Adaptation of the Use of the Makerspace Resources for the Improvement of the Education System in East Africa

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ABSTRACT

Adopting new teaching and learning methods to improve learning outcomes is a critical concern in contemporary education. In line with this, the Makerspace movement, accompanied by Design Thinking, is being ingrained into teacher education as a strategy to enhance the performance of teacher educators and the quality of pre-service teachers. Borrowing from constructivism theory, Makerspaces provide opportunities for tutors, student teachers, and school learners to develop artifacts that aid and demonstrate their learning. This paper examines how Makerspace materials might be incorporated into teacher education and school classrooms, emphasizing strategies, empirical findings, and actionable recommendations derived from a study across four East African teacher preparation institutions. Findings from the concurrent mixed methods approach show that Makerspaces foster a culture of experimentation, iteration, and continuous learning, encouraging innovation, empowering teachers, and promoting the development of inclusive and genderresponsive resources. The study concludes that the initiative marks a revolutionary turn in education, aligning with global trends for inclusive and creative learning while offering a highly scalable pedagogical model for resource-constrained contexts. The report recommends sustained continuous professional development and the integration of competency-based assessment strategies to ensure long-term sustainability.

Keywords: Design thinking, gender-responsive resources, makerspace, teacher educator

INTRODUCTION

The education landscape has undergone a transformative shift in recent years, shifting from traditional paradigms to dynamic and participatory approaches. This has necessitated the inclusion of improvement initiatives, some of which target teacher education. One groundbreaking initiative gaining traction in East Africa is incorporating Makerspace pedagogy to reimagine and revitalise the educational system. Spearheaded by educators at the Institute for Educational Development at Aga Khan University, East Africa, this endeavour seeks to establish collaborative workspaces within educational institutions dedicated to fostering innovation, experiential learning, and the collective creation of knowledge.

1.1 Background

A Makerspace, in essence, is more than a physical room equipped with an array of tools, from cutting-edge technology to basic crafting materials. The philosophy embraces a hands-on, participatory approach to learning and problem-solving. These spaces, strategically placed within schools, colleges, libraries, and public or private facilities, serve as crucibles for creativity, exploration, and knowledge-sharing. Open to students and teachers, Makerspaces transcend the traditional boundaries of education, offering a dynamic platform where individuals can evolve from passive recipients of knowledge to active creators and inventors.

The primary goal of Makerspace is to empower learners and educators alike, encouraging them to perceive themselves as architects of their educational journey. By providing a setting where trial and error, critical thinking, and self-confidence are nurtured, Makerspaces become catalysts for the development of essential

21stcentury skills. In these environments, students and teachers alike engage in hands-on activities, allowing them to experiment, collaborate, and iterate on ideas, fostering a profound sense of agency and ownership over the learning process.

Each Makerspace room, strategically established within teacher training colleges, represents more than a physical space filled with tools. It symbolises a commitment to progressive pedagogy, curriculum innovation, and the overarching improvement of educational practices. The inclusion of tools such as computers, printers, cutters, soldering irons, sewing machines, and woodworking tools transforms these spaces into vibrant hubs of interdisciplinary exploration.

Makerspaces, when integrated into teacher training colleges, can foster a growth mindset among educators and students alike. By providing opportunities for hands-on, project-based learning, makerspaces encourage experimentation, iteration, and continuous improvement, which are core components of a growth mindset. For instance, teachers can use makerspaces to design and develop educational resources that reflect their evolving understanding of pedagogy and curriculum. Similarly, students can engage in makerspace activities that challenge their assumptions and encourage them to think critically and creatively. This integration of makerspaces with a growth mindset can profoundly impact learning and teaching, as it promotes a culture of experimentation, risk-taking, and continuous learning. As educators in East Africa grapple with the imperative to prepare students for a rapidly evolving workforce, Makerspaces emerge as a beacon of innovation. This initiative recognises the need for innovation, problem-solving, and collaboration skills. Moreover, Makerspaces strive to be inclusive environments where individuals are encouraged to explore their interests and passions and develop new skills in a supportive and collaborative milieu.

1.2 Makerspace Development in Education

The current discourse on education underscores the need to equip students with skills that transcend traditional academic knowledge. Authors such as Wagner and Dintersmith (2015) in "Most Likely to Succeed" emphasize the importance of fostering skills such as critical thinking, collaboration, and creativity. Makerspaces, emphasising hands-on learning and problem-solving, are ideal environments for nurturing these 21st-century skills.

Incorporating design thinking is a key element in the makerspace philosophy at AKU-IED. Design thinking, emphasising co-creation, innovation, and iteration, places human-centred problem-solving at its core, aligning well with the educational objectives of developing empathetic and innovative graduates. Makerspaces provide fertile ground for applying design thinking principles, allowing faculty and students to engage in a structured, iterative process of identifying challenges, ideating solutions, prototyping, and testing. This approach encourages a growth mindset, as learners are empowered to experiment, learn from failures, and continuously refine their ideas and creations. By integrating design thinking into makerspace activities, AKU-IED can foster the critical thinking, collaboration, and problem-solving skills needed to tackle complex, real-world issues related to the Sustainable Development Goals. This pedagogical model helps prepare students to become agents of positive social change in their communities.

Martinez and Stager (2013) explored the role of educators in makerspaces in "Invent to Learn." The authors advocate for a shift from traditional teaching roles to facilitators, mentors, and collaborators. Makerspaces, by design, necessitate educators to assume multifaceted roles, aligning with the contemporary view of teachers as guides, advocates, and co-learners in the educational process.

The imperative for inclusive education and the consideration of gender-responsive practices align with the goals of Makerspaces. Research by Margolis and Fisher (2002) in "Unlocking the Clubhouse" highlights the importance of creating environments that welcome individuals from diverse backgrounds. Makerspaces, emphasising collaborative learning and developing gender-friendly resources, address the call for inclusive and equitable education. This is supported by Eckhardt et al., (2021) that by focusing on gender-friendly resources, the initiative aims to accelerate diverse children's learning by creating an environment that addresses all students' varied needs and interests.

Integrating makerspaces into teacher training institutions aligns well with the shift towards competency-based curricula in East African education systems. Makerspaces provide hands-on, project-based learning environments where teachers and students can develop the critical thinking, problem-solving, and collaborative skills emphasized in competency-based approaches (Saorin et al., 2017b) By engaging in makerspace activities, pre-service teachers can gain practical experience in designing learning experiences that foster the application of knowledge and the mastery of real-world competencies. This synergy between makerspaces and competencybased curricula can help equip educators with the pedagogical tools and mindsets needed to effectively implement these reforms and better prepare students for the challenges of the 21st century.

1.3 Evaluation and Continuous Improvement

Evaluation mechanisms in the context of Makerspaces find resonance in Falloon's (2015) work in "Making a Maker Culture: Necessary Learning Outcomes." The author stresses the importance of formative and summative assessment strategies to gauge the impact of maker programs on learners. The recommendations in the current initiative, such as Makerspace Hub Audits and diverse evaluation tools, align with the broader literature on assessing the effectiveness of maker education.

In the backdrop of this literature review, the integration of Makerspace resources into the educational system in

East Africa emerges not as a mere local experiment but as a strategic response to global educational challenges. Makerspaces, influenced by principles of maker education, design thinking, growth mindset, inclusivity, and continuous improvement, position themselves as dynamic spaces where education transcends traditional boundaries. As educators embark on this transformative journey, the alignment with established educational principles underscores the potential of Makerspaces to shape a future where learners are not just recipients of knowledge but active participants in their educational narratives. This initiative, rooted in both local needs and global educational discourse, becomes a beacon illuminating a path toward a more inclusive, innovative, and learner-centric educational paradigm.

1.4 Makerspace as a Professional Development Tool for Teacher Educators

The concept of Makerspace was introduced through workshops to teacher educators of the four primary teacher colleges involved in the five-year Foundation for Learning Project. Two of the colleges were in West Nile of Uganda, while Kenya and Tanzania had one college, respectively. The aim was to empower the college tutors with knowledge and skills to develop innovative and contextually relevant teaching and learning materials. The tutors were equipped with skills of design thinking and resource development procedures which they needed to be able to identify, develop and use contextually relevant teaching and learning materials in line with the competency-based curriculum. Special consideration was made to gender-responsive teaching and learning resources and integration of Information Communication Technology (ICT) in the respective classes taught at primary and Early Childhood Care and Education (ECCE) levels of teacher education.

1.5 Workshop Implementation Strategies

The strategies employed in integrating Makerspace resources into the educational framework are designed to create transformative experiences for educators and learners, who, in this case, are the student teachers. Each strategy contributed uniquely to the overarching goal of fostering a dynamic and participatory learning environment. The strategies are as shown below;

Modelled on Design Thinking Process – This ideology is concerned with solving complex problems humanely, creatively, and user-centric (Stevens, 2023). The participants were introduced to a design challenge, that is, a problem to solve and then taken through the 5 steps of the design thinking process, which would enable them to master developing and using relevant resources to facilitate their teaching for improved learning. These steps include, in order of occurrence, empathise, define, ideate, prototype, and test. The workshops the participants engaged in were modelled on design thinking and engaged in in-person and hands-on activity-based sessions. In the workshops, participants worked collaboratively to identify problems related to their practices and develop solutions.

Adopting the Maker Framework: This framework, adopted as part of the intervention, included four essential stages: Front Loading, Experience, Documentation, and Reflection, each ensuring educators and learners could fully benefit from Makerspaces.

1. **Front Loading** involved preparing participants by introducing them to the design challenge, the tools, materials, and concepts of the Makerspace. This stage included hands-on demonstrations, safety training, and theoretical overviews of relevant principles. Additionally, it involved project planning, where learners brainstormed, developed proposals, and set achievable goals.

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2. **Experience** was the core phase where participants engaged in making, that is, building, crafting, or drawing projects. It emphasized iterative development, encouraging exploration, testing, feedback, and revisions. Collaboration was key, with learners working in teams to share ideas and solve problems together.
3. **Documentation** involved capturing the process, progress, and outcomes of projects through journals, digital portfolios, or presentations. This stage aided in self-assessment and provided valuable resources for educators and peers to understand learners' experiences and growth.
4. **Reflection** enabled learners to critically evaluate their experiences, recognizing successes and challenges. It included structured feedback sessions, self-assessment, and future planning, promoting continuous improvement and metacognition.

Adopting a growth mindset. A growth mindset played a significant role in participants' motivation for learning. In the Makerspace, participants were given the freedom to tinker, overcome challenges, and explore independently, fostering resilience and perseverance. Makerspace allowed participants to make mistakes and learn in their own way, viewing mistakes not as errors but as the next iteration of an idea on the journey toward a working solution. Failures were seen as opportunities for growth, with an emphasis on celebrating incremental progress. Embracing a growth mindset meant that participants understood they could improve by dedicating time, effort, and energy, focusing on the process rather than the outcome. Over time and with practice, participants with a growth mindset believed they could achieve their goals, making this approach integral to the success of Makerspace.

1.5 Research Questions

The following questions guided this study:

1. What is the role of makerspace in improving education?
2. What are tutors' experiences of learning about and implementing makerspace in their practices?
3. How does engaging in makerspace improve tutor practices?
4. How does the adoption of makerspace impact on student teacher learning outcomes?
5. What challenges and opportunities are available to implement makerspace in teacher preparation institutions?

RESEARCH METHODOLOGY

A concurrent mixed methods approach was applied in this study. This design involved the simultaneous collection and analysis of both qualitative and quantitative data, which were then triangulated to provide a holistic and comprehensive understanding of the complex socio-pedagogical phenomenon of Makerspace adoption.

Qualitative Component: Phenomenological Design

For the qualitative component, a phenomenological research design was adopted. This approach was essential for achieving an in-depth understanding of the lived experiences of teacher educators (tutors) regarding the learning about and implementation of Makerspace initiatives. Specifically, phenomenology allowed the researchers to explore the tutors' attitudes and the ways in which their newly acquired knowledge and skills were subsequently translated into the field, impacting student teacher practices during practicum. This qualitative depth was critical for addressing Research Questions 2 and 3 concerning tutor experiences and the improvement of their pedagogical practices.

Qualitative Sampling and Data Collection

Purposive sampling was used to select the primary qualitative participants. Eight tutors, two from each of the four colleges, were identified as key participants for detailed classroom observations and subsequent semistructured interviews. These individuals were often early adopters or designated Makerspace leaders, allowing for focused insights into innovative classroom practices. A few schools were visited to enable the researchers experience how student teachers applied the makerspace concept in their practices.

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Furthermore, Focus Group Discussions (FGDs) were conducted with four groups of college tutors, totaling 36 participants (approximately 8-9 tutors per group), and with 24 student teachers (six from each college). The FGDs used related guides to elicit shared experiences and collective insights. The transcribed data from the interviews and focus group discussions was analyzed using Dedoose, a computer-aided data analysis program. The qualitative analysis followed the principles of Interpretive Phenomenological Analysis (IPA), focusing on identifying core themes, commonalities, and essential structures within the participants' experiences.

Quantitative Component: Survey Data

For the quantitative component, a questionnaire was administered to 60 college tutors (15 from each college). This sample size approximated a census of the faculty involved in teacher preparation across the four institutions. The questionnaire utilized a combination of Likert scales and open-ended items designed to quantify tutors' attitudes toward and self-reported experiences on the use of makerspace, addressing the measurable aspects of all five research questions (e.g., perceived impact on student teacher learning outcomes, challenges, and opportunities).

Quantitative Data Analysis

Quantitative data analysis primarily employed descriptive statistics (e.g., means, standard deviations, and frequencies) to summarize the prevalence of certain attitudes and experiences. Depending on the question structure, inferential statistics, such as correlations, were used to explore relationships between self-reported levels of Makerspace engagement and perceived effectiveness in curriculum alignment and skill development. The concurrent use of these data streams provided a robust mechanism for data triangulation in the final discussion.

FINDINGS

The integration of Makerspace resources into the education system in East Africa reveals a multifaceted and significant impact on teacher educators (tutors), student teachers, and the broader educational landscape. The analysis of qualitative and quantitative data converged on several key thematic areas underscoring the transformative potential of Makerspaces.

3.1 Catalytic Shift in Educator Roles and Competency

The Makerspace initiative served as a catalyst for professional transformation, significantly impacting educators' roles and pedagogical capabilities. Tutors were empowered to become "champion teachers" through intensive, hands-on workshops that fostered competencies transcending traditional didactic approaches.

1. **Evidence of Role Transformation:** The successful establishment of Makerspaces necessitated the identification and elevation of leaders among college tutors and student teachers. These leaders assumed responsibility for operational management, including coordinating activity schedules, monitoring resource traffic, managing replenishment, and mentoring student teachers.
2. **Embracing Reflective Practice:** Tutors demonstrated a commitment to reflective practice, actively engaging in follow-up and critical reflection and action research to improve their pedagogical application. A tutor captured the essence of this transition: *"Makerspaces are more than just rooms filled with tools; they are crucibles for creativity, exploration, and knowledge-sharing, where individuals evolve from passive recipients of knowledge to active creators and inventors."*
3. **Confidence and Capability:** The immersive experiences instilled measurable confidence, transforming educators into proactive agents of change (Max et al., 2023), resulting in the development of demonstrable outcome-oriented qualities.

3.2 Fostering Innovation and an Iterative Design Mindset

Makerspaces emerged as powerful platforms for igniting creativity, innovation, and robust problem-solving skills by promoting a culture of experimentation and risk-taking (Soomro et al., 2023).

1. **Cultivation of Creativity and Problem-Solving:** In a classroom challenge, student teachers moved beyond basic art techniques to create intricate, symbolically meaningful patterns, demonstrating creative output fueled by a growth mindset. The activity fostered lively discussions and peer questioning, highlighting the cultivation of problem-solving skills and the ability to embrace calculated risks.

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2. **Acquisition of Design Thinking:** Both tutors and student teachers demonstrated increased conceptualisation and the ability to meaningfully apply terminology related to Design Thinking, such as *ideation*, *prototypes*, and *iteration*. This facilitated collaborative problem-solving, yielding diverse solutions to common institutional challenges. Student teachers noted: *"We are usually given the same problems or tasks in our groups. During presentations, we learn from other groups whose presentation differs from ours. In our ways, we can know which presentation works better or is relevant to our context."*
3. **New Ways of Knowing:** Empirical evidence overwhelmingly supports the role of Makerspaces as a catalyst for cognitive and pedagogical improvement. The findings highlight the introduction of New Ways of Knowing including promoting sustainability and environmental responsibility (Smith and Light, 2017). New ways of knowing, specifically, is evidenced by observations of student teachers creating intricate patterns and using diverse colors, moving "beyond basic techniques" through experimentation and a growth mindset.

3.3 Enhancement of Participant Agency and Ownership of Learning

A critical finding was the significant development of participant agency, fostered by the environment's support for independent exploration and a growth mindset (Pepin, Knock & Razat 2023).

1. **Autonomous Exploration:** The Makerspace provided a supportive environment that encouraged participants to take ownership of their learning, setting goals, experimenting, and learning from mistakes.
2. **Empirical Evidence of Agency:** The student teachers developed the sense of ownership of learning from engagement in the makerspace activities which required them to design and make the resources which would enable them to teach the intended concepts effectively. Participant A observed: *"The Makerspace allowed us to think critically and creatively. We were not just following instructions; we were generating ideas and finding our own solutions to challenges."* This confirms the promotion of independent thinking and decision-making. Participant B further noted a transformative shift: *"We were initially hesitant to take risks but with time and facilitators encouragement become more confident and willing to experiment. The process of trying, failing, and trying again helped us understand that we have control over their learning journey."* This transformation underscored enhanced resilience and self-efficacy.

3.4 Operationalizing Curriculum Alignment and Competency Development

The initiative directly supported the implementation of the Competency-Based Curriculum (CBC) by providing resources and guidance for practical, competency-based learning opportunities (Saorín et al., 2017).

1. **Strategic Planning and Resource Utility:** Teacher educators engaged in extensive planning, aligning Makerspace activities with curriculum content, competencies, learning outcomes, and assessment. One tutor affirmed the utility: *"when she goes to the makerspace room, she can 'easily decide on the teaching strategy after identifying the resources available'."*

2. **Efficiency in Resource Development:** The provision of assorted tools and equipment reduced the time previously spent developing teaching aids. This efficiency allowed student teachers to refocus their time on *"implementing more active learning strategies as we prepare for the school practicum exercise."*

3. **Suitability for CBC:** Tutors identified Makerspaces as highly suitable for implementing the CBC, providing an engaging, iterative environment that directly supports the development of required skills. A faculty member summarized: *"The competency-based curriculum is about empowering students to acquire skills... Makerspaces give them the space to develop those mindsets and skills in an authentic, engaging way."*

3.5 Promoting Collaboration, Inclusivity, and Sustainability

The Makerspace environment fostered a strong culture of collaboration and interdisciplinary learning while driving efforts toward inclusivity and environmental consciousness.

1. **Development of Collaborative Culture:** Makerspaces thrived on teamwork, shared learning experiences, and co-creation, which was crucial for fostering a sense of community (Soomro et al 2023). Participants often worked on interdisciplinary projects, enhancing their holistic understanding. Participant C noted, *"The Makerspace environment encouraged us to work together, share their expertise,*

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and develop solutions collaboratively. This not only improved our technical skills but also fostered a strong sense of community."

2. **Inclusivity and Gender Responsiveness:** A concerted effort was made to develop resources and environments that were gender-responsive and inclusive. This included ensuring the choice of the Makerspace considered inclusive needs and establishing guiding principles (shunning discrimination, collaborative code of conduct). This enabled colleges to open spaces to cooperating schools and local communities.
3. **Environmental Responsibility:** The emphasis on using sustainable materials and techniques positioned Makerspaces as agents of positive change, promoting sustainability and environmental responsibility among educators and learners (Smith & Light, 2017).

3.6 Challenges and Opportunities of implementing Makerspace

The successful development of Gender-Responsive and Inclusive Resources is among the primary opportunities identified in the implementation of Makerspace. The intentional focus on diversity and inclusion, exemplified by the student with physical disabilities whose self-esteem "improved when a visiting education officer appreciated his work," highlights Makerspace's capacity to serve as an equity tool. This is evident in a statement by a head of school that,

… we have learners with physical disabilities here. This model weighing machine was made by one of them, a boy walking with assistance of crutches. His self-esteem improved when a visiting education officer appreciated his work before the whole school during the morning assembly. (Head of school, Respondent)

The allowance for student teachers to develop their own schedule in a "more relaxed environment" empowers the "timid to participate," demonstrating a strategic opportunity for improving participation rates beyond the classroom.

The discussion of related challenges is further elaborated below**.**

Challenges to Sustainability (Beyond Funding, Infrastructure, and Policy)

While the challenges of funding, physical infrastructure, and policy support are acknowledged constraints, the long-term sustainability of the East African Makerspace initiative faces critical pedagogical and systemic hurdles rooted in professional culture and assessment:

1. Pedagogical Inertia and Resistance to Change: Despite expressed positive attitudes, the most significant challenge is the potential for pedagogical inertia. Tutors who are deeply entrenched in traditional, transmission-based teaching methods may revert to these practices when faced with time constraints or large class sizes. The open-ended, non-linear nature of maker-based learning requires significant cognitive and time investment from the facilitator, a level of commitment that may not be sustained without ongoing institutional accountability.
2. Assessment Integration Difficulty: A persistent challenge is the difficulty in formally assessing learning outcomes generated in the Makerspace (e.g., creativity, collaboration, iterative design) within a national testing system that may still prioritize rote memorization. If formal assessment mechanisms do not evolve to value these competencies, the pressure on tutors to "teach to the test" will inevitably marginalize Makerspace activities, undermining their sustainability and perceived value.
3. Technical Expertise and Resource Maintenance: The "assorted collections of power and hand tools" mentioned require more than simple restocking. Sustained functionality requires high-level technical expertise for maintenance, calibration, and strategic replacement of equipment. If this technical support is not institutionalized and embedded within the college staff—and is solely reliant on the teaching tutors, the quality and safety of the Makerspace resources will inevitably decline.
4. Curriculum Saturation and Time Constraints: Implementing iterative Design Thinking and complex projects requires significant time. The challenge of curriculum saturation—integrating these new activities into an already packed teacher training syllabus without sacrificing core content—poses a practical barrier. Tutors require specialized training in time-efficient facilitation models to overcome this.

DISCUSSION

The empirical findings from the integration of Makerspace resources in East African teacher preparation institutions provide compelling evidence of a comprehensive pedagogical transformation. This discussion synthesizes the emergent themes, links them explicitly to the research questions, and employs a critical lens to enhance the depth of analysis.

4.1 Reframing Pedagogy: The Shift to Experiential and Reflective Practice

This theme addresses RQ2 (Tutors' experiences) and RQ3 (Improvement in tutor practices). The findings illustrate a fundamental shift in pedagogical orientation, moving away from traditional instruction towards experiential and reflective models. The role of the educator is redefined from a content dispenser to a "champion teacher" and facilitator, a transition noted in wider literature (Martinez & Stager, 2013).

The establishment of the Makerspace successfully enforced this shift by requiring tutors to engage in operational and reflective responsibilities—managing resources, coordinating activities, and mentoring student teachers. This necessitated outcome-oriented professional development centered on critical reflection and action research, which goes beyond mere attendance at training and confirms a genuine transformation in practice. The immersive experience acts as a crucible, instilling the necessary confidence to abandon traditional comfort zones and embrace the dynamic, interactive learning environment.

4.2 Nurturing 21st-Century Competencies: Agency, Creativity, and Growth Mindset

This theme is central to answering RQ1 (Role of Makerspace) and RQ4 (Impact on student outcomes). The data demonstrates that the Makerspace environment is highly effective in cultivating core 21st-century skills that are difficult to foster in conventional classrooms.

The promotion of Design Thinking concepts—evidenced by the use of technical terms like *ideation* and *iteration*—is directly linked to igniting creativity and problem-solving (Soomro et al., 2023). Crucially, the environment empowers student agency by normalizing failure and encouraging autonomous exploration (Pepin, Knock & Razat, 2023). The shift from being "hesitant to take risks" to becoming "confident and willing to experiment" confirms that the iterative nature of the Makerspace builds resilience and self-efficacy, foundational components of a growth mindset. Furthermore, the interdisciplinary and collaborative nature of projects provides a natural setting for students to refine their critical thinking through shared critique and collective problemsolving (Abdurrahman, 2019; Blackley et al., 2017).

4.3 Makerspace as a Strategic Tool for Curriculum Reform and Equity

This theme directly addresses RQ1 (Role of Makerspace) and the Opportunities identified in RQ5. The findings confirm the Makerspace's strategic utility in operationalizing the Competency-Based Curriculum (CBC) and driving educational equity.

Makerspaces are identified as a "highly suitable pedagogical approach" because they compel tutors to engage in extensive planning that strictly aligns resource creation with curriculum outcomes, thereby enhancing the relevance of teacher training. The finding that a tutor can "easily decide on the teaching strategy after identifying the resources available" points to the Makerspace's role in streamlining instruction and facilitating resourcebased teaching.

Critically, the initiative champions inclusivity and gender responsiveness by actively considering diverse needs, setting guiding principles against discrimination, and ensuring accessible infrastructure. This focus transcends mere access, moving towards equity in learning outcomes by designing "gender-friendly resources" (Margolis & Fisher, 2002). This intentional design, coupled with efforts to promote community access and environmental responsibility (Smith & Light, 2017), establishes the Makerspace not just as a learning area, but as a proactive agent for social and curricular change.

4.4 Institutionalizing Efficiency and Applicability in Teacher Preparation

This theme speaks to the practical impact of the Makerspace on the mechanics of teacher training, addressing RQ3 (Improvement in tutor practices) and the Efficiency aspect of RQ4.

The availability of specialized tools, even at a relatively low-tech level, significantly enhanced efficiency. The time saved in resource development was demonstrably converted into time focused on "implementing more active learning strategies," a crucial improvement in practice. This practical enhancement aligns the training with the realities of the school practicum, ensuring that the skills acquired—from tool use to resource creation—are experiential and applicable (Oswald & Zhao, 2021). The Makerspace thus serves as a critical bridge between abstract theoretical knowledge and the concrete skills required of a practicing teacher, reinforcing the practical dimension of competency development.

4.5 Persistent Obstacles to Long-Term Institutionalization

While the findings demonstrate high efficacy, the sustained scaling of the Makerspace initiative faces significant institutional challenges beyond the conventional constraints of funding, infrastructure, and policy. The most critical hurdle is pedagogical inertia, where tutors, despite expressing positive attitudes, may revert to traditional, didactic methods under the pressure of time constraints or large class sizes. This is compounded by the Assessment Integration Difficulty, as national systems often prioritize rote memorization, failing to formally evaluate complex outcomes like creativity, collaboration, and iterative design fostered by the Makerspace. This assessment mismatch risks marginalizing Makerspace activities. Furthermore, the sustainability of the resources is threatened by a lack of institutionalized technical expertise for maintaining and calibrating the "assorted collections of power and hand tools." Finally, the pressure of curriculum saturation poses a practical barrier, as tutors struggle to allocate sufficient time for complex Design Thinking projects within an already dense teacher training syllabus. Addressing these systemic, cultural, and technical challenges is paramount for achieving true institutionalization and maximizing the long-term impact of the initiative.

COMPARATIVE ANALYSIS AND IMPLICATIONS FOR SCALABILITY

The East African Makerspace initiative exhibits a unique profile when compared to prominent global Maker movements, specifically in its focus and resource model:

Project/Context	**Core Focus**	**Unique Contrast/Regional Context**	**Scalability Potential**
East African Teacher Colleges (This Study)	Pedagogical Transformation & CBC Alignment: Preparing future teachers for a Competency-Based Curriculum (CBC). High emphasis on Gender-Responsive Education and utilizing locally sourced/repurposed materials.	Uniqueness: Anchored in teacher training and school practicum; a social and pedagogical focus rather than purely technological.	High Scalability (Regional): Model relies on tutor leadership and low-cost ingenuity, making it highly adaptable to other resource-constrained East African schools and colleges.
MIT's Global FabLab Network (Massachusetts Institute of Technology)	Digital Fabrication & Entrepreneurship: Focus on advanced, high-tech tools (3D printing, CNC machines) for rapid prototyping and technical skill development (Gershenfeld, 2005).	Contrast: Requires substantial capital investment and specialized technicians, relying on high-end digital infrastructure.	Limited Scalability (Infrastructure): Direct replication is difficult in resource-constrained settings due to prohibitive operational costs.
USA/UK K-12 "Maker-Ed" Movement	STEM/STEAM Integration: Integrating making into primary/secondary curricula using specialized educational kits, coding platforms, and design challenges.	Contrast: Operates with established budgets for purchasing curriculumspecific technology kits. Similarity: Shared goal of fostering Design Thinking and student agency.	Medium Scalability (Conceptual): The underlying pedagogical concepts are highly scalable. However, the reliance on prepackaged, imported technical kits may prove cost-prohibitive for
			widespread adoption in East Africa.

The East African project demonstrates a regional uniqueness by successfully anchoring the Makerspace model not in high-tech fabrication (like FabLabs) but in pedagogical transformation and curriculum alignment (CBC) within the context of teacher preparation and acute attention to inclusivity. This pedagogical focus, utilizing locally sourced/repurposed materials, suggests a more sustainable and highly scalable pathway for educational reform across similar resource-constrained environments in the Global South. By focusing on the *mindset* and *pedagogy* over the complexity of the *technology*, the model offers a replicable template for developing teacher competency in 21st-century skills.

The findings confirm the transformative potential of Makerspaces in East African teacher preparation,

effectively answering all five research questions by demonstrating improvements in education's role, tutor experience, tutor practice, and student outcomes, alongside identifying key opportunities and challenges. While the success is evident in the fostering of agency and a collaborative, inclusive environment, sustained success is dependent on proactively addressing the systemic challenges of pedagogical inertia and integrating non-traditional assessment methods that truly value the competencies developed within these spaces.

RECOMMENDATIONS

Based on the empirical findings, the successful adoption of Makerspace principles, and the identified challenges to long-term sustainability (particularly pedagogical inertia and assessment difficulty), the following recommendations are put forth to ensure the continued efficacy, innovation, and institutionalization of Makerspace initiatives in teacher preparation colleges.

1. Sustaining Pedagogical Excellence and Methodology

The findings affirm the success of a diverse pedagogical approach; therefore, future efforts must focus on reinforcing and expanding these strategies:

1. Prioritize Hands-on Making and Design Thinking: Making, as an activity involving the design and construction of artifacts, must remain central. It is recommended to further emphasize making as a nonnegotiable learning activity, ensuring that a minimum percentage of course contact hours are dedicated to hands-on making and the iterative cycles of Design Thinking (ideation, prototyping, and iteration). This reinforces the connection between theory and tangible application.
2. Maintain and Diversify Instructional Strategies: Continue the successful utilisation of diverse instructional strategies, including demonstration, group discussion, and inquiry learning. These methods directly support the development of competencies in collaboration, creativity, and problem-solving (RQ4), which are central to the competency-based curriculum (CBC).
3. Reframe Challenges as Learning Opportunities: To counteract potential pedagogical inertia, actively encourage both educators and student teachers to view challenges encountered within Makerspaces not as impediments but as essential pathways to creative problem-solving. This mindset shift must be formally integrated into tutor training to nurture resilience and adaptability (RQ5).

2. Institutionalizing Continuous Professional Development (CPD)

Martinez and Stager's (2013) assertion that educators in Makerspaces should transition from traditional roles to facilitators, mentors, and collaborators, fostering a more dynamic and interactive learning environment, is in line with the continuous learning that participants engage in through makerspace. This calls for institutions to have well structured professional development programmes. As observed by a participant,

Recognizing the evolving nature of education, it is recommended to establish a framework for continuous professional development. Regular workshops, seminars, and collaborative events can keep educators abreast of emerging trends, tools, and pedagogical approaches within Makerspaces. (Teacher respondent)

To ensure that the initial enthusiasm and expertise are sustained and evolve, the following framework for continuous professional development is recommended:

1. Establish a Formal CPD Framework: It is crucial to institutionalize regular workshops, seminars, and collaborative events dedicated to emerging trends, new tools, and innovative pedagogical approaches within Makerspaces. This ensures that educators remain abreast of developments and can continually integrate innovative practices into their teaching methodologies.
2. Build Collaborative Networks and Knowledge-Sharing Platforms: To sustain the collaborative spirit and facilitate ongoing peer learning, establish formal collaborative networks and knowledge-sharing platforms (e.g., online forums or community-building initiatives). This collaborative ecosystem extends

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the impact of Makerspaces beyond individual colleges, creating a sustained culture of shared learning and resource-sharing.

3. Enhancing Evaluation and Assessment for Competency

To rigorously capture the impact of the initiatives and address the systemic challenge of assessment integration, a comprehensive and competency-aligned evaluation framework is necessary:

Adopt Diverse, Competency-Based Assessment Strategies: Move beyond traditional testing. It is recommended to utilize a comprehensive suite of assessment tools that capture the multifaceted impact of the workshops, including:

1. Artifacts and Sample Descriptions: Assessing the quality and relevance of designed and constructed resources.
2. Design Thinking Sheets/Journals: Evaluating the iterative process, critical thinking, and problemsolving documented during the making process.
3. Self-Assessments and Reflections: Capturing the development of student agency and metacognitive skills (RQ4).
4. Resource Evaluation Tools: Systematically critiquing the pedagogical effectiveness and inclusivity of created resources (RQ5).

Mandate Pre- and Post-Training Audits: Before facilitating Makerspace courses, mandate the conduct of Makerspace Hub Audits in collaboration with faculty. This process should thoroughly compare the required inventory with available physical resources. This ensures the necessary tools are available, preventing logistical barriers and contributing to the seamless implementation of planned activities, thereby protecting the investment and planning (RQ5).

By implementing these recommendations, teacher preparation institutions can transition the Makerspace initiative from a successful project to a sustainable, integrated, and continually evolving pillar of the educational system, ensuring the long-term preparation of champion teachers for the Competency-Based Curriculum.

CONCLUSION

The present study concludes by exploring the incorporation of Makerspace resources into the East African education system and highlighting the revolutionary effects of this creative endeavour. By thoroughly examining various approaches, conclusions, and suggestions, the study highlights how Makerspaces can transform teaching methods, provide instructors with more authority, and improve students' educational experiences.

The strategies used in the workshops, include gallery excursions and tangram exercises, combine to provide a stimulating and dynamic learning environment. These tactics, thoughtfully chosen to encourage critical thinking, problem-solving abilities, and practical experiences, perfectly capture the spirit of Makerspaces as group gathering places for creativity and inquiry.

The findings provide light on the concrete effects of integrating Makerspace. Teachers become champion educators, capable of navigating the changing educational environment. Creating gender-responsive resources best illustrates the wide-ranging effects on educators and students, encouraging creativity and innovation, and supporting competency-based learning, (Saorin et al., 2017). Makerspaces encourage a sense of community beyond individual programs by offering a venue for cooperation and knowledge exchange.

The study's recommendations are benchmarks for maximising the incorporation of Makerspace resources. These ideas, which range from adopting varied instructional methodologies to performing audits to verify resource availability, are designed to maintain the momentum created by Makerspaces. Prolonged professional growth, cooperative networks, and an emphasis on viewing obstacles as teaching moments add to this revolutionary project's durability and efficacy.

The study confirms that maker spaces constitute a paradigm shift in education rather than just physical facilities with tools. Makerspaces become catalysts for a more creative, inclusive, and sustainable educational future as teachers transform into learning facilitators and students become engaged learners. This study, which has its roots in the East African local setting, reflects the Makerspaces' global relevance as change agents in the educational landscape.

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