

Integrating Justice-Centered Making into STEM Teacher Preparation: A Literature Review

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Abstract: This paper examines the integration of justice-centered making into STEM teacher preparation programs, focusing on how these programs can foster equity and inclusivity while acknowledging the need for more research on the overlapping areas of STEM teacher preparation, social justice, and makerspace. Therefore, I synthesize recent literature in the overlapping areas and identify how each component brings insight to purposeful activity, identity formation, and connection. The discussion leads to how utilizing justice-centered-making activities can prepare educators to address systemic inequities in STEM fields. The implications of these pedagogical approaches for both teachers and students are discussed.

Keywords: STEM, justice-centered pedagogy, makerspaces, teacher preparation, social justice

Introduction

The rapid advancement of science, technology, engineering, and mathematics (STEM) disciplines highlights their critical role in fostering societal progress and innovation. However, STEM education currently faces significant challenges concerning equity, diversity, and inclusiveness. STEM instruction has often neglected social justice issues in favor of focusing on technical skills and theoretical knowledge, which can inadvertently perpetuate systemic inequalities and limit the potential for diverse perspectives in scientific innovation (Dimick, 2012; Nicol et al., 2019). The underrepresentation of certain groups in STEM fields underscores a critical need for embedding inclusive and diverse perspectives within these disciplines (Whipp, 2013). STEM curricula and pedagogy often lack critical examination and inclusion of diverse cultural, societal, and personal contexts that influence inquiry and technological development (Morales-Doyle, 2017; Calabrese Barton & Tan, 2019; Whipp, 2013; Cochran-Smith et al., 2009). The lack of culturally sustaining pedagogies exacerbates disparities in educational outcomes and limits STEM education's potential to be a transformative force for all students (Cheuk & Morales-Doyle, 2022).

Makerspaces have emerged as vital incubators for innovation and creativity in STEM education, offering unique environments where students and teachers can engage with hands-on projects that foster practical and critical thinking skills and encourage more equitable participation in STEM. In the field of education more broadly, there has been a surge of interest in how teaching and learning can benefit from the tools, processes, and practices of making (e.g., Clapp et al., 2016; Fields et al., 2018; Halverson & Sheridan, 2014; Stager & Martinez, 2013).

The effectiveness of STEM education largely hinges on the quality of its teachers (Yang & Ball, 2024; Corum & Nichols, 2024; Rodriguez et al., 2019; Ekmekci & Serrano, 2022). The preparation of STEM teachers plays a pivotal role in shaping the educational experiences that can either perpetuate or dismantle longstanding educational and societal inequities (Calabrese Barton & Tan, 2019). As STEM fields continue to evolve rapidly, there has been growing recognition of the need to incorporate social justice into STEM education, particularly in teacher preparation programs (Browne et al., 2022; Cochran-Smith et al., 2009; Roofe et al., 2018). This growing need calls for educators who are adept in these disciplines and committed to promoting diversity and inclusivity (Morales-Doyle, 2017; National Science and Technology Council, 2021).

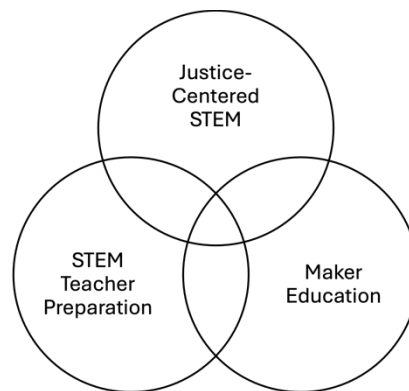
Frameworks and Rationale

Building on the foundational discussions of the current state and challenges in STEM education and teacher preparation, it is evident that innovative solutions are crucial to address equity, diversity, and inclusiveness gaps. Among these solutions, justice-centered science pedagogy has emerged as a transformative approach, advocating for integrating social, cultural, and political contexts into STEM teaching practices (Morales-Doyle, 2017). Grounded in the principles of critical pedagogy (Freire, 1970) and culturally relevant pedagogy (Ladson-Billings, 2014), justice-centered science pedagogy aims to “increase the complexity of the ways they think about [STEM] issues and issues of social justice” (Morales-Doyle, 2017, p. 1055). This research suggests extending Morales-Doyle’s science framework and extending justice-centered pedagogy to STEM disciplines more broadly. This significant educational shift requires a systemic reevaluation of how STEM education is conceptualized and delivered (Cheuk & Morales-Doyle, 2022; Pourdavood & Yan, 2022).

Simultaneously, the role of makerspaces as collaborative, hands-on learning environments complements the goals of justice-centered pedagogy (JCP) by inherently supporting community, inclusivity, and creativity (Peppler & Bender, 2013; Halverson & Sheridan, 2014; Cohen et al., 2017). These spaces democratize access to STEM learning, dismantling traditional barriers and promoting a participatory learning environment where students from diverse backgrounds can engage creatively and innovatively (Calabrese Barton et al., 2021; Lindstrom et al., 2017). This communal and inclusive ethos not only promotes equitable access to technological resources but also positions makerspaces as fertile ground for cultivating projects with a social justice orientation (Nichols & Corum, 2023; DesPortes et al., 2021; Calabrese Barton et al., 2021).

Integrating justice-centered making into STEM teacher preparation exists at the intersection of STEM teacher preparation, justice-centered STEM, and maker education (Figure 1).

Figure 1. Justice-Centered Making in STEM Teacher Preparation



This approach represents a pivotal strategy for developing technologically adept educators deeply committed to fostering equity and inclusion within their teaching practices. This integration challenges traditional teacher education programs to incorporate these innovative pedagogical approaches, making it essential to prepare educators equipped to use STEM as a tool for social change and justice. While there is an extensive literature base related to each of these themes individually, there is an identified gap in the literature regarding the intersection of all three themes. Given the potential for integrating justice-centered making into STEM teacher preparation, this literature review explored the following research questions: 1) What are the implications for integrating justice-centered making into STEM teacher preparation programs? and 2) How does engaging preservice teachers in makerspace activities that center social justice issues impact their teaching practices and students’ engagement in STEM subjects?

Methodology

This literature review endeavors to articulate the current state of research, underscoring the observed scarcity of literature directly addressing the integration of justice-centered making within STEM teacher preparation. The overall goals for this study were: 1) to examine the overlapping areas of makerspace activities, social justice in

STEM, and STEM preservice teacher preparation, and 2) to identify trends and potential impacts of integrating justice-centered making activities into STEM teacher preparation. The method employed was a systematic narrative review of research papers retrieved from major academic article databases.

Database Search and Screening

The search for relevant literature was conducted in the research databases Education Research Complete (ERC), Academic Search Ultimate, Educational Resources Information Center (ERIC), Library, Information Science & Technology Abstracts, Professional Development Collection, and Teacher Reference Center within the EBSCO interface. Keywords and the corresponding like terms included: (1) “justice-centered STEM pedagogy,” “justice-centered,” or “social justice,” (2) “makerspace,” or “making,” and (3) “STEM teacher preparation,” or “preservice STEM,” or “teacher preparation.” The search terms were selected based on the core concepts, an exploration of existing literature, alternative terms, and database-specific terminology to ensure a comprehensive and relevant search. This literature review includes empirical studies, theoretical papers, systematic reviews, methodological studies, and practitioner literature. Articles focusing primarily on library media makerspaces or community makerspaces were generally excluded as the focus of these articles employed makerspaces not generally utilized by teachers or as part of teacher preparation. The database searches were conducted during April 2024 and originally restricted to the years 2014-2024. The initial database search was limited to capture the most recent and relevant research on justice-centered STEM and maker education, reflecting current trends and practices in these emerging fields. However, the search was expanded to include studies from 1994-2024 to ensure a comprehensive review of foundational works on culturally relevant pedagogy and justice-centered pedagogies, which underpin the theoretical frameworks guiding this research.

Initial selection criteria focused on works explicitly discussing integrating justice-centered making activities into STEM teacher preparation. Due to the specificity of this criteria, the initial pass resulted in no articles meeting the selection criteria. Rather than focusing on the intersection of all three themes, the selection criteria was broadened to focus on the duality of the themes: STEM Teacher Preparation and Makerspace, STEM Teacher Preparation and Social Justice, and Makerspace and Social Justice. Using the same databases and keywords/like terms, this selection criteria resulted in a total of 40 articles (Table 1).

Table 1. Number of Articles in Each Dyad

Dyad	Number of Articles
Justice-Centered STEM and STEM Teacher Preparation	11
STEM Teacher Preparation and Maker Education	14
Justice-Centered STEM and Maker Education	15

Thematic Analysis

Each set of articles in the overlapping areas and, in total, were analyzed thematically in six steps, as outlined by Braun and Clarke (2006). The analysis followed an inductive approach to identify patterns and recurring themes. First, each article was reread to identify content relevant to the research questions, with detailed notes taken. The notes were then coded and organized into meaningful units, identifying patterns in how makerspace and justice-centered pedagogies were applied in STEM teacher education, along with potential challenges and limitations. See Table 2 for an excerpt of the coding chart used during the thematic analysis. After identifying preliminary themes with supporting examples, the themes were reviewed for consistency across the data, defined in terms of their core characteristics, and logically organized and named. Finally, representative examples were selected to illustrate each theme in relation to the study’s research questions, culminating in three main themes (see Figure 2).

Table 2. Excerpt of Coding Chart for Social Justice Integration

Code	Descriptor	Example
Mentioned (M)	Social justice was acknowledged but not explicitly connected to making activities.	A study discussing inequities in STEM fields but not integrating justice-centered making as a solution.

Applied (A)	Social justice themes were woven into the discussion of making but not central to its implementation.	An article where students reflected on equity after completing a making activity, but the activity itself was not designed with justice at its core.
Core Focus (C)	Social justice was explicitly embedded into the making activity and its learning goals.	A study where students created projects addressing environmental racism using makerspace tools.

Findings

The findings from this study highlight the transformative potential of integrating justice-centered making into STEM teacher preparation programs. By focusing on equity and inclusion, these programs not only enhance preservice teachers' technical skills but also reshape their pedagogical practices to foster more inclusive and socially conscious STEM education environments. The following sections detail the key themes that emerged from the analysis, illustrating the multifaceted impacts of justice-centered making on both teaching practices and student engagement.

Dyad 1. Justice-Centered STEM and STEM Teacher Preparation

Justice-centered STEM education represents a comprehensive approach to reforming STEM teaching and learning. By focusing on equity, diversity, and inclusion and by engaging students in projects that address real-world social injustices, educators can make STEM fields more accessible and relevant to a broader range of students (Calabrese Barton & Tan, 2019; Nichols & Corum, 2023). The research consistently noted that learning and developing a justice-centered pedagogy is a “lifelong undertaking” and would not be wholly developed in one or two teacher preparation courses (Pourdavood & Yan, 2022, p. 59). Both Pourdavood and Yan (2022) and Steele and Jeong (2023) conclude that preservice teachers, through their experiences engaging in justice-centered teaching and projects, developed social consciousness, more aptly identified and addressed inequities in the classroom and curricula, and asserted the significance of community and connection within the classroom and content.

Implementing JCP poses significant challenges and limitations, necessitating a reevaluation of traditional educational frameworks and methodologies (Steele & Jeong, 2023). One of the primary challenges lies in the implementation process, which demands a comprehensive shift in curriculum design, educator training, and policy support (Pourdavood & Yan, 2022; Steele & Jeong, 2023). Teachers, pivotal to enacting JCP, require robust professional development and resources to effectively integrate social justice issues into STEM education. The lack of such support can lead to inconsistent and superficial application of JCP principles across different educational contexts (Gutstein, 2003; DesPortes et al., 2021). Moreover, assessing the impact of JCP on student learning and engagement presents another significant hurdle. Traditional STEM assessment methods may not fully capture the depth of understanding and critical thinking skills developed through JCP, complicating efforts to evaluate its efficacy (Calabrese Barton & Tan, 2018). Another limitation is ensuring that JCP does not compromise the breadth and depth of traditional STEM content coverage. Calabrese Barton and Tan (2018) strongly urge an approach that balances focusing on social justice issues with rigorous STEM content and pedagogical instruction to adequately prepare students for future academic and professional pursuits in STEM fields.

Dyad 2. STEM Teacher Preparation and Maker Education

Given making's capacity to embed preservice teachers in experiences that mirror the practices of real-world STEM professionals, fostering a deep understanding of scientific inquiry, engineering design processes, and technological fluency, making can be a powerful pedagogical tool for preservice teacher education (Rodriguez et al., 2019; Greenstein & Olmanson, 2018). Cohen (2017) found that in U.S. teacher education programs, 12.7% offered a full undergraduate course on maker technologies, while 57.4% included at least a unit or module on the subject. Additionally, 17% of programs had a makerspace or laboratory, and 42.3% had plans to develop such infrastructure within three years. Alternatively, the University of Texas at Austin employs a micro-credentialing program to equip preservice teachers with maker education skills (Rodriguez et al., 2018).

While the literature celebrates maker education for its ability to engage preservice teachers in meaningful, context-rich learning experiences, research in this overlapping area emphasized the positive impact of these

programs on preservice teachers' views about making activities, principles, and teaching methods (Jones et al., 2017; Rodriguez et al., 2018). Rather than focusing on specific technologies or maker tools, the most effective programs were built upon the principles of the maker movement and developing a maker mindset (Cohen et al., 2017; Rodriguez et al., 2019; Vossoughi & Bevan, 2014; Bullock, 2015). Dougherty (2012) submits that the maker mindset, a blend of curiosity, creativity, and resilience, is crucial for the development of future educators. Dougherty (2012) and Clapp et al. (2016) argue that teachers should be given firsthand experience in making and makerspaces to develop their maker mindset. Moreover, Jin and Harron (2022) illustrated the broader educational value of makerspace training beyond STEM content mastery, demonstrating that preservice teachers increased collaborative skills and innovative teaching methods. Experiences in makerspaces help preservice teachers grasp the practical aspects of teaching STEM subjects, providing them with a firsthand understanding of managing and utilizing these innovative spaces effectively (Cohen et al., 2017).

Educators prepared in "theory, knowledge, and skills about making" are crucial to maximizing the potential benefits of maker-centered learning (Hsu et al., 2017, p. 592). However, many new teachers are reluctant to add making to their curriculum, citing a lack of adequate technological knowledge and confidence in their ability to teach with technology (Bevan, 2017). Blikstein and Worsley (2016) found that those new to making require "a considerable amount of onboarding and facilitation" before adding making to their own teaching (p. 71). Incorporating makerspaces into preservice teacher education programs can enhance teachers' readiness to integrate making and tinkering into their future classrooms (Cohen, 2017; Rodriguez et al., 2018). Furthermore, both Douglass (2023) and Rodriguez et al. (2018) note the need for changes in teacher preparation to match new teaching and learning standards, which have integrated inquiry and engineering standards. This national shift in STEM education "provides an opportunity to diversify the methodologies of preparing teachers, which may be part of a larger conversation into diversifying who is teaching and how they teach a variety of students in today's American classrooms" (Douglass, 2023, p. 2).

Dyad 3. Justice-Centered STEM and Maker Education

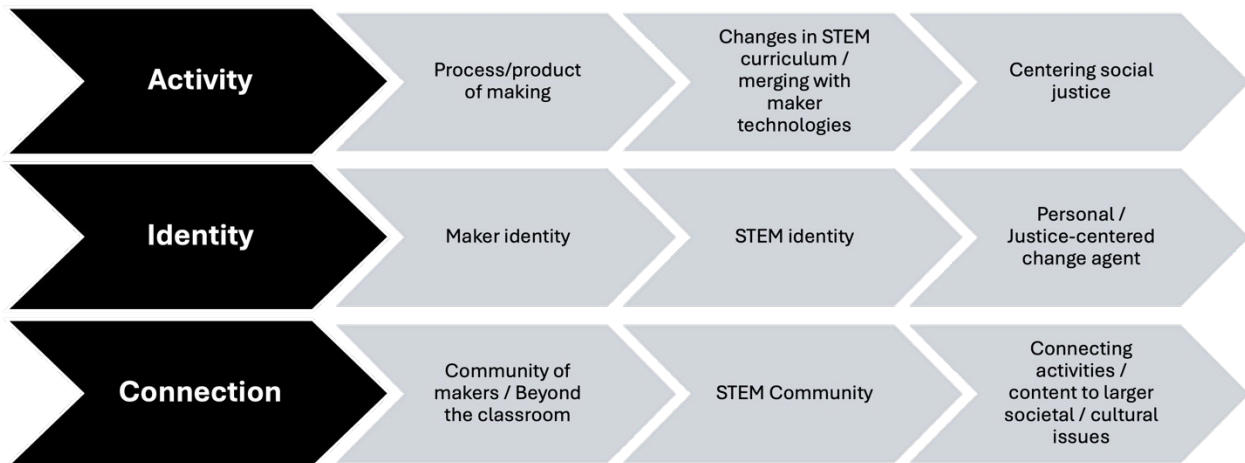
Justice-centered making as an educational approach extends beyond providing access to makerspace resources and, instead, focuses on the transformative nature of maker activities that center social justice. Fully realizing the transformative power of makerspaces requires that these spaces be inclusive for all students. Nichols and Corum (2023) note that justice-centered and equity-based frameworks inform the central practices of inclusion and accessibility in makerspaces. However, this sense of belonging is not shared by all students. Black, Indigenous, and People of Color (BIPOC) do not regularly participate in makerspaces (Kafai et al., 2014; Sang & Simpson, 2019). The discussions across the literature share a common thread in emphasizing the importance of making/makerspace activities to engage historically marginalized groups in STEM (Calabrese Barton & Tan, 2018; Ryoo & Calabrese Barton, 2018; Morales-Doyle, 2017; Calabrese Barton et al., 2021; Vossoughi et al., 2016).

Research in this overlapping area suggests that coupling making and makerspaces with JCP creates contexts that enable students to connect STEM learning with their personal identities (Tan & Calabrese Barton, 2018; Shin et al., 2022; Nadelson, 2021) and broader societal issues (Morales-Doyle, 2017; Ladson-Billings, 1995; DesPortes et al., 2021), thereby empowering them as agents of change (Calabrese Barton & Tan, 2018; Nichols & Corum, 2023). Morales-Doyle (2017) and DesPortes et al. (2021) recognize the use of makerspaces as platforms for addressing systemic inequalities and fostering equity and social justice by engaging students in projects that challenge societal norms and encourage community involvement. These makerspace activities aim to educate about differences in treatment and impacts by society and are a venue for social action, allowing students to explore and address the realities of their communities (Calabrese Barton et al., 2021; DesPortes et al., 2021).

Discussion

This literature review exploring the intersections of STEM teacher preparation, justice-centered STEM, and maker education reveals three critical dimensions when considering how to effectively integrate justice-centered making into STEM teacher preparation: activity, identity, and connection (Figure 2). These dimensions underscore how justice-centered making fosters a deeper understanding of making within STEM educational settings, enhancing both teaching and learning experiences.

Figure 2. Dimensions informing the integration of justice-centered making in STEM teacher preparation



Dimension 1. Activity

Activity emphasizes the hands-on, iterative process of making, which supports preservice teachers in translating theoretical STEM concepts into practical applications (Papert, 1980; Rodriguez et al., 2019). This dimension was prevalent across all three dyads. Studies demonstrate that engaging preservice teachers in makerspace activities improve their technological proficiency and pedagogical skills while fostering their confidence as educators (Halliburton et al., 2024; Stigberg et al., 2024). Moreover, integrating justice-centered activities into these makerspaces allows teachers to focus on real-world social issues, fostering critical thinking and problem-solving (Calabrese Barton & Tan, 2018; Corum & Nichols, 2024).

Dimension 2. Identity

Makerspaces support the formation of a triune identity in preservice teachers: that of a maker, a STEM educator, and a socially conscious agent of change (Barton et al., 2017; Vossoughi et al., 2016). Developing these identities is key to empowering teachers to bring equitable and socially impactful practices into their classrooms. This dimension was most prominent in Dyad 3. Studies show that consistent practice with justice-oriented teaching methods strengthens preservice teachers' ability to foster these identities in students (Vossoughi et al., 2016; King & Butler, 2015). This identity development is essential in STEM education, as it enables teachers to view themselves as educators and as contributors to their communities and the broader world (Morales-Doyle, 2017).

Dimension 3. Connection

Connection emphasizes the importance of building a community of practice around makerspaces that includes educators, students, and broader societal engagement (Corum & Nichols, 2024). This dimension was also evident across all three dyads. This community aspect fosters collaboration, peer learning, and mentorship, which helps bridge the gap between novice and experienced teachers (Rodriguez et al., 2019; Halliburton et al., 2024). However, scholars caution that without an intentional focus on justice-centered pedagogies, makerspaces can inadvertently perpetuate existing disparities, particularly for students from marginalized backgrounds (Ryoo & Calabrese Barton, 2018; Vossoughi et al., 2016). The research stresses that effective integration of justice-centered making requires sustained engagement with justice-centered teaching strategies, as they help teachers commit to and proficiently apply these methods in their classrooms (King & Butler, 2015; Pourdavood & Yan, 2022).

Implications for Teaching Practice

To fully realize the potential of integrating justice-centered making into STEM teacher preparation in transforming STEM education, teacher educators must ensure that making is not just an engaging hands-on activity, but also a powerful vehicle for meaningful inquiry and social transformation. Preservice teachers should have opportunities to design and implement maker-based lessons that explicitly address authentic issues of equity, justice, accessibility, and representation in STEM fields. Researchers argue that merely incorporating making activities into

curricula is insufficient; instead, how teachers connect with students through these activities determines their success in promoting active participation and learning for all students (Cohen, 2017; Vossoughi et al., 2016). Furthermore, programs should provide structured opportunities for preservice teachers to reflect on how their own identities and experiences shape their approaches to justice-centered STEM teaching. By embedding these experiences into coursework and field experiences, teacher preparation programs can cultivate educators who are not only skilled in STEM pedagogy but also deeply committed to fostering inclusive learning environments.

Institutionally, this research suggests the need for greater support in equipping teacher education programs with the necessary infrastructure, resources, and professional development to facilitate justice-centered making. Faculty training and curriculum redesign should emphasize how to integrate social justice into maker-based instruction while maintaining rigorous STEM content. Additionally, collaborations with community organizations, local schools, and industry partners can help strengthen the real-world applications of justice-centered making, offering preservice teachers authentic experiences working with diverse learners and addressing systemic inequities in STEM education.

Limitations

This study's findings should be interpreted with caution due to several methodological limitations. A key limitation of the research methodology lies in the reliance on database searches, which may exclude relevant studies not indexed in the selected databases. As this was an exploratory review of the literature, future reviews can incorporate more nuanced search terms to capture a broader range of perspectives, populations and emerging discussions. Additionally, most of the reviewed studies were based on small sample sizes, often limited to a single course, degree level, or university, restricting generalizability. Additionally, the use of self-selected participants and reliance on case studies, surveys, interviews, and observational studies, while providing valuable qualitative insights, raises concerns about biases, such as single-source bias from self-reported data. Studies like those by Rodriguez et al. (2019), Vossoughi & Bevan (2014), and Martin (2015) offered brief observational insights into student engagement with justice-centered making, potentially missing long-term outcomes. Furthermore, research by Morales-Doyle (2017) and Ladson-Billings (2014) provided useful analyses of curriculum materials but were limited by the availability of curriculum documentation. Finally, the variability in how justice-centered making is implemented across programs complicates efforts to measure its distinct impact on student attitudes, engagement, and critical thinking skills.

Conclusion

Findings from this study indicate that integrating justice-centered making into STEM teacher preparation fosters equity and inclusion within educational spaces. Moreover, incorporating justice-centered pedagogies into makerspaces enhances preservice teachers' technical skills and transforms their pedagogical practices, fostering more inclusive and socially conscious STEM education environments. Based on these conclusions, future research should examine the effectiveness of different implementation models for justice-centered making activities within teacher preparation programs. Additionally, research should investigate the long-term impacts of justice-centered making on teachers and students in diverse educational settings. Further studies might also explore how teacher-student relationships formed through justice-centered making activities influence student engagement and achievement, particularly among historically marginalized groups. This comprehensive approach will provide deeper insights into the effectiveness and scalability of justice-centered pedagogies in fostering inclusive and equitable STEM education environments.

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