2020

Who Is Welcome Here? A Culturally Responsive Content Analysis of Makerspace Websites

Hannah Kye

Rowan University, kye@rowan.edu

Follow this and additional works at: <https://docs.lib.purdue.edu/jpeer>

Part of the [Bilingual, Multilingual, and Multicultural Education Commons](#), and the [Science and Mathematics Education Commons](#)

Recommended Citation

Kye, H. (2020). Who Is Welcome Here? A Culturally Responsive Content Analysis of Makerspace Websites. *Journal of Pre-College Engineering Education Research (J-PEER)*, 10(2), Article 1.

<https://doi.org/10.7771/2157-9288.1190>

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.

This is an Open Access journal. This means that it uses a funding model that does not charge readers or their institutions for access. Readers may freely read, download, copy, distribute, print, search, or link to the full texts of articles. This journal is covered under the [CC BY-NC-ND license](#).

Who Is Welcome Here? A Culturally Responsive Content Analysis of Makerspace Websites

Abstract

Makerspaces and maker education are widely seen as means to democratize science and engineering education. A small but growing body of scholarly work warns against this assumption and calls for an explicit focus on equity in makerspaces both online and in person. With an understanding of learning as a social and cultural process, this paper proposes that disrupting the cycle of racial and cultural inequity in science education requires makerspace educators and staff to ground their work in multicultural theories and practices. In particular, culturally responsive pedagogy (CRP) provides guidance for infusing science and engineering with equity approaches in order to cultivate both academic success and students' cultural identities. Recognizing the online world as a driving force of the maker movement, this paper reports the findings from a content analysis of twelve makerspace websites to determine the extent to which they address CRP in their guidance for the development and facilitation of makerspaces. Results indicate a low occurrence of the tenets of CRP and that guidance was not informed by existing literature in multicultural maker education. Recommendations include application of the framework of CRP in makerspaces and addressing both practical guidance for educators as well as recommendations for advancing scholarly dialogue regarding diversity, access, and equity in maker education.

Keywords

maker education, culturally responsive pedagogy, STEM education

Document Type

Research Article

Journal of Pre-College Engineering Education Research 10:2 (2020) 1–16

Who Is Welcome Here? A Culturally Responsive Content Analysis of Makerspace Websites

Hannah Kye

Rowan University

Abstract

Makerspaces and maker education are widely seen as means to democratize science and engineering education. A small but growing body of scholarly work warns against this assumption and calls for an explicit focus on equity in makerspaces both online and in person. With an understanding of learning as a social and cultural process, this paper proposes that disrupting the cycle of racial and cultural inequity in science education requires makerspace educators and staff to ground their work in multicultural theories and practices. In particular, culturally responsive pedagogy (CRP) provides guidance for infusing science and engineering with equity approaches in order to cultivate both academic success and students' cultural identities. Recognizing the online world as a driving force of the maker movement, this paper reports the findings from a content analysis of twelve makerspace websites to determine the extent to which they address CRP in their guidance for the development and facilitation of makerspaces. Results indicate a low occurrence of the tenets of CRP and that guidance was not informed by existing literature in multicultural maker education. Recommendations include application of the framework of CRP in makerspaces and addressing both practical guidance for educators as well as recommendations for advancing scholarly dialogue regarding diversity, access, and equity in maker education.

Keywords: maker education, culturally responsive pedagogy, STEM education

Introduction

Making and makerspaces are widely regarded as means to democratize science and engineering education. In a white paper on maker education, the White House stated, "Access to spaces with the right tools and mentors will help level the playing field for all Americans, particularly for girls and under-represented minorities" (Office of the Press Secretary, 2016). The statement responds to persistent gaps in science outcomes across lines of race, culture, and gender in terms of standardized test scores (National Center for Education Statistics, 2015), attitudes toward science, enrollment in high school science courses, earning college and graduate degrees in science (Lee & Luykx, 2006), and entrance into science occupations (National Science Foundation [NSF], 2017). For example, in 2015, White men made up 49% of scientists and engineers working in science and engineering occupations, Black men made up 3%, and Hispanic men 4% (NSF, 2017). The same study showed that White women made up 18% of scientists and engineers working in science and engineering occupations, while Black women made up 2% and Hispanic women another 2%. In response to these persistent patterns, national and state science standards have urgently called for more equitable learning opportunities for all students

(National Research Council [NRC], 2011), particularly those from groups that have been underserved by traditional approaches to science education (Next Generation Science Standards [NGSS] Lead States, 2013). For maker educators, this call requires attention to the design of inclusive educational settings and instructional methods that affirm learning as a social and cultural process (NRC, 2009).

As makerspaces multiply in schools, museums, libraries, and community centers, K–12 students increasingly encounter these informal learning environments as a context for learning science and engineering. These include both physical and online environments. Although making requires physical engagement with materials, much of the information about making resides online, and scholars have proposed “that platforms like maker-spaces should be seen as the physical counterparts of online content production and sharing platforms” (Pandey & Srivastava, 2016, p. 1). Institutions and organizations ranging from research universities and museums to grassroots do-it-yourself communities have makerspace websites where they provide ample, accessible, and road-tested guidance for educators interested in developing and facilitating maker experiences. A small but growing body of scholarly work calls for attention to equity as in-person and online makerspaces rapidly develop.

This interpretive study uses a framework of culturally responsive pedagogy (CRP) (Gay, 2010) to first make a case for culturally responsive maker education based on scholarly literature, and then to develop a content analysis of current online guidance on makerspaces. The content analysis investigates the question: How prevalent is CRP on makerspace websites that offer public guidance for makerspaces? The findings inform recommendations for practice and research that support the development and facilitation of culturally responsive makerspaces.

Theoretical Framework

Multicultural frameworks regard education as an inherently social and cultural endeavor. Sociocultural theories call attention to the ways that learning is shaped by the historical, social, and cultural realities of a learning community (Lave & Wenger, 1991). While learning communities were typically defined in research as members residing in the same location, the recent growth of online systems for instruction and collaboration has resulted in an increasing focus on web-based experiences and resources (Li et al., 2009). Studies of learning in informal settings in person and online have explored students’ identities and positions in relation to resources, tools, and individuals within the community (Barton & Tan, 2010; Smith, Hayes, & Shea, 2017). Aligned with these theories, CRP is a response to patterns of inequity in schools. These patterns include the use of ethnocentric curricula, disproportionate suspension and expulsion of students of color, disproportionate placement of students of color in special education, and low teacher expectations of students of color (Sleeter, 2011). To work against these racial, cultural, and linguistic injustices, educators and scholars developed social justice approaches to education, including multicultural education (e.g., Banks, 1996; Grant & Sleeter, 1985; Nieto, 1999), culturally relevant teaching (Ladson-Billings, 2006), and CRP (Gay, 2010). CRP recognizes science learning as more than the act of accumulating knowledge and skills and emphasizes cultural practices and ways of knowing as part of learning science. The tenets of CRP provide clear direction for educators seeking to develop their cultural competence. The tenets follow:

1. Developing a knowledge base about cultural diversity.
2. Including ethnic and cultural diversity content in the curriculum.
3. Demonstrating caring and building learning communities.
4. Communicating with ethnically diverse students.
5. Responding to ethnic diversity in the delivery of instruction.

In maker education, CRP would require in-person and online experiences that connect the cultural worlds of students to science and engineering (Moje, Collazo, Carrillo, & Marx, 2001) and include multiple ways of knowing (Barton, 1998; Rodriguez, 1998). These approaches to science learning push back on a universal perspective of modern Western science which “discounts and devalues cultural diversity because it expects students to identify with science as universal knowledge and to leave their cultural beliefs and values behind” (Lee & Buxton, 2008, p. 127). Honoring students’ beliefs and values requires cultural competence, or teachers’ understanding of culture and its role in education (Gay, 2002; Ladson-Billings, 2004). Culturally responsive teachers work to reverse educational trends by “dealing directly with controversy; studying a wide range of ethnic individuals and groups; contextualizing issues within race, class, ethnicity, and gender; and including multiple kinds of knowledge and perspectives” (Gay, 2002, p. 108). Because much of the infrastructure for making exists online, these issues would need to be addressed directly in both face-to-face experiences and online resources and guidance.

This study uses CRP as its framework because of its promising outcomes for traditionally marginalized students. Sleeter (2011) provides a full detailed review of CRP approaches and outcomes. As a few examples, Lee (2006) found that when teachers link African American students’ knowledge (e.g., cultural scripts and contexts) with academic subject matter (e.g., literary analysis strategies), students engaged in much higher levels of cognition than is the case with a traditional curriculum. Cammarota and Romero (2009) taught in and evaluated the Social Justice Education Project in Tucson,

Arizona, where over 40% of its Chicano students left school during the high school years. Cammarota and Romero created a four-semester social studies curriculum that was historically relevant to Chicano students, focused on racism in their school and community, and grounded in authentic care. Where teachers used CRP in social studies, Chicano students outscored White students on State reading, writing, and math exams, and Chicano students' graduation rates exceeded those of White students. Recent research highlights a growing interest in teaching practices of CRP in online environments (e.g., Heitner & Jennings, 2016), but the impact of CRP on student outcomes in online environments has not yet been explored.

Culturally responsive approaches to science and engineering education are commonly referred to as *multicultural science education* (MSE). The goal of MSE is to give all students opportunities to succeed and develop an interest in science. It is driven by social justice, equity, and the value of other people. Lee and Buxton (2010) provided an in-depth review of literature on MSE that represents a variety of topics, theoretical orientations, and methodologies. They found that the field of MSE gained traction in the mid-1990s, likely due to the explicit call for focus on both excellence and equity in Science for All Americans (American Association for the Advancement of Science, 1989) and National Science Education Standards (NRC, 1996). In the time since these policy documents called for "science for all," the Framework for K–12 Science Education (NRC, 2012) and Next Generation Science Standards (NGSS Lead States, 2013) each devoted a chapter to equity and diversity, drawing even more public and scholarly attention to the need for more inclusive science and engineering education. However, Atwater, Russell, and Butler (2014) found that many educators continue to assume science and engineering are neutral, objective fields of study and therefore CRP has no place in science and engineering. A growing number of scholars and educators argue for a CRP of science education (e.g., Atwater, 2010; Emdin, 2010; Lee & Buxton, 2010; Mensah, 2013). Ferguson (2008) asserts that MSE has, in part, been driven forward by two perpetual problems.

First, women and racial minorities have historically been marginalized and excluded in school science and thus are less likely to pursue science careers. Research has found persistent empirical evidence of inequity in science education, including reports that boys outperform girls in science at Grades 4, 8, and 12, and reports of achievement gaps between students who are White or Asian and students who are Black, Hispanic, Native Hawaiian/Other Pacific Islander, or American Indian/Alaska Native in Grades 4, 8, and 12 (National Center for Education Statistics, 2015).

Second, the changing U.S. public school demographics show that students are becoming more diverse in their ethnic and cultural origins while teachers continue to be mostly middle-class and White. This has contributed to ethnocentric teaching methods and curricula which exclude the presence and contributions of other cultural groups. The maker movement reflects a similar pattern: In her keynote address at a FabLearn conference, Buechley (2013) noted that of the 40 people featured on covers of Make Magazine, a driving force of the U.S. maker movement, none had been people of color. By featuring only White experts and leaders, Make Magazine forwarded an ethnocentric vision of making that is out of touch with the increasing diversity in the United States. In the same address, Buechley also pointed to a "very narrow definition" of maker activities and called for projects more accessible to women and people from different cultures, such as ceramics, costume-engineering, and weaving. By including and calling attention to diverse content and processes, the maker movement can align with MSE scholars and educators who seek to provide more equitable opportunities in science and engineering for male and female students of all racial and ethnic backgrounds.

Online Resources and Culture in Makerspace Literature

The following review discusses how literature on makerspaces has begun addressing two issues: the influence of online resources and the role of culture. The intersection of these issues remains underexplored and is the focus of this paper, which explores the question: How prevalent are the tenets of CRP on makerspace websites that offer public guidance for developing and facilitating makerspaces?

Websites have been a driving force of the maker movement (Martin, 2015), but scholarship has only recently begun to explore this platform. In her book, Fleming (2015) noted that a key distinction between the maker movement and earlier do-it-yourself affinity groups, such as local woodworking or sewing clubs, is the centrality of digital spaces where makers can view and display products and exchange insights on processes with an audience that extends beyond their local community. For their conference paper, Kuznetsov and Paulos (2010) surveyed over 2,600 individuals across a range of do-it-yourself online communities and found that their shared values emphasized open sharing and learning over profit and social capital. These values of collaboration and reciprocity align with the tenet of CRP, demonstrating caring and building learning communities. Similarly, Gerstein (2019) recognized how makerspace websites promote a participatory culture which values "low barriers to engagement and expression, support for creating and sharing one's creations with others, and informal types of mentorship whereby those with the most experience pass along information, strategies, and resources to beginners" (p. 9). In the process of developing a makerspace on campus, Dousay (2017) documented her use of online guidance regarding technology, personnel, and access drawn from the makerspace websites of PK–12, university, and community settings, while

other conference presentations examined individual maker websites created for community building (Kafai et al., 2014) and individual maker kits represented across multiple websites (Buechley & Hill, 2010). For example, in one conference paper, Chu and colleagues (2017) conducted a content analysis of maker websites for children and found that online venues provide much of the guidance and information that support the physical act of making. Although these studies addressed the same value of building learning communities, none of the above studies addressed the remaining four tenets of CRP. Beyond these examples focused on online resources, studies on making and the maker movement primarily focus on in-person experiences.

In order to apply a framework of CRP to the vast and dynamic world of maker education, it is important to first understand the underlying philosophy of making. Research on maker education has connected making with constructivist, child-centered approaches to education. In their review of the literature on making and tinkering, Vossoughi and Bevan (2014) found that the majority of studies focused on making as learner-driven, playful, and open-ended inquiry in contrast to test-driven, text-based, and teacher-centered science, technology, engineering, and mathematics (STEM) education. Martin (2015) conceptualized three essential elements of the maker movement: digital tools, community infrastructure, and the maker mindset. He called for maker educators to focus on fostering maker communities and supporting playful, failure-positive, collective learning for “a wider and more diverse audience than ever before” (p. 37). Through the lens of CRP, an online and in-person community infrastructure would specifically take up the identities and expertise of ethnically and culturally diverse participants. Online infrastructure includes the abundance of instructional resources on makerspace websites, considering that makers use online research to improve and learn new skills (Knibbe, Grossman, & Fitzmaurice, 2015). These studies drew alignments between making and students’ natural capacities for learning through play and trial-and-error. A crucial next step is to focus this capacity-oriented lens on youth who have been traditionally underserved in science and engineering education.

Several researchers have identified a need to address equity in maker education and have moved the field closer to an equity-oriented framework. Halverson and Sheridan (2014) located the maker movement within scholarly conversations about progressive education and best practices for teaching and learning. The authors challenged the notion of making as fundamentally democratizing and concluded, “An expanded sense of what counts may legitimate a broader range of identities, practices, and environments—a bold step toward equity in education” (p. 503). This step could encourage makerspaces to address CRP tenets such as developing a knowledge base about cultural diversity and including ethnic and cultural diversity content in the curriculum. Papavlasopoulou, Giannakos, and Jaccheri (2016) reviewed 43 empirical studies on making from 2011 to 2015, including studies of online communities that enable virtual collaboration and instruction. They raise the issue of equity, stating, “A surprising result from our review is that few studies focused on gender issues. We expected more studies to provide insights on how making activities benefit females specifically” (p. 62). While the authors describe the “do it yourself culture” (p. 58) and “making culture” (p. 59) of online communities, they do not address ethnic or cultural diversity. Vossoughi, Escudé, Kong, and Hooper (2013) found “a dearth of public discussion around issues of culture and equity” (p. 1). To address equity in makerspaces, they called for shifting the focus from broadening access to changing pedagogies. While the authors study an in-person Afterschool Tinkering Program, their proposals for “recognizing and leveraging the cultural, linguistic, and intellectual resources” (p. 7) of underserved learners and creating access points to science through everyday activities can be applied to online communities, which can greatly influence the teaching and learning of in-person programs. Though they do not explicitly use CRP as a framework, their recommendations address two tenets of CRP: including ethnic and cultural diversity content into the curriculum by “incorporating students’ cultural and intellectual histories” (p. 2), and demonstrating caring and building learning communities through experiences such as a daily “circle time” to reflect, plan, and share about their making. Gutiérrez, Schwartz, DiGiacomo, and Vossoughi (2014) address the CRP tenet of developing a knowledge base about cultural diversity by reminding educators that making and tinkering are indigenous to non-dominant communities. They call on educators to question assumptions about who does and does not engage in making and to counter narrow definitions of “making” and “makers.”

Few examples of CRP in makerspaces exist in scholarly literature. The following studies demonstrate various ways to move toward the second tenet of CRP: including ethnic and cultural diversity content in the curriculum. In a qualitative study, Norris (2014) analyzed how an urban schoolteacher used digital media to support female Latina and African American tenth-grade students to develop positive self-images in contrast to essentializing or “negative constructions that were forced upon them by their families, school, and the media” (p. 73). In a youth participatory ethnography, Tan, Barton, Shin, and Turner (2016) supported youth in identifying community problems linked to systemic oppression and developing prototypes of solutions to those problems. The makerspace project embedded local knowledge and practice into the engineering design process: youth interviewed community members on safety issues in the community and sought feedback on their designs from community experts. In a two-year critical ethnography, Barton, Tan, and Greenberg (2016) found that three forms of engagement sustained youth engagement in a makerspace: *critical* engagement with issues that framed their lives, *connected* engagement with peers and mentors, and *collective* engagement around community experiences and struggles rather than individual interests. These three studies show promise for an equity-oriented approach to making.

While prior studies have addressed digital technologies, research on CRP in makerspaces has not yet fully attended to the online resources available to guide makerspaces, which can greatly influence the development and direction of such spaces. It is important to consider how CRP is represented in these resources. Further research is needed to develop shared understandings and exemplars of equitable maker education inclusive of the online infrastructure that supports in-person experiences. One important step toward this goal is to assess how equity has been taken up thus far in publicly available online exemplars and guidance.

Methods

The internet is widely used by makers to share their work, access do-it-yourself tutorials, and find guidance for developing makerspaces. In order to gain a sense of the relevance of CRP in these online spaces, the author piloted a content analysis of nine makerspace websites between October and December of 2017 then presented and discussed the coding of preliminary findings with other maker scholars at a national conference for multicultural education. The author revisited the analysis in January and February 2020 to include three additional websites and update current information from previously accessed websites.

The analysis focused on the research question: How prevalent are the tenets of CRP on makerspace websites that offer public guidance for developing and facilitating makerspaces? In both the pilot and current study, two popular search engines (Google and Yahoo) were used to search for the term *makerspace* in combination with the following search terms: *guide*, *how-to*, *develop*, *facilitate*. To determine the data sources, each link in the first three pages of search engine results was reviewed using the following selection criteria: (1) it was the website of an active makerspace or active maker community; (2) it was a static content site (in contrast to a blog or forum); (3) it contained publicly available guidance for developing and facilitating makerspaces; and (4) the guidance included a section on teachers or facilitators of makerspaces. These criteria ensured relevance to the research question. Excluded websites were those of individual maker educators, libraries and facilities providing visitor information, consumer product companies (e.g., Sphero, Demco, Amazon links to books), and websites with posts on maker education or lists of linked resources among a variety of other STEM or educational topics (e.g., EdSurge, Education Closet, Edutopia). The author printed guidance materials for developing and facilitating makerspaces, including downloadable documents, that were available directly on the included websites. Table 1 contains the data sources for the study retrieved or updated in January and February 2020.

Table 1
Makerspace websites included in analysis.

	Name of makerspace	Associated institution	Data under study	Amount of data	Date of data
1	The Creativity Lab	K–12 Lighthouse Community Charter Schools	Making in Schools Making Space	12-page document and 26-page document	2014
2	d.school	Hasso Plattner Institute of Design at Stanford University	How to Start a d.school	1 webpage	2020
3	Edgerton Center Makerlab	Massachusetts Institute of Technology (MIT)	Run a Makerspace	7 webpages	2019
4	Fab Foundation	Began in MIT's Center for Bits and Atoms; now over 1,000 FabLabs in schools and communities around the world	Setting up a Fab Lab; Fab People; FabLab Guide	2 webpages and 59-page document	N.D.
5	Girl Scouts and the Maker Education Initiative	STEM Centers and MakerSpaces throughout the USA affiliated with Girl Scouts of the United States of America	Get Making with Get Moving!	21-page document	ND
6	Imaginarium Innovation Lab	Denver Public Schools	Who We Are & What We Do; 6 Things You Must Include in Your Makerspace; 5 Things to Consider Before You Build Your Makerspace	Two 1-page documents and 1 webpage	2016
7	Maker Media	Maker Education Initiative (non-profit organization)	Makerspace Playbook	84-page document	2013
8	Makerspace for Education	University of British Columbia MET Program	The Making of a Makerspace Curriculum Guide	41-page document	2016
9	Makeshop	Children's Museum of Pittsburgh	Making + Learning Massive Open Online Course; Make a Makerspace Introduction; Additional Considerations	1 course and 2 webpages	ND
10	NYSCI: Design, Make, Play	New York Hall of Science	Blueprint for Maker Programs for Youth	40-page document	2013
11	San José Public Library	San José Public Library STEAMstacks maker programs	Mobile Makerspace Guide	21-page document	ND
12	SparkTruck	Began in the Stanford University Design Program	How to Make a SparkTruck	18-page document	2014

This study uses five aspects of CRP (Gay, 2002, 2010) to deductively code guidance for developing and facilitating makerspaces. The coding protocol in Table 2 is adapted from Brown (2007), whose explication of CRP tenets has been used to inform teacher education programs (Taylor, 2010).

Data were coded deductively using the pre-established tenets of CRP. Each tenet was used as one code, or label, to describe segments of text with the goal of establishing themes in the data (Creswell, 2008). This coding process revealed how the websites related to one another and to the theoretical framework.

Findings

Recognizing the online world as essential infrastructure for maker education, a content analysis was conducted on twelve makerspace websites. Analysis showed that while the third tenet of building community was addressed on each website, the occurrence of the other four tenets of CRP was low across the twelve data sources. Table 3 presents the content coded using the five tenets of CRP for each makerspace resource. The following presentation of results begins with the most common tenet of CRP and ends with the tenets not addressed.

All twelve websites addressed the third tenet: demonstrating caring and building learning communities. This is the social aspect of CRP that speaks to group norms, such as the prioritization of group over individual and expectations of reciprocity and collaboration. Each website recognized the potential social impact of makerspaces and offered guidance on how to maximize this impact. The Edgerton Center Makerlab and Maker Media stated that maker spaces must be welcoming and inclusive, as seen in the screenshots in Figures 1 and 2. Makerspace for Education (Figure 3), the New York Hall of Science (Figure 4), Makeshop (Figure 5), and d.school (Figure 6) also propose an inclusive culture and note that facilitators must be skilled in fostering community among diverse participants. Each statement in Figures 3 through 6 points to a focus on relationship and positive intergroup attitudes. In fact, the diversity of participants' backgrounds, expertise, and interests is discussed as an asset to a space for creative collaboration. Several websites took this further and called for facilitators to view their work as a response to community or social problems. FabLabs referred to its community mission of improving the quality of participants' lives and listed seven reasons to set up a FabLab. The screenshot in Figure 7 shows that two of these reasons are motivated by community needs. Further, the Creativity Lab (Figure 8), the Imaginarium (Figure 9), and the San José Public Library (Figure 10) offered models of makerspace development in low-income, majority-minority communities to provide STEM experiences for populations that have been underserved by traditional STEM education. All of the reviewed websites emphasized the need to demonstrate care and build learning communities. Their guidance for this work varied from fostering a welcoming community to establishing a mission focused on the specific needs and well-being of the local community.

Two websites provided guidance for the first tenet of CRP: developing a knowledge base about cultural diversity. This tenet addresses the preparation of makerspace facilitators, including self-reflection on cultural biases and learning about ethnic groups' contributions to making and the STEM fields. Makeshop (Figure 11) encouraged facilitators to engage in self-reflection by offering questions to ask oneself. Another way the guidance addressed the first tenet was to take a learning stance toward families, which would allow facilitators to develop a knowledge base about cultural diversity in practice.

Table 2
Coding protocol, adapted from Brown (2007).

Code	Website addresses
1 Developing a knowledge base about cultural diversity	<ul style="list-style-type: none"> • Self-reflection on one's biases, attitudes, and practices • Knowledge of ethnic group's contributions to making, communication and learning styles, relational patterns • Understanding of cultural characteristics of different ethnic groups
2 Including ethnic and cultural diversity content in the curriculum	<ul style="list-style-type: none"> • Multicultural content in the curriculum • Identification of strengths and weaknesses of instructional materials through a lens of equity and diversity • Curricula used to convey information and values about diversity and equity
3 Demonstrating caring and building learning communities	<ul style="list-style-type: none"> • Value of cooperation and collaboration • Reciprocity between teachers and participants • Group takes precedence over individual • Develop positive intergroup attitudes
4 Communicating with ethnically diverse students	<ul style="list-style-type: none"> • Understanding of students' cultural codes, including how culturally informed notions of etiquette, speech codes, dress, and other attributes affect social interactions
5 Responding to ethnic diversity in the delivery of instruction	<ul style="list-style-type: none"> • Matching instruction to the learning styles of diverse students • Using multiethnic and multicultural examples during instruction

Table 3
Linking makerspace web guidance to tenets of CRP.

	Site name	CRP tenet addressed	Coded content from web guidance
1	The Creativity Lab (K–12 Lighthouse Community Charter Schools, 2014)	3	<ul style="list-style-type: none"> “Our vision...is to provide opportunities for a diverse group of people to participate in designing and making. At our school site, we are focused on low-income students of color from Oakland.” “Lighthouse expanded its program to include all students (K–12) on campus as well as families and staff.”
2	d.school (2020)	3	<ul style="list-style-type: none"> “Our 7th graders created fraction kits for younger students to be able to use.” “Bringing students together from different parts of the university on teams meant that [they] had to learn how to collaborate across disciplines and perspectives.” “Many d.school methods are sparked by weaving together relevant disciplinary traditions from many fields. These methods become the common vocabulary that allows people from very different backgrounds to collaborate.”
3	Edgerton Center Makerlab (2019)	3	<ul style="list-style-type: none"> “The most important thing is that the Makerspace is welcoming and accessible to the community of Makers who use it, making it easy for them to engage in creative, empowering activities and projects.” “A variety of people with diverse skills and perspectives should be included in the design and possibly implementation process.”
4	Fab Foundation (2020; Johns & Fab Foundation, n.d.)	3	<ul style="list-style-type: none"> A facilitator should have “a personal commitment to and community mission for that center.” The community mission is “for ordinary people to not just learn about science and engineering but actually design machines and make measurements that are relevant to improving the quality of their lives and the communities around them.” “There are many motivations for setting up a FabLab. These include...to help regenerate places, communities and neighborhoods; to provide services to the local community.”
5	Girl Scouts and the Maker Education Initiative (n.d.)	1	<ul style="list-style-type: none"> “Families: Remember the value in intergenerational learning! Grandparents, aunts and uncles, parents, and siblings may have a skill you never knew about. All you need to do is ask!”
		3	<ul style="list-style-type: none"> “Let girls lead the way with their own passions and interests...‘making’ is: girl-led, cooperative learning.” “Makerspaces serve as gathering spots, often bringing together...people with different backgrounds.”
6	Imaginarium: Denver Public Schools Innovation Lab (n.d.)	3	<ul style="list-style-type: none"> “We envision public education that is radically reinvented by the communities it serves, is equitable in all its practices, and empowers all learners to thrive in their chosen path.” “The core principles of human-centered design merged with best practices in research, strategic planning, and cultural proficiency is our unique approach to empowering community and school driven innovation.”
7	Maker Media (2013)	3	<ul style="list-style-type: none"> “When choosing a starter project, consider the diverse interests and skill sets of the members of your Makerspace...Build on the kids’ prior interests and knowledge.” “Good mentors encourage students to support one another and help each other with the problems they face to build community within your Makerspace. They are ready to learn from the kids.” “We all come from diverse backgrounds and experiences...Avoid prejudging who they are, their skills, or their cultures.”
8	Makerspace for Education (Roffey, Sverko, & Therien, 2016)	3	<ul style="list-style-type: none"> “Possibly one of the most valuable skills is the ability to embrace and function within multiple communities with varying cultures. This may include the cultures of the people participating, or the culture of the virtual community.” “Authentic, relevant collaboration in a medium that transfers directly to one’s real-life application needs is crucial to a thriving community.”
9	Makeshop (Children’s Museum of Pittsburgh and Institute of Museum and Library Services, n.d.)	1	<ul style="list-style-type: none"> “Do you have a way to greet or talk to every visitor who comes in to make sure that everybody is on equal ground when it comes to the expectations of the space? What expectations do you have about where these people are coming from and what shared history they may have? Are your assumptions correct...Are all visitors equally welcomed or are there barriers to participation?” “Through making experiences, families may relate and reinforce past experiences, family history, and develop shared understanding and interest.”
		3	<ul style="list-style-type: none"> “Facilitators [use] conversation and open-ended questioning to learn about visitors, their interests and backgrounds.” “Making experiences encourage learners to value, seek out, contribute to, and share expertise with and among the community.”
10	New York Hall of Science (2013)	3	<ul style="list-style-type: none"> “Build a database of knowledgeable Making talent in the community.” “Well-developed interpersonal skills to work effectively with diverse student, staff and volunteer participants.”

Table 3
(Continued)

	Site name	CRP tenet addressed	Coded content from web guidance
11	San José Public Library (n.d.)	3	<ul style="list-style-type: none"> • “The first step in the Design Thinking process is empathy. This step involves going and talking to people in the community. Through interviews, teams can gain an understanding of community needs.” • “Work in collaborative teams builds communication, team building, and cooperation skills.”
		4	<ul style="list-style-type: none"> • “We at SJPL began looking at how we might expand upon the current model to offer services directly to the people who need it the most...SJPL began dreaming up a mobile makerspace [which] allows the library to create partnerships with schools, community partners, and other establishments without requiring their target demographic to seek out the library, taking location and transportation out of the equation.” • “Have someone who is energetic, personable, and eager to serve many different populations. If the vehicle is traveling into linguistically diverse areas, it is highly desirable to have at least one staff member speak the language of the population you’re serving.” • “Invite staff who have experience working with your target demographic.”
12	SparkTruck (n.d.)	3	<ul style="list-style-type: none"> • “Collaboration is important...More and more challenges in the world are becoming too complex to be solved by a lone genius, so we want to inspire and encourage teamwork at an early age.”

A variety of people with diverse skills and perspectives should be included in the design and possibly implementation process. In a

Figure 1. Edgerton Center Makerlab (2019).

Treat all participants with respect.

Make sure everyone—young and old—feels welcome, important, and a part of the program. Learn names and greet each other by name. Show your interest in their projects—and in their presence. Respect the kids for who they are and where they are developmentally. We all come from diverse backgrounds and experiences. Take the time to get to know everyone individually. Avoid prejudging who they are, their skills, or their cultures.

Figure 2. Maker Media (2013).

Networking and Negotiation

(The ability to collaborate with people in various contexts)

Possibly one of the most valuable skills in the ability to embrace and function within multiple communities with varying cultures. This may include the cultures of the people participating, or the culture of the virtual community. Flexibility and

Figure 3. Makerspace for Education (2016).

- **Well-developed interpersonal skills to work effectively with diverse student, staff and volunteer participants.**

Figure 4. New York Hall of Science (2013).

Facilitators engage with visitors through a guided inquiry approach, using conversation and open-ended questioning to learn about visitors, their interests and backgrounds.

Figure 5. Makeshop (n.d.).

In fact, many d.school methods are sparked by weaving together relevant disciplinary traditions from many fields. These methods become the common vocabulary that allows people from very different backgrounds to collaborate.

Figure 6. d.school (2020).

Why set up a FabLab?

What motivates FabLab founders?

There are many motivations for setting up a FabLab. These include:

- formalising an existing Makerspace
- to help regenerate places, communities and neighbourhoods
- to provide services to the local community

Figure 7. Fab Lab (n.d.).

Our vision through the Lighthouse Community Charter School Creativity Lab is to provide opportunities for a diverse group of people to participate in designing and making. At our school site, we are focused on low-income students of color from Oakland. We are building a K-12

Figure 8. Creativity Lab (2014).

Figure 9. Imaginarium (n.d.).

The first step in the Design Thinking process is empathy. This step involves going and talking to people in the community. Through interviews, teams can gain an understanding of community needs.

Figure 10. San José Public Library (n.d.).

comes to the expectations of the space? What expectations do you have about where these people are coming from and what shared history they may have? Are your assumptions correct? Is it clear who can

Figure 11. Makeshop (n.d.).

Two sites recommended this stance. Makeshop (Figure 12) suggested incorporating family history and past experiences into making experiences. This guidance encourages facilitators to develop awareness of the impact of a family's culture on educational experiences. Similarly, Girl Scouts (Figure 13) posited that family members can make valuable contributions with their skills and expertise. These resources encourage facilitators to seek out the expertise of family members and learn about family history and experiences in relation to maker experiences. This tenet requires teachers to understand students' and families' relationships to STEM knowledge and practices.

The San José Public Library (Figure 14) discussed the fourth tenet of communicating with diverse learners. The library's guidance emphasized the importance of speaking participants' language and having prior experience working with the population served by the mobile makerspaces.

None of the guidance documents or webpages addressed the second and fifth tenets: including ethnic and cultural diversity content in the curriculum and responding to ethnic diversity in the delivery of instruction.

Limitations

The systematic search process used in this study produced a select set of makerspace websites. However, the online world is both vast and dynamic in nature, and even static content websites contain living documents that change over time. This study thus presents one snapshot of online makerspace guidance at a particular moment in time through a particular lens. Different methods of website selection, such as acquiring recommendations from makers themselves, could result in different snapshots. That being said, this analysis explores a significant portion of makerspace guidance online and contributes new insights to scholarship on making.

The websites in this study provided invaluable guidance to support those seeking to develop and facilitate makerspaces. They generously shared insights regarding educational philosophy, participant recruitment, hiring considerations, initial

motivations and agendas for participation. Through making experiences, families may relate and reinforce past experiences, family history, and develop shared understanding and interest (e.g. Ellenbogen, Luke & Dierking, 2004). A family's agenda, or goals, can be

Figure 12. Makeshop (n.d.).

Figure 13. Girl Scouts and the Maker Education Initiative (n.d.).

staff member. Have someone who is energetic, personable, and eager to serve many different populations. If the vehicle is traveling into linguistically diverse areas, it is highly desirable to have at least one staff member speak the language of the population you're serving.

Figure 14. San José Public Library (n.d.).

project ideas, and materials lists. It is not possible to provide guidance on every detail of makerspace education, and it is unrealistic to expect information on every aspect of educational best practice in the programming guidance. In some cases, the scarcity of culturally responsive recommendations, particularly regarding the second and fifth tenet, may show that topics of equity and diversity simply fall outside of the scope of the guidance. As an example, while the Imaginarium guidance for developing and facilitating makerspaces did not specifically address race or culture, the website provided links to additional resources, such as urban science scholar Christopher Emdin's 2017 book, *For White Folks Who Teach in the Hood*. It is thus possible that educators are expected to draw from other resources and prior knowledge to supplement their work. This study, however, proposes moving equity and diversity to the forefront of makerspace development and guidance to help ensure that groups who have been underserved by STEM education in the past will be better served in new approaches.

Discussion and Recommendations

Websites have spurred the growth of the maker movement, and a variety of established institutions have made online resources for new maker educators and communities abundant and easily accessible. The findings regarding the makerspace websites reflect the same issues as scholarly literature on makerspace education as well as larger issues in STEM education. The overall low occurrence of tenets of CRP in online guidance for developing and facilitating makerspaces points to a need for discussion of how online and in-person makerspaces can effectively serve students who have historically been marginalized in STEM. In order to disrupt the cycle of racial and cultural inequity in STEM education, researchers and practitioners interested in maker education must ground their in-person and online work in multicultural theories and practices. Following are recommendations for taking up or more deeply engaging with the tenets of CRP. Throughout the discussion, the word "teachers" is used to indicate the grownups in the makerspace who, in the reviewed websites, are also referred to as facilitators, guides, mentors, or staff members. In addition, the word "makerspace" is inclusive of both in-person and online resources and experiences due to the centrality of websites in the maker movement.

First, there is a clear need for accessible guidance that ensures maker teachers develop their knowledge base about cultural diversity. Makeshop recommended reflecting on one's cultural assumptions and learning about the shared histories of participants, which is a crucial step toward developing culturally responsive practices in a makerspace. In order to include and sustain the interest of diverse children and families, teachers should be familiar with students' background knowledge

and experiences, including “how the children use and display knowledge, tell stories, and interact with peers and adults at home and in their communities” (Zeichner et al., 1998). Online guidance for teachers can emphasize the need to engage families and community members in discussions about cultural knowledge and skills. Teachers may develop this framework through engagement in ongoing professional development regarding cultural competence, including critical self-reflection and location of the makerspace within “preexisting and unequal relations of power and privilege” (Zeichner et al., 1998). Teachers can be encouraged to learn about making from a variety of cultural perspectives, including contributions of different ethnic groups. When sharing lessons learned and reflections on practice online, teachers may discuss students’ and families’ relationships to STEM knowledge and practices.

Second, guidance is needed to ensure inclusion of ethnic and cultural diversity content in makerspace experiences. This tenet was not discussed in the online guidance in this study. Teachers may benefit from further support to explicitly challenge notions of STEM as culture-less and plan for maker experiences that reflect the cultural and linguistic diversity of the students. These are essential steps toward making science “accessible, meaningful, and relevant for all students” (Lee, 2004). Maker experiences can require that students inquire about themselves, their community, and society. For example, Norris (2014) found that an urban schoolteacher successfully taught design-thinking processes through a project on creating and resisting self-image with female tenth-grade students. The young women inquired about themselves and society as they developed tangible artifacts through designing and making. In addition, maker experiences should make students aware of various cultural perspectives and the materials should reflect a variety of cultures (tools, construction materials, crafting materials, etc.). These steps help to counter narrow definitions of “making” and “makers.” Gutiérrez et al. (2014) remind us that ingenuity and creativity are fundamental human practices, and that making and tinkering are indigenous to non-dominant communities.

Third, there is a need for deeper engagement with the third tenet of CRP: demonstrating caring and building learning communities. While the makerspace websites broadly recommended building community among participants, CRP requires particular attention to populations traditionally marginalized in intellectual communities, which was present in the online guidance from the San José Public Library. For example, when sharing practices or developing online resources, maker teachers can discuss how to make the space hospitable to groups and individuals from diverse cultures. Questions for such reflections can include: Have we displayed child- and/or family-made creations in the makerspace? Do we showcase learners’ identities? Is our work relationship-driven? A caring learning community also looks beyond itself, as demonstrated in the mission of Fab Foundation of using design and maker experiences to improve the quality of lives in the community. Thus, a makerspace should provide opportunities to recognize and empower children and families as change agents regarding community and societal problems. Blikstein (2013) writes that for making to align with equity pedagogy, “students’ projects should be deeply connected with meaningful problems, either at a personal or community level, and designing solutions to those problems would become both educational and empowering” (p. 5). In their youth participatory ethnography, Tan and colleagues (2016) invited youth to identify community problems linked to systemic oppression, including decaying infrastructure (limited street lighting), police brutality (need for protection), and youth concerns (bullying). Youth contributed to the improvement of conditions by making and presenting prototypes of solutions to the wider community, and the authors urged researchers to similarly position youth with agency to contribute to the improvement of community conditions. To move beyond broad references to “community” currently stated in makerspace websites, guidance and examples can draw from current scholarship to better support teachers in developing critical and collaborative activities that are cognitively demanding and rich in STEM learning.

Fourth, guidance is needed to ensure communication with diverse students. The online guidance in this study did not address ways to decipher students’ cultural codes. While guidance on the makerspace websites focused primarily on the tools and materials for making, Martin (2015) warns against a tool-centric approach to maker education which assumes that the mere presence of tools increases access. Makerspace teachers cannot assume that “access would lead to increased use, and increased use to improved learning” (p. 37), particularly for culturally and linguistically diverse children and families. Instead, development of a makerspace should include a concrete plan for recruiting diverse students and families. Guidance can also include recommendations for recruiting diverse teachers, including bilingual maker teachers and interpreters who are available during oral communication with children and families with limited English proficiency. Teachers need resources to ensure that written communications with children and families with limited English proficiency are provided in their home language. Research and practice would do well to include examples of intentional, systematic ways of gaining input and suggestions from families and staff. Each of these steps ensures intentional engagement with diverse children and families and challenges the common assumption that children and families take unequal advantage of available opportunities.

Fifth, there is a need for guidance on responding to ethnic diversity in the delivery of instruction. The development of a makerspace should include a plan to recruit teachers with expertise in CRP or with knowledge of and insight into minority

Table 4
Recommendations for CRP in makerspaces.

CRP tenet	Recommendations
Developing a knowledge base about cultural diversity	<ul style="list-style-type: none"> • Maker educators are familiar with students' background knowledge and experiences. • Educators engage participants in discussions about cultural knowledge and skills. • Educators engage in ongoing professional development regarding cultural competence. • Educators learn about and share making from a variety of cultural perspectives, including contributions of different ethnic groups. • When sharing/reflecting on practice, educators discuss students' and families' relationships to STEM knowledge and practices.
Including ethnic and cultural diversity content in the curriculum	<ul style="list-style-type: none"> • Maker educators explicitly challenge notions of STEM as culture-less. • Maker experiences reflect the cultural and linguistic diversity of the students. • Maker experiences require that students inquire about themselves, their community, and society. • Maker experiences make students aware of various cultural perspectives. • Maker materials reflect a variety of cultures (tools, construction materials, crafting materials, etc.).
Demonstrating caring and building learning communities	<ul style="list-style-type: none"> • Maker educators plan collaborative activities that are cognitively demanding and rich in STEM learning. • Educators are relationship-driven. • Educators display child- and/or family-made creations in the makerspace. • Educators recognize and empower students as change agents regarding community and societal problems. • When sharing/reflecting on practices, educators discuss how to make spaces hospitable to groups and individuals from diverse cultures.
Communicating with ethnically diverse students	<ul style="list-style-type: none"> • Maker educators have a concrete plan for recruiting diverse students and families rather than assuming children/families take unequal advantage of available opportunities. • A concrete plan exists to recruit diverse educators, including bilingual maker educators. • Interpreters are available during oral communication with children and families with limited English proficiency. • Written communications with children and families with limited English proficiency are provided in their home language.
Responding to ethnic diversity in the delivery of instruction	<ul style="list-style-type: none"> • Intentional, systematic ways of gaining input and suggestions from families and staff are utilized. • A plan exists to recruit educators with expertise in CRP or with knowledge and insight into minority communities and experiences in the USA. • Educators select and use materials that are relevant to students' experiences at home and in their communities. • Educators design maker activities that engage students in personally and culturally appropriate ways. • Educators use examples or analogies drawn from students' daily lives to introduce or clarify new skills and concepts. • When sharing/reflecting on practice, educators give specific attention to marginalized ethnic and social groups.

communities and experiences in the USA. Teachers should be supported in their selection and use of materials that are relevant to students' experiences at home and in their communities. Clear guidance and practical examples can aim to support teachers in learning about and using examples or analogies drawn from students' daily lives to introduce or clarify new skills and concepts. When sharing and reflecting on practice, teachers can give specific attention to marginalized ethnic and social groups. These steps can help ensure that maker activities engage students in personally and culturally appropriate ways. Blikstein (2013) asserts that teachers who facilitate making in the classroom must consciously merge, rather than exclude or replace, students' social values and expertise with the practices of tinkering, inventing, and constructing, in order to empower students and increase self-esteem. In addition, Vossoughi and colleagues (2013) found that children believed play was separate from science: "the more fun it is, the less scientific, the more scientific the less fun" (p. 6). The authors support the recommendation of Nasir, Rosebery, Warren, and Lee (2006) to highlight the overlap between everyday activities and the "official" activities of science in order to provide access to science for learners who may not see themselves as science-doers. By making science and engineering ideas transparent and explicit throughout playful experiences, teachers can help widen notions of intellectual activity. This is particularly important for children and families whose knowledge and capacities have been marginalized in traditional measurements and representations of science knowledge. These recommendations can be seen in Table 4.

While each tenet represents only one dimension of practice, the issues raised in the discussion must be addressed together in a holistic approach to maker education. For example, effective makerspace teachers need opportunities to reflect on how their cultural experiences inform their practice; these reflections can then lead to more purposeful and effective use of maker resources, examples, and materials that represent a variety of cultures.

Conclusion and Implications

Providing online guidance for developing makerspaces aligns with the maker mindset of sharing and learning from one another's successes and failures. An analysis of both scholarly literature and online guidance on makerspace websites found that the tenets of CRP have largely been overlooked. In order to ensure that this rapidly growing movement contributes to equalizing science and engineering education, practitioners need guidance and support that addresses current gaps in science outcomes and engages current research on making with children and families who have been underserved by traditional approaches to science education. The internet is an important medium for communication about making, and while online resources have provided some guidance on CRP, particularly around building learning communities, there is more work to be done.

More broadly, future studies on making would do well to expand understandings of teacher pedagogies in maker education both in person and online, particularly how educators infuse making with students' cultures. While the literature review included examples of positive outcomes when using CRP broadly, further studies are needed to analyze the particular impact of CRP on students' interest, skills, and knowledge in science and engineering. Ultimately, research and practice on the maker movement in education should explicitly recognize the maker capacities in culturally and linguistically diverse students, and view traditionally marginalized students as creators, inventors, and imaginative problem-solvers of authentic problems.

As physical and online makerspaces grow in number, they have the potential to contribute to a more equitable system of STEM opportunities for traditionally marginalized students. However, without conscious effort to teach against the grain, maker educators are likely to perpetuate the cycles of racism and sexism that have plagued STEM fields and contributed to persistent gaps in student outcomes across lines of race, ethnicity, gender, and socioeconomic status. In order to break these cycles, makerspace educators can design spaces and experiences that ensure access to rich science learning for traditionally marginalized students.

Author Bio

Hannah Kye, Ed.D., is an assistant professor in the Department of Interdisciplinary and Inclusive Education at Rowan University. She conducts research on STEM education for young children, family engagement, and teacher preparation with a focus on diversity, access, and equity.

Email: kye@rowan.edu

References

- American Association for the Advancement of Science. (1989). *Science for all Americans*. Washington, DC: American Association for the Advancement of Science.
- Atwater, M. M. (2010). Multicultural science education and curriculum materials. *Science Activities: Classroom Projects and Curriculum Ideas*, 47, 103–108.
- Atwater, M. M., Russell, M., & Butler, M. (Eds.). (2014). *Multicultural science education: Preparing teachers for equity and social justice*. New York, NY: Springer.
- Banks, J. A. (1996). *Multicultural education, transformative knowledge, and action*. New York, NY: Teachers College Press.
- Barton, A. C. (1998). *Feminist science education*. New York, NY: Teachers College Press.
- Barton, A. C., & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. *Journal of the Learning Sciences*, 19(2), 187–229.
- Barton, A. C., Tan, E., & Greenberg, D. (2016). The makerspace movement: Sites of possibilities for equitable opportunities to engage underrepresented youth in STEM. *Teachers College Record*, 119(6), 11–44.
- Blikstein, P. (2013). Digital fabrication and "making" in education: The democratization of invention. In Walter-Herrmann J. & Büching C. (Eds.), *FabLabs: Of machines, makers and inventors* (pp. 1–21). Bielefeld, Germany: Transcript Publishers.
- Brown, M. R. (2007). Educating all students: Creating culturally responsive teachers, classrooms, and schools. *Intervention in School and Clinic*, 43(1), 57–62.
- Buechley, L. (2013). Keynote address. FabLearn Conference, Stanford University, Palo Alto, CA. Retrieved October 20, 2017, from <http://edstream.stanford.edu/Video/Play/883b61dd951d4d3f90abeec65ead2911d>
- Buechley, L., & Hill, B. M. (2010). LilyPad in the wild: How hardware's long tail is supporting new engineering and design communities. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems* (pp. 199–207). Aarhus, Denmark.
- Cammarota, J., & Romero, A. F. (2009). A social justice epistemology and pedagogy for Latina/o students: Transforming public education with participatory action research. *New Directions for Student Leadership*, 2009(123), 53–65.
- Children's Museum of Pittsburgh and Institute of Museum and Library Services. (n.d.). Making + Learning Massive Open Online Course; Make a Makerspace Introduction; Additional Considerations. Retrieved February 15, 2020, from <http://p2pu.github.io/makingandlearning/modules/session%20four/Activity-Sequence/> and <http://makeshoppgh.com/resources/make-a-makerspace/>
- Chu, S. L., Quek, F., Bhangaonkar, S., & Berman, A. (2017, October). Physical making online: A study of children's maker websites. In *Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education* (pp. 1–8). Stanford, CA.

- Creswell, J. (2008). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (3rd ed.). Upper Saddle River, NJ: Pearson.
- d.school at Hasso Plattner Institute of Design at Stanford University. (2020). How to Start a d.school. Retrieved February 15, 2020, from <https://dschool.stanford.edu/how-to-start-a-dschool>
- Dousay, T. A. (2017). Defining and differentiating the makerspace. *Educational Technology*, 57(2), 69–74.
- Edgerton Center Makerlab at Massachusetts Institute of Technology. (2019). Run a Makerspace. Retrieved February 15, 2020, from <http://k12maker.mit.edu/run-a-makerspace.html>
- Emdin, C. (2010). Affiliation and alienation: Hip-hop, rap, and urban science education. *Journal of Curriculum Studies*, 42, 1–25.
- Fab Foundation. (n.d.). Fab People. Retrieved February 15, 2020, from <https://fabfoundation.fablabbcn.org/index.php/fab-people/index.html>
- Fab Foundation at the Hasso Plattner Institute of Design at Stanford University. (2020). How to Start a d.school. Retrieved February 15, 2020, from <https://dschool.stanford.edu/how-to-start-a-dschool>
- Ferguson, R. (2008). If multicultural science education standards' existed, what would they look like? *Journal of Science Teacher Education*, 19(6), 547–564.
- Fleming, L. (2015). *Worlds of making: Best practices for establishing a makerspace for your school*. Thousand Oaks, CA: Corwin Press.
- Gay, G. (2002). Preparing for culturally responsive teaching. *Journal of Teacher Education*, 53(2), 106–116.
- Gay, G. (2010). *Culturally responsive teaching: Theory, research, and practice*. Chicago, IL: Teachers College Press.
- Gerstein, J. (2019). *Learning in the making: How to plan, execute, and assess powerful makerspace lessons*. Alexandria, VA: ASCD.
- Girl Scouts of the United States of America and the Maker Education Initiative. (n.d.). Get Making With Get Moving! Retrieved February 15, 2020, from <https://makered.org/wp-content/uploads/2014/09/GSUSA-Get-Making-with-Get-Moving.pdf>
- Grant, C. A., & Sleeter, C. E. (1985). The literature on multicultural education: Review and analysis. *Educational Review*, 37, 97–118.
- Gutiérrez, K. D., Schwartz, L., DiGiacomo, D., & Vossoughi, S. (2014). Making and tinkering: Creativity, imagination, and ingenuity as a fundamental human practice. Paper presented to American Educational Research Association conference, Philadelphia.
- Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, 84(4), 495–504.
- Heitner, K. L., & Jennings, M. (2016). Culturally responsive teaching knowledge and practices of online faculty. *Online Learning*, 20(4), 54–78.
- Imaginarium: Denver Public Schools Innovation Lab. (n.d.). Who We Are & What We Do. Retrieved February 15, 2020, from <https://imaginarium.dpsk12.org/about>
- Johns, J., & Fab Foundation. (n.d.). FabLab Guide. Retrieved February 15, 2020, from https://issuu.com/j_johns/docs/bu_fablabs_document_final?e=35968760/66510214
- K–12 Lighthouse Community Charter Schools. (2014). Making in Schools Making Space. Retrieved February 15, 2020, from <https://lighthousecreativitylab.files.wordpress.com/2014/01/lighthousecreativitylabdpdpacket.pdf>
- Kafai, Y. B., Rusk, N., Burke, Q., Mote, C., Peppler, K., Fields, D. A.,... Magnifico, A. M. (2014). Motivating and broadening participation: Competitions, contests, challenges, and circles for supporting STEM learning. In *Proceedings of the International Society of the Learning Sciences* (p. 1219–1227). Boulder, CO.
- Knibbe, J., Grossman, T., & Fitzmaurice, G. (2015, November). Smart makerspace: An immersive instructional space for physical tasks. In *Proceedings of the 2015 International Conference on Interactive Tabletops & Surfaces* (pp. 83–92).
- Kuznetsov, S., & Paulos, E. (2010). Rise of the expert amateur: DIY projects, communities, and cultures. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries* (pp. 295–304). Reykjavik, Iceland.
- Ladson-Billings, G. (2004). New directions in multicultural education: Complexities, boundaries, and critical race theory. In Banks J. A. & Banks C. A. (Eds.), *Handbook of research on multicultural education* (2nd ed., pp. 50–65). San Francisco, CA: Jossey-Bass.
- Ladson-Billings, G. (2006). From the achievement gap to the education debt: Understanding achievement in U.S. schools. *Educational Researcher*, 35(7), 3–12.
- Lave, J., & Wenger, E. (1991). *Situated learning. Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.
- Lee, O. (2004). Teacher change in beliefs and practices in science and literacy instruction with English language learners. *Journal of Research in Science Teaching*, 41(1), 65–93.
- Lee, O., & Buxton, C. (2008). Science curriculum and student diversity: A framework for equitable learning opportunities. *Elementary School Journal*, 109(2), 123–137.
- Lee, O., & Buxton, C. A. (2010). *Diversity and equity in science education: Research, policy, and practice*. New York, NY: Teachers College Press.
- Lee, C. D. (2006). 'Every good-bye ain't gone': analyzing the cultural underpinnings of classroom talk. *International Journal of Qualitative Studies in Education*, 19(3), 305–327.
- Li, L. C., Grimshaw, J. M., Nielsen, C., Judd, M., Coyte, P. C., & Graham, I. D. (2009). Evolution of Wenger's concept of community of practice. *Implementation science*, 4(1), 11.
- Maker Media. (2013). Makerspace Playbook: School Edition. Retrieved February 15, 2020, from <https://makered.org/wp-content/uploads/2014/09/Makerspace-Playbook-Feb-2013.pdf>
- Martin, L. (2015). The promise of the Maker Movement for education. *Journal of Pre-College Engineering Education Research*, 5(1), 4.
- Mensah, F. M. (2013). Theoretically and practically speaking, what is needed in diversity and equity in science teaching and learning? *Theory into Practice*, 52, 66–72.
- Moje, E. B., Collazo, T., Carrillo, R., & Marx, R. W. (2001). "Maestro, what is 'quality'?: Language, literacy, and discourse in project-based science. *Journal of Research in Science Teaching*, 38(4), 469–498.
- Nasir, N., Rosebery, A. S., Warren, B., & Lee, C. D. (2006). Learning as a cultural process: Achieving equity through diversity. In Sawyer K. (Ed.), *Handbook of the learning sciences* (pp. 489–504). Cambridge, UK: Cambridge University Press.
- National Center for Education Statistics. (2015). *National assessment of educational progress*. Washington, DC: Institute of Education Sciences. Retrieved from <https://nces.ed.gov/timss/timss2015/>
- National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.
- National Research Council. (2009). *Learning science in informal environments: People, places, and pursuits*. Washington, DC: National Academies Press.
- National Research Council. (2011). *Expanding underrepresented minority participation: America's science and technology talent at the crossroads*. Washington, DC: National Academies Press.

- National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13165>.
- National Science Foundation. (2017). *Women, minorities, and persons with disabilities in science and engineering*. Retrieved October 28, 2017, from <https://www.nsf.gov/statistics/2017/nsf17310/digest/occupation/overall.cfm>
- New York Hall of Science. (2013). *Blueprint for Maker Programs for Youth*. Retrieved February 15, 2020, from https://nysci.org/wp-content/uploads/nysci_maker_blueprint.pdf
- Next Generation Science Standards Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: National Academies Press.
- Nieto, S. (1999). The light in their eyes: Creating multicultural learning communities. *Harvard Educational Review*, 69(2), 216–218.
- Norris, A. (2014). Make-her-spaces as hybrid places: Designing and resisting self-constructions in urban classrooms. *Equity & Excellence in Education*, 47(1), 63–77.
- Office of the Press Secretary, the White House. (2016). Fact sheet: New commitments in support of the President’s Nation of Makers Initiative to kick off 2016 National Week of Making. <http://www.weekofmaking.org/wp-content/uploads/2016/03/2016-National-Week-of-Making-Fact-Sheet.pdf>
- Pandey, S., & Srivastava, S. (2016). Pop-up maker-spaces: Catalysts for creative participatory culture. In *9th International Conference on Advances in Computer-Human Interactions* (pp. 50–56). Venice, Italy.
- Papavlasopoulou, S., Giannakos, M. N., & Jaccheri, L. (2016). Empirical studies on the Maker Movement, a promising approach to learning: A literature review. *Entertainment Computing*, 18, 57–78.
- Rodriguez, A. J. (1998). Strategies for counterresistance: Toward sociotransformative constructivism and learning to teach science for diversity and for understanding. *Journal of Research in Science Teaching*, 35, 589–622.
- Roffey, T., Sverko, C., & Therien, J. (2016). *Makerspace for Education Curriculum Guide*. Retrieved February 15, 2020, from <http://www.makerspaceforeducation.com/curriculum-guide.html>
- San José Public Library. (n.d.). *Mobile MakerSpace Guide*. Retrieved February 15, 2020, from <https://www.sjpl.org/sites/default/files/2019-01/mobile-makerspace-guide-cc-license-large.pdf>
- Sleeter, C. (2011). An agenda to strengthen culturally responsive pedagogy. *English Teaching*, 10(2), 7–23.
- Smith, S. U., Hayes, S., & Shea, P. (2017). A critical review of the use of Wenger’s Community of Practice (CoP) theoretical framework in online and blended learning research, 2000–2014. *Online Learning*, 21(1), 209–237.
- SparkTruck. (n.d.). *How to Make a SparkTruck: An Open-Source Guide for Anyone Making an Edu-Maker Truck*. Retrieved February 15, 2020, from <https://docs.google.com/document/d/14Z7kaBYsU90LmA8ozaXfqt6cNtDtORswRG3-Xzjbho/edit>
- Tan, E., Barton, A. C., Shin, M., & Turner, C. (2016, October). Probing participatory partnerships: Equitably-consequential making by, for and with marginalized youth. In *Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education* (pp. 1–8).
- Taylor, R. W. (2010). The role of teacher education programs in creating culturally competent teachers: A moral imperative for ensuring the academic success of diverse student populations. *Multicultural Education*, 17(3), 24–28.
- Vossoughi, S., & Bevan, B. (2014). Making and tinkering: A review of the literature. *National Research Council Committee on Out of School Time STEM*, pp. 1–55.
- Vossoughi, S., Escudé, M., Kong, F., & Hooper, P. (2013). *Tinkering, learning & equity in the after-school setting*. Paper presented at FabLearn, Stanford, CA. Retrieved August 24, 2014, from <http://fablearn.stanford.edu/2013/papers/>
- Zeichner, K. M., Grant, C., Gay, G., Gillette, M., Valli, L., & Villegas, A. M. (1998). A research informed vision of good practice in multicultural teacher education: Design principles. *Theory into Practice*, 37(2), 163–171.