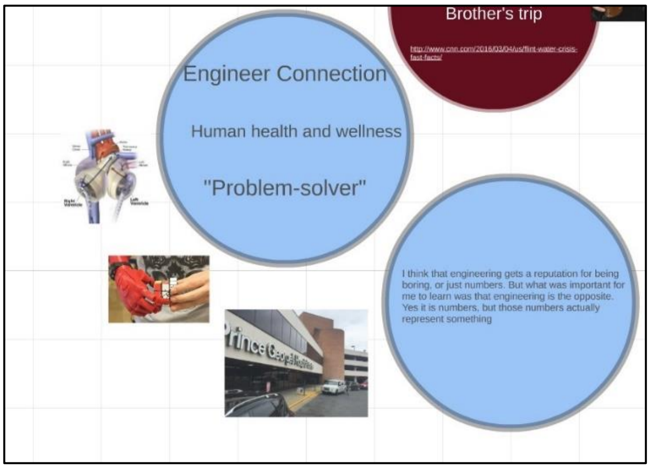

Figure 3. Kevin's connection to biomedical engineering

Content Connections

Kevin used online research to examine models of how water can be carried long distances. He put images, articles, videos, and web resources on Google Drive and shared them with a STEM educator who helped him add them to his Prezi©; Kevin used these representations as modeling resources for students. As demonstrated in his Prezi©, Kevin found examples of water carrying devices and of flowcharts that illustrated the engineering design process to inform his students' future designs. He allowed students to perform their research on the issue using their own devices. He emailed STEM educators again to share how his resources connected to formulas related to area, load dispersion, the density of materials used, and volume. modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions (Common Core State Standards of Mathematics [CCSSM], 2009). Kevin's content connections in Prezi© are shown in Figure 4.

Figure 4. Kevin's connections to mathematics and engineering content

Reflection of the Process

Through an online discussion board, Kevin thoughtfully reflected on the goals of the CoP and described how he was inspired by the process of co-designing a student-driven EDC using online tools. He realized that his project-based curriculum was not naturally connecting to students. While Kevin viewed himself as a professional with an expansive understanding of applied STEM concepts, he realized how important it is to connect his way of knowing with that of his students. He reflected on one of the professional development classes and explains:

> [The process] opened my eyes to designing something more relevant to what [students] needed. I wanted to focus on designing something with the 'user' in mind to develop empathy in my students through the design process, and this led to me picking a medium to show that through, which is water.

Kevin constructed his learning resources using more of his own knowledge and experiences rather than his engineer's experiences. Despite this, he acknowledged that "a good number of students have never met an engineer or scientist." He shared a video of Nancy's experiences to his students and asked his students to write questions for her that he emailed to her and facilitated dialogue between them. The co-constructed Prezi© (See Figure 5) illustrates how a planning resource was constructed that drew concrete connections to students' perspectives, his engineers' stories, and his own worldview to support students in considering a problem of interest to them. In a small in-person focus-group, Kevin reflected on challenges that he had with the digital tools. He shared that his introduction to communicating online and sharing via Prezi was like "a trial by fire," and that he felt that it took time for him to transition to listening and others and speaking online. However, he eventually became comfortable with this and recognized that many professional developments were transitioning to online forums and that it was "becoming standard." Kevin further shared that even though he had used Prezi© before, he needed more instruction on how to use it in collaborative groups to plan for EDC. Kevin struggled to see how the tool could be used as a resource for implementation and saw it more as an afterthought. While he completed his map with a STEM educator, he felt he was never "clear in the purpose of how were using Prezi©."

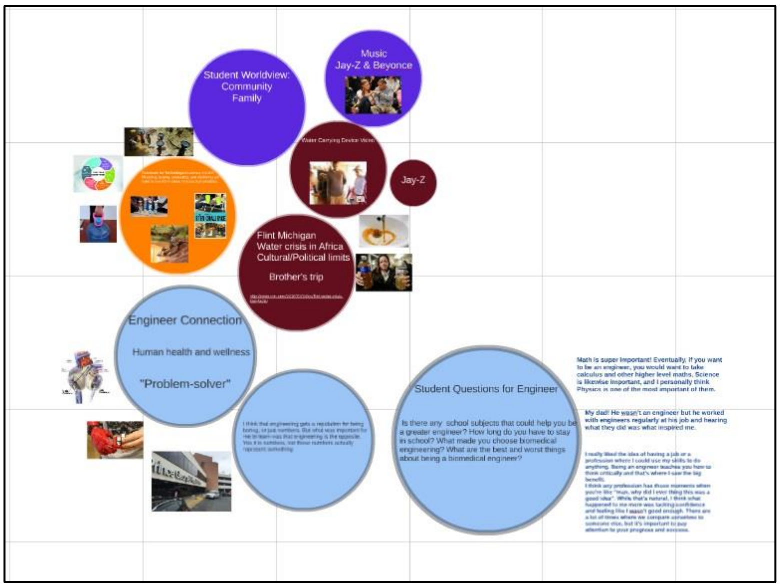

Figure 5. Kevin's complete Prezi© map

Tania

Tania is a 30-year-old Black female who teaches the eighth-grade science. Within this course, Tania teaches physical and chemical science principles to her students. Tania had been teaching middle school science for nine years. Tania's out of school interests and pursuits included photography and her doctoral degree in Science Education at a local Historically Black University. The following paragraphs describe how technology, particularly her own interests of photography and social media, helped Tania to implement digital literacy to research and develop the culturally specific EDC, "Create an energy source that can initiate and sustain motion of an object for nineteen seconds."

Eliciting the Perspectives/Voices of Students

Tania iteratively elicited, documented, and communicated the worldviews of her students through various strategies in planning and implementing her EDC, while sharing them with the CoP at each stage. Tania asked her students to create their own Prezi© maps, placing their names in the center and depicting three things that they love around them on their map. She asked students to break down these pictures into smaller words and phrases and connect these images to science. She encouraged students to stretch their imaginations and build as many connections as possible. Tania's passion for photography inspired her to engage her students in using technology to display visual connections. From her students' Prezi© maps (including her own), Tania found that they all valued family, friends, and food. One strategy that she used to elicit students' ideas was to give them time to blog about their values and their in-school and out of school interests. She also posted observations of her students during non-instructional time (e.g., "lunch time, hallway, when they were arriving to school or when they were dismissed or waiting for their buses") that she posted to the teachers' community discussion board. Tania reflected in an asynchronous online reflection:

> My students love food. They love to eat. They are constantly spending money to buy snacks, fast food and junk. Their adolescent metabolism allows for them to eat all the time. It is one of their favorite things to do. I wanted to help the students more readily connect food to energy, to truly understand why they eat. As energy drinks and iced coffee are fast becoming the new norm (for even middle schoolers), I want them to see the connection [to health and wellness].

Figure 6. Tania's connections to students

She added her students' representations to Prezi© and this process drove her line of inquiry in planning. Tania focused on students' love of food and prompted students to use Prezi© as a tool to organize ideas for a website that showed how they connected to their favorite foods. Students used imagery to illustrate both biological and sociocultural concepts such as images of their favorite food, captions or quotes of what they love about food, why they think food is important, short stories about their favorite or interesting food moments, food traveling throughout the body, and the economic impact of food choices. Tania pulled images and phrases from her students' map and websites on her Prezi©, seen in Figure 6. She shared images of food that her students' frequently consumed (e.g. depicting diverse fast food logos and 'junk food'), she used imagery to show them being metabolized. Her ideation of images led to her considering how food was transferred through the body and the amount of energy that was gained through different foods and caloric intake.

Connections to Social Justice

Tania used online research to find and display infographics on Prezi© that portrayed the obesity epidemic across the United States. She posted the questions that she would use during instruction to facilitate students' research for their website. These questions included: What are some issues with our food supply and public health? How does food accessibility impact diet and well-being? How are we trying facilitate access to more food and energy (e.g., alternative energy sources)? The connections that she makes to social justice are found in Figure 7.

Figure 7. Tania's connections to social justice issues

Connections to Community-based Engineers

Tania used an iPad to access and watch engineers' videos and read their storyboards. It was through this process that she connected her lesson to King (pseudonym), a medical biophysicist. Tania purposefully selected to work with King during face-to-face professional development meetings where they discussed how she could incorporate her own love of photography and imagery to his career, and to her students' interest and knowledge. She saw that King developed and used tools that showed images of energy being transferred through the body. She wanted her students to consider this movement, and featured pictures on her Prezi© so that could demonstrate energy transfer and illustrate the movement of this energy. King built upon Tania's ideas of social justice connections and virtually shared with her that his imaging tools allow doctors to see how toxins in our food can interrupt and impede healthy bodily function. The radiology images inspired Tania to think of a design challenge that could connect healthy eating to the mechanics of the body. She explained:

> I had a good conversation with my engineer and was inspired [for this design challenge] by his work in healthcare, technology, and his work with imagery. I use all of these concepts in my instruction and I use them readily to connect with what my engineer does. I love photography, again, and this enabled me to make further connections.

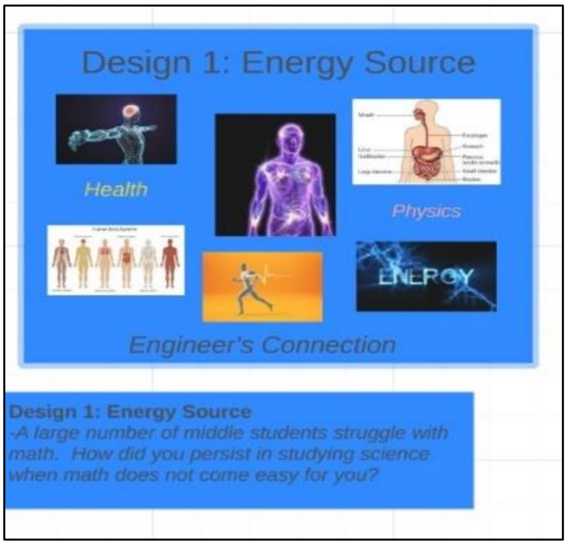

Figure 8. Tania's connections to engineering

Tania added King to her Prezi© to share her students' perspectives and interests. In person, King and Tania discussed how it would be interesting to emphasize public health in her design challenge. Tania brainstormed ideas of the many biopsychosocial and socio-economic implications of the consumption of food and added the ideas to her Prezi©. These connections are seen in Figure 8.

Content Connections

Tiana used her curriculum on body systems and energy transfer to research the role of food as energy in the body. She added research links and images to her own Prezi© that could support students in their own research. She listed questions such as: Why do we need to eat food? What are the different types of food (nutrients)? What are some of the different diets around the world? What are some of the pros and cons for each diet? Why do some diets work? Why don't they work? What are technological innovations within the food industry? How has food changed in the past 20 years? In the past 50 years? She saw clear connections to the NGSS (2013) MS-LS1-7: Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism. Tania wanted to bring to life an abstract concept, which led to her prompt for students to design an energy source that can initiate and sustain motion.

She began forming mathematical connections on her Prezi© that she found to be important to her own teaching and to students' future conceptualizations of prototypes. These concepts including calculating calories, volume, area, and facilitation of energy transfer. She also wanted to depict how calories could be thought of as a budget regulated by nutrition and exercise. Tania used her collaboration with King and her students to develop learning resources around an EDC related to food and energy. Her EDC was contextualized around energy transfer in the body and moving objects different places efficiently. She pictured representations of motion on her Prezi©, to inspire students in the design of their prototype. One of Tania's content connections can be seen in Figure 9.

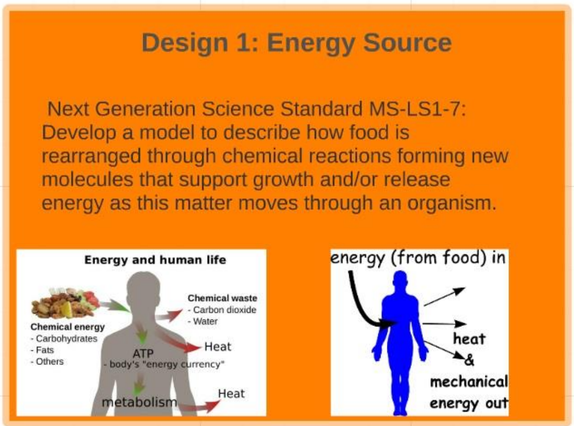

Figure 9. Tania's connection to content

Tania used one Prezi© to make connections for all of her engineering design challenges. Her inspirations are found in Figure 10.

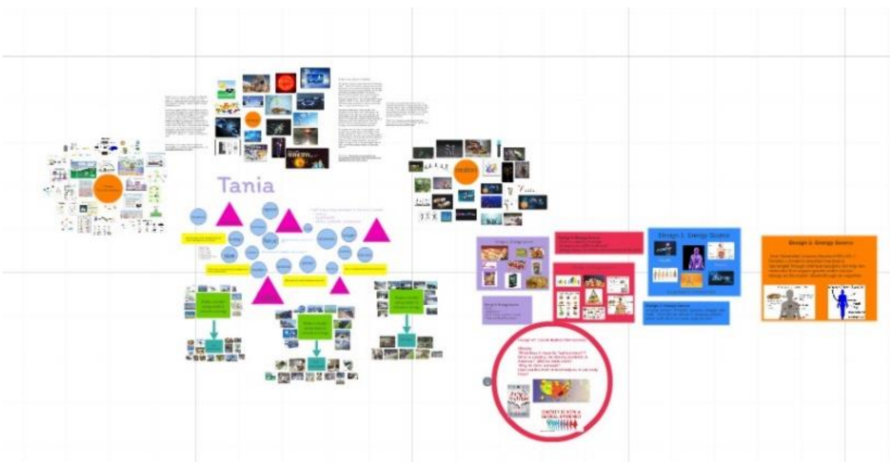

Figure 10. Tania's complete Prezi©

Reflection of the Process

Tania was motivated to design an EDC for her students and believes that their engagement in science is critical to learning disciplinary concepts. She believes that technology facilitates connections to their life, and "can help scaffold learning...inquiry, and critical thinking." The process of using a tablet to map connections helped her to re-engage with her curriculum. She wrote in a discussion board reflection:

> [The process] supported my development to focus on a systems mindset. I was more protocol. You can implement a lot of different concepts into each other and helped me to incorporate big idea thinking. [My resource map] helped me when I presented to my students so that when we had conversations I could pull [resources]. I was no longer focused on just covering the standard independently and by themselves. I could incorporate things that I didn't necessarily teach but they learned over the years.

As much as Tania enjoyed imagery and photography, she had only used Prezi© as a presentation tool for slides, and had never mapped or collaborated with others within the technology. She admitted that she was challenged by Prezi© and at times, overwhelmed by revising connections that she made between students, content, social justice, and her engineer within the resource map. Tania reflected in a small focus group on why she valued the tool and placed effort into learning how to use it:

> I like that you can house everybody's ideas all in one place. The downside is that working with others who are not tech savvy, sometimes they can accidentally delete things. I also really like that you can look at revision history. Overall, it was an interesting experience.

Discussion

Through this study, we described how two middle school teachers used digital technologies to engage in a CoP committed to centering learning on students' funds of knowledge (González, Moll, & Amanti, 2005) and to communicating this with stakeholders. Within the professional development and CoP, digital technologies accessed through tablets were intended to afford teachers, engineers, STEM educators, and students with rapid communication, sharing, and ideation to create equitable learning resources for minoritized students in the form of EDCs (Mumtaz, 2000). The STEM educators introduced teachers and engineers to a variety of tools during professional development including Zoom, Prezi©, and Google tools to share information and collaborate. Teachers developed their equitable challenges over time, and the structure of the CoP created opportunities for teachers to have ongoing support and time to share successes and failures (Courduff & Szapkiw, 2015). Despite experiencing the same professional development in the CoP, Kevin and Tania utilized digital technologies to different extents and for different purposes to meet similar affordances for their students. The differences in how teachers participate with digital technologies evidence the nature of digital technologies being place-based and adaptable to the different social needs of individuals who use them (Prinsloo, 2005).

The CoP had many opportunities for collaborations and sharing of ideas. STEM educators developed asynchronous discussion boards, social media platforms, and held monthly online meetings to foster communication between stakeholders. We found synchronous and asynchronous online communication to be effective in developing social presence between teachers and engineers and in talking through ideas that applied in different contexts and required explanations (Tu & McIsaac, 2002). For this CoP, it was critical that we offered multiple platforms for teachers to communicate. Barab (2003) suggests that communication in a CoP will evolve based on the needs individual stakeholders and the tools available to them. Kevin communicated most frequently in large synchronous online groups, as he had a wealth of personal experience and content connections that he used to contextualize his design challenge. He was eager to share his knowledge verbally in synchronous online discussions and explain his connections between the components of design thinking. He participated in every online reflection and valued the process of drawing connections between students, social justice, and content to develop more relatable and contextualized designs. Tania chose to communicate less verbally in synchronous online meetings but engaged in multiple virtual meetings and emails with her engineer collaborator to learn more about how his work related to her curriculum and students Tania used camera applications on her tablets to share pictures of her students' ideas and her classroom space to her CoP. Her photos provided contextual information for teachers and engineers to understand each other and communicate more effectively (Martin & Martin, 2004). Studies have shown that visual storytelling and using art to inspire writing have supported students in developing their vocabulary, ability to describe and explain processes, their abilities to make arguments, and increase the amount of connections that they can form to other concepts and ideas (Andrzejczak, Trainin, & Poldberg, 2005; Sadik, 2008). While the online meetings were held specifically for engineers and teachers to plan, teachers and engineers also communicated outside of these meetings through their own email exchanges and virtual communications to share their experiences. Within this CoP with teachers and engineers, it was important for digital technologies that allow communication be flexible to allow for multiple modes of communication and different times depending on the preferences of individuals in the community.

Kevin and Tania also demonstrated different practices within their domain. Kenneth formed connections to his own experiences and used Prezi© as an archival tool to show his connections. The STEM educator facilitated this archival process and prompted Kevin to use these resources in his instruction such as the online video and the pictures that his engineer posted on his resource map. Tania however, engaged with Prezi© as a planning and implementation resource as she used the tool with her students to pursue her line of inquiry about how content related to the personalized histories and the culture of her students (Cook et al., 2011). Both teachers incorporated technology and professional development models into their own classrooms when asking students to communicate their perspectives and interests. Kevin incorporated online discussion boards. In addition to Prezi©, Tania used a student website assignment and blogging tools to more thoroughly understand how students perceived their food choices to affect their health, and how they perceived personal health to be related to issues of food access and economics in the community. These examples suggest that teachers are more likely to implement technology with their students when they have opportunities to see tools used in novel ways (MacDonald, 2008). Similar to others, the process of teachers engaging in their own online research supported students' online research in creating an engineering solution to a problem (e.g., Murata, 2002; Sandholtz, 2000). For both Kevin and Tania, their experience with digital technologies in the CoP supported a shift in their mindset about how to use students' experiences as pedagogical resources (Khalil & Kier, 2017; Courduff & Szapkiw, 2015).

While both teachers valued the goals of the CoP and committed to the process of forming deeper connections between their students and engineering practices, they placed different values on the purposes and roles of digital technologies. Within CoPs, it is important for all participants to have clear understandings of the purpose and functions of integrated digital technologies. The teachers were challenged by Prezi© and needed STEM educators to model all of the tool's collaborative capabilities, as they were less familiar with these functions. For Kevin, he did not use Prezi© as a tool for planning, and valued it less than Tania who committed to learning more about the tool's functionalities. This is a lesson learned for STEM educators as research asserts that technology used in community of practice must be purposeful and intentional (Ardichvili, 2008; Hsu, Ju, Yen & Chang, 2007). Kevin needed the support of another member of the community to prompt his development of Prezi©, as he negotiated the tool's purpose and function in his own professional development. One of the specific challenges that Kevin faced with Prezi© was learning how to embed images and videos or remembering to include all of their research into the Prezi©. As important as it is for the technology to be flexible and accessible, the community must be flexible as well to support different levels of participation, experience with digital technologies, and values placed on technology (Cook et al., 2011; MacDonald, 2008).

Kevin and Tania demonstrated teacher agency by tailoring the technologies to meet the needs of their student perspectives, content, and social justice. This process highlights that one practical method for making EDCs more relevant is by having teachers collaborate with stakeholders to connect their content to a larger story. This work is supported by research suggesting that students develop a deeper applied content knowledge when using digital storytelling and mapping tools (Sadik, 2008). Teachers and engineers purposefully sought intersections with sociocultural and sociopolitical values (e.g. water crisis in Flint, Michigan), and contributed in Prezi© to focus on and share new ideas. While we do not focus on the implementation of designs and student outcomes in this study, collaborative tools were also used to showcase students' prototypes to other teachers and engineers. Using cloud-based tools to share ideas addressed the challenge of meaningfully connecting community and students' interests into engineering design tasks (Bacow et al., 2012; Christie & Jurado, 2009).

In *E-Communities*, and in the case studies of Kevin and Tania, we explored how digital technologies were used to collaboratively plan, research, discuss, ideate, and revise ideas and inspirations for EDCs, in a strategy of lesson planning shown to improve both teacher and student development. The teachers each modeled their process differently, yet had the same end goal, which illuminates the potential power of these technologies to adapt to each learner. Through this process they showed a commitment to their students' interests and values, a particularly important quality for social justice teachers (Khalil & Brown, 2015). They exemplified that students' interests and values are important to both the problem and the solution, and diverse perspectives can help conceive the best contextualized outcome. Thus, teachers' assets and "accumulated wisdom of practice" (Ding, Jones, Pepin & Sikko, 2014, p. 407) could also inspire students of color to consider their own assets when conceiving solutions to EDCs. Teachers approached their mathematics, science, and technology standards though the students' vantage point and utilized the socio-material resources afforded by digital technologies to empathize with minoritized students' perspectives and community challenges. This process highlights a practical method to make engineering design tasks more culturally specific by having teachers collaborate with stakeholders by connecting their content to a larger story.

Conclusions and Implications

This study explored how two teachers used digital technologies to co-design more equitable learning opportunities for their students. We argue that these technologies, including content sharing technologies (e.g., blogs, Prezi©, Dropbox, wikis, podcasts), collaboration technologies (e.g., Google tools, Prezi©, Wikis, Blogs), social networks (e.g., Facebook), and interpersonal technologies (e.g., Zoom, Adobe Connect, chat tools) afforded *E-Communities*' stakeholders the relational and representational opportunities to iteratively discover, discuss, and disseminate educational resources to personalize STEM tasks. The findings showed how two teachers in a CoP used the same digital technologies to participate and produce outcomes differently. Findings also showed that teachers place different values on the use and purpose of digital technologies in CoPs and need time and practice to adapt to their use (Wenger-Trayner & Wenger-Trayner, 2015). Both teachers were equally committed to designing more equitable resources and pedagogies for their students but needed varying levels of support to integrate the technology in planning and implementation. For those facilitating professional development, integrating technology into a community of practice is a design challenge in itself. Ultimately, the participants in the CoP *and* the digital technologies must be flexible to include STEM professionals into planning resources for students. While intentions and outcomes may be clear for some members of the community, it is important to reiterate goals and the rationale for using digital technologies in practice. Digital technologies allow for communication across communities (e.g. schools and professional spaces) and need to be further explored to provide research-based guidance to others who hope to design equitable learning opportunities for all students (Conole & Dyke, 2004). Without digital technologies to facilitate communication between stakeholders, share images and stories, and ideate connections, we would not have been successful in including the voices of minoritized students and stakeholders within challenges to create equitable learning ecologies.

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