Maker Education and STEM+ in the Context of Contemporary Constructionism: Iterative Resilience and Community

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Abstract

Maker Education and STEM+ initiatives are often celebrated for fostering creativity, problem-solving, and innovation. However, as these approaches gain global traction and the Maker Education movement matures, its technocentric underpinnings are increasingly critiqued for overshadowing deeper pedagogical aims. This paper examines initial insights from qualitative interviews with Maker educators and researchers, highlighting challenges and strategies for shifting Maker Education from a focus on tools and spaces towards pedagogies that prioritise the significance and centrality of community for learning, as well as a mindset of resistance to failure and a resilient approach to problem-solving. By re-centering constructionist ideas of creativity, iteration, and human connection, the findings demonstrate how community-centric practices can transform makerspaces into inclusive ecosystems of collaboration and growth. This work contributes actionable recommendations for embedding Maker Education into diverse educational settings, in the context of contemporary constructionism and in line with the conference's theme of "Building Communities, Bridging Ideas."

Keywords and Phrases: Maker Education, Iterative Resilience, Productive Failure, Community, Constructionism, Iterative Learning, STEM+, STEAM

1. Introduction

Rooted in Seymour Papert's (1980, 1999) Constructionist learning theory, Maker and STEM/STEAM education, hereafter referred to as Maker Education, encourages learners to design, build, and share artifacts as a means of constructing knowledge. These approaches have been seen as transformative responses to systemic challenges in traditional education. They aim to foster creativity and interdisciplinary problem-solving among learners through hands-on, project-based activities. Over the years, this approach has expanded from grassroots makerspaces into formal education systems, where it is often paired with STEM or STEAM curricula, also referred to as STEM+ (Ioannou & Gravel, 2024). The integration of arts within STEM has broadened the focus, fostering holistic learning experiences that engage learners' creativity and critical thinking.

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However, as Maker Education gains traction in formal and informal settings, critical gaps in its implementation and pedagogy have become apparent. Early implementations of Maker Education often prioritised the tools and physical spaces rather than pedagogical outcomes. While these spaces enabled access to innovative technologies like 3D printers, laser cutters, Arduinos, and Micro:bits, they sometimes failed to engage learners meaningfully or achieve broader educational goals. The timing for this work is interesting, given the spread of makerspaces and maker education practices. With hundreds of such spaces and initiatives, especially across Europe and USA, one could argue that the impact hasn't appeared yet, at least not in scientific publications.

This research project has been guided by the following central question: how can Maker Education evolve to enforce its initial vision, transcend current limitations, and deliver meaningful, scalable, and inclusive learning experiences? By asking this question and documenting responses from researchers and practitioners in the field, the study places its focus on the emergent pedagogical priorities of community and resilience. This paper clarifies how community-based approaches and resilience-building contribute to a redefined Maker Education implementation and pedagogy, revitalizing its original principles and vision based on Constructionism.

For the purposes of this short paper, we focus on two central themes that stand out in our interviews:

- The emergence of discourse around community and the realisation among experts that the secret ingredient to successful Maker Education programmes is community, sometimes eclipsing the need for advanced technological equipment. We present possible dimensions and the significance of this realisation for learning design for Maker Education.
- An emphasis on the pedagogic priority of countering the mainstream's aversion to failure by designing opportunities for developing "resilience" during problem solving. This can be conceptualised as cultivating atmospheres and activities that encourage persistence, adaptability, and experimentation that validates and values failure and fosters collaboration for overcoming hurdles, respecting and learning from our and others' mistakes.

By pulling out these two threads as emergent pedagogic priorities in Maker Education discourse, we wish to contribute to Maker Education's mission of preparing individuals not only for technical proficiency but also for creativity, adaptability, and collaborative problem-solving in a rapidly changing world.

2. Methodology and Ethics

This study employed a qualitative research design, using semi-structured interviews to explore the evolving priorities in Maker Education focusing on challenges, successes, and opportunities. Participants (n=8) were selected for their expertise in Maker-centred learning and included researchers and practitioners from K-12 and higher education contexts in the broader area of New England, USA. To recruit participants, we leveraged existing connections who also made recommendations for others (i.e., snowballing). Profiles of interviewees included: (i) three researchers and maker-practitioners with expertise in creative coding, personal fabrication, and low-cost approaches to STEAM education, respectively, affiliated with two different major institutions in the area (5+ yrs of expertise); (ii) two researchers and professionals in the field of teacher professional development for STEAM education, at a

major institution in the area working (15+ yrs of expertise); (iii) one K-12 professional with a leadership role in a private K-12 school adhering to constructivist education, project-based learning, and interdisciplinary curriculum design (15+ yrs of expertise); (4) two professionals in K-12 initiatives and maker education /FabLab programs at a major institution in the area.

All interviews were conducted in person, by the same researcher (first author), based on the participants' preference for the meeting location. An initial protocol was used to guide conversations while allowing lots of flexibility for participants to elaborate on their unique perspectives and daily work experiences. Each interview lasted 60-90 minutes. All interview recordings were securely stored, and transcripts were anonymized to ensure confidentiality. The study had ethical approval by the national research ethics committee of Cyprus.

3. Findings and Discussion

For the purposes of this short paper, we focus on two central themes that stand out in our interviews.

3.1 From Technocentrism to Community Connection

The importance of community emerged as a dominant theme in the interviews, with participants consistently highlighting that successful Maker Education programmes depend far more on cultivating a sense of belonging and shared purpose than on the availability of cutting-edge tools. One interviewee observed, "It's not about the tools, it's about the relationships we build around them." Community – whether referring to a community of practice involving various stakeholders in Maker Education or a collaborative peer learning environment – was central to the participants' vision of effective Maker Education. Without a doubt, proficiency with digital technology is as fundamental as traditional literacy in today's world (Papert, 1999) as acknowledged by the participants. Yet, effective makerspaces are characterised by shared goals, mentorship, and collaboration, transforming them into hubs of innovation and mutual support.

The centrality of community in pedagogy has long been recognised as a foundation for effective and inclusive education. Wenger (1998) conceptualised communities of practice as groups that share a domain of interest and collectively engage in learning, underscoring the role of social interaction in knowledge construction. This aligns with Vygotsky's (1978) theory of social constructivism, which posits that learning occurs within social contexts through interactions with peers and mentors. In Maker Education, these principles are amplified, as collaborative learning fosters shared purpose and mutual support (Johnson & Johnson, 1989). Furthermore, Freire's (1970) pedagogy of the oppressed emphasises the transformative power of collective agency, advocating for participatory and dialogic approaches that empower learners to engage critically with their environment. The significance of community also extends to equity and inclusion, as Noddings (1984) argued for an ethic of care in education, where relationships form the basis of meaningful and supportive learning environments. In Maker Education, embedding community-centric practices ensures that learners not only acquire technical skills but also develop interpersonal abilities and a sense of belonging, which are essential for holistic development. By integrating these pedagogical frameworks, Maker Education transforms from a technocentric model to a human-centred approach that prioritises collaboration, connection, and shared growth.

Participants also stressed that community-centric practices ensure broader access and equity in Maker Education. By embedding makerspaces within local contexts and tailoring activities to community needs, educators can create inclusive environments that empower diverse learners. This aligns directly with constructionist principles by prioritising shared learning experiences and fostering collective growth.

3.2 Iterative Resilience: A New Pedagogical Priority

Another key theme was the prioritisation of resilience as a core pedagogical aim. Resilience in this context is not about enduring adversity in isolation but fostering a mindset of persistence, adaptability, and collaboration. Participants described how designing iterative processes – where failure is normalised and seen as an essential step in learning – builds learners' confidence and problem-solving abilities. One participant noted, "If students learn to embrace failure as part of the journey, they become more innovative and less afraid to tackle complex challenges." Awareness of the value of iterative resilience in Maker Education is deeply intertwined with established pedagogical theories offering a multidimensional framework for fostering adaptability, creativity, and persistence. Central to this concept is the growth mindset, which posits that abilities and intelligence can be developed through effort and learning from failure (Dweck, 2006). Complementing this is grit, defined as perseverance and passion for long-term goals, which underscores the importance of sustained effort in achieving mastery (Duckworth, 2016). Experiential learning provides the cyclical foundation for iterative processes, emphasizing learning through reflection on doing and experimentation (Kolb, 1984). Manu Kapur (2008), coined the term 'Productive Failure' to describe a learning design where students attempt to solve complex problems before receiving direct instruction, leading to initial failure but ultimately resulting in deeper understanding and better learning outcomes. Reflective practice deepens this learning cycle by encouraging critical examination of one's actions to refine future strategies (Schön, 1983). Collaborative learning further enriches iterative resilience by embedding it in a social context, enabling learners to navigate challenges collectively (Johnson & Johnson, 1989). Finally, self-regulated learning equips individuals with the tools to plan, monitor, and adapt their own learning processes, reinforcing the independence necessary for iterative growth (Zimmerman, 2002). Together, these interconnected theories provide a robust pedagogical foundation for embedding iterative resilience in Maker Education.

Participants also highlighted the role of educators in modelling resilience. By openly sharing their own iterative processes and demonstrating how to learn from setbacks, teachers can create safe spaces for experimentation. These practices establish resilience as a shared cultural value, reinforcing collaboration and mutual support.

4. Implications for Practice

We briefly outline the key implications of this research in order to provide actionable strategies for educators, policymakers, and practitioners to embed community and resilience into Maker Education. These insights aim to guide the implementation of inclusive, adaptable, and transformative pedagogies that align with the evolving needs of learners in a rapidly changing world.

4.1 Embedding Community in Maker Education

Fostering connections between makerspaces and their surrounding communities is vital for ensuring relevance and inclusivity. When Maker Education is embedded in local contexts, it can address specific community needs, creating a sense of shared

ownership and mutual benefit. Educators should focus on involving community members, local organizations, and industry professionals in the learning process to ensure that learning is not just an isolated activity but a dynamic, socially engaged practice.

Mentorship and peer-to-peer learning should be prioritised, as they provide learners with opportunities to develop through collective experiences. These practices are particularly important in Maker Education, where collaboration is key to success. Building strong ties within the community encourages collaboration, widens participation, and supports learners' personal and professional growth. To ensure inclusivity, makerspaces should actively reach out to underrepresented groups, offering mentorship and pathways to engagement that may otherwise be inaccessible. Furthermore, creating a feedback loop between makerspace activities and the community will help refine educational approaches to better meet the evolving needs of all stakeholders.

By embedding community-centric practices in the design and implementation of Maker Education, schools and other educational institutions can foster a sense of belonging and purpose that transcends the traditional classroom model. This inclusive approach nurtures long-term engagement and ensures that learners develop skills and relationships that are directly applicable to the world beyond the makerspace.

4.2 Cultivating Resilience

Designing activities that normalise failure and emphasise iterative learning processes is critical for equipping learners with the skills to adapt and persevere in a changing world. Traditional educational systems, which often treat failure as a setback, can discourage learners from experimenting and taking risks. Maker Education, by contrast, provides an environment where failure is seen as a necessary and constructive part of the learning process. Educators must intentionally design project-based learning opportunities that encourage learners to iterate, test, and refine their ideas without fear of judgment.

Professional development initiatives should prepare teachers to model resilience in their own practices, demonstrating that failure can lead to growth when embraced as a learning opportunity. Teachers should be trained to create an environment where setbacks are seen as learning moments, not as obstacles. Additionally, educators should encourage reflective practices in students, where learners can evaluate their failures, identify lessons learned, and apply those insights to future projects.

Overall, it is essential for resilience-building to be embedded into the curriculum across subjects, where the focus is placed on problem-solving and adaptation rather than merely correct answers. This approach can help learners build the cognitive and emotional flexibility necessary to thrive in both academic and real-world settings.

4.3 Bridging Community and Resilience

Collaborative projects that integrate community-centric values with iterative resilience have the potential to create transformative learning ecosystems in which technological competencies can also be developed. By focusing on shared goals, these projects help learners connect with others, foster a sense of accountability, and build

their confidence in overcoming challenges together. This approach not only builds technical skills but also nurtures the interpersonal skills that are vital in today's interconnected world.

Learners benefit from working alongside others in a community, where each person brings their own experiences, perspectives, and strengths. This collaborative environment encourages students to engage in problem-solving as a collective effort, where success is shared, and setbacks are collectively addressed. This sense of mutual support and shared responsibility makes the learning process more meaningful and impactful, as students see the value of their contributions in a larger context.

By integrating iterative resilience into community-driven projects, Maker Education can ensure that collaboration and mutual support are central to the learning experience. This model prepares learners to not only face challenges with creativity and persistence but also to work collaboratively in dynamic, complex environments. Whether within a school, community centre, or industry setting, the ability to collaborate and innovate together will be essential for learners as they move forward in their academic and professional journeys.

While these strategies are widely applicable, it is also important to acknowledge that educational settings may vary significantly in terms of available resources, institutional support, and community engagement. Educators in underfunded or resource-constrained environments should be supported with practical strategies for adapting these principles within their specific contexts. Small-scale community-driven initiatives can be a valuable starting point in such settings, if the emphasis is placed on low-cost, high-impact practices like peer-to-peer mentoring and local partnerships. Collaborative funding models, including partnerships with local businesses and industries, can also provide crucial resources not just for community involvement, but also to scale these practices beyond the classroom.

5. Conclusion

This short paper focuses on two major themes emerging from our broader research project: (1) the shift towards community-centric practices and (2) the prioritisation of iterative resilience as pedagogical foundations in Maker Education. Although, proficiency with digital technology in today's world is as fundamental as traditional literacy (Papert, 1999), our findings highlight a significant shift away from technocentric paradigms towards human-centred approaches that articulate adaptability, collaboration, iterative resilience, and connection as critical conditions for learning in our rapidly changing world. These ideas of community-based approaches and resilience during problem solving are not new. Rather, they are well present in constructionist theory, as seen in early texts by Papert (1980) and the eight big ideas behind the constructionist learning lab (Papert, 1999). The findings and examples present in the paper aim to strengthen these ideas in the context of Contemporary Constructionism and transform what is now known as Maker Education into practices filled with meaning and deeper pedagogical aims.

The broader research project also examines complementary themes, such as the role of teacher training in embedding constructionist practices, discourse around "learning to learn," and challenges associated with scaling Maker Education and STEM+ in underfunded settings. These dimensions enrich our understanding of Maker Education's transformative potential, suggesting systemic strategies to integrate its

principles into diverse educational contexts. Future work will synthesise these findings into a holistic framework, connecting the emergent themes of community and resilience with broader considerations of inclusivity, sustainability and innovation in STEM+ and Maker Education. By addressing these interconnected priorities, this research aims to empower educators, policymakers, and practitioners to harness Maker Education's potential for creating inclusive, impactful learning environments.

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