

SPECIAL FOCUS PAPER

How Blended Makerspaces Activities Elevate Learning Outcomes and Engineering Skills: A Mixed-Methods Case Study

Sayed M. Eldebeky  

Zayed University, Dubai, UAE

sayed.mahmoud@zu.ac.ae

ABSTRACT

Makerspaces can potentially support learning and teaching across different learning environments using new ways to enhance 21st-century and engineering skills. Although there has been extensive work on makerspaces within museums and libraries, more work must be done concerning their effects on learning and teaching and how the spaces might enhance students' engineering skills. This paper explores the notion of blended makerspaces—a new model, developed by the author, of blending hands-on, engineering, and technological skills—and their effects on learning. Based on a mixed-methods case study, this paper describes how the blended method used within the state-of-the-art makerspace stations creates critical thinking, inventiveness, and cooperation. This paper also examines how the spaces enhance life skills, such as flexibility and employability, preparing students for their prospective careers. The suggested blended makerspace method—learning in person, online, or both—emerges as a novel pedagogical structure. Furthermore, the study results indicate that through the infusion of blended activities in makerspace projects, students can enhance 21st-century engineering skills. This paper adds to the discussion on maker pedagogy. It suggests pathways for integrating makerspaces into educational contexts to enable students to develop engineering and other skills to be future-ready.

KEYWORDS

makerspaces, innovation, engineering skills, STEAM

1 INTRODUCTION

The transformative potential of makerspaces in educational settings has received more attention recently, underscoring their ability to prepare students for the demands of the 21st century because they help prepare students for today's world [1]. At their core, makerspaces can provide students with opportunities to engage in creative, collaborative, and hands-on learning experiences that transcend traditional

Eldebeky, S. M. (2025). How Blended Makerspaces Activities Elevate Learning Outcomes and Engineering Skills: A Mixed-Methods Case Study. *International Journal of Engineering Pedagogy (iJEP)*, 15(8), pp. 45–55. <https://doi.org/10.3991/ijep.v15i8.59095>

Article submitted 2025-10-07. Revision uploaded 2025-10-12. Final acceptance 2025-10-22.

© 2025 by the authors of this article. Published under CC-BY.

classroom boundaries and apply what they have learnt inside classrooms in real life. These spaces foster a unique blend of cognitive and practical skills, equipping learners with the tools to address real-world challenges. While research has extensively documented the implementation of makerspaces in museums and libraries, their integration into K–12 schools remains an underexplored area of inquiry.

Using Vygotsky's framework, Tilak et al. [2] demonstrate how makerspaces with peer and teacher scaffolding establish personal learning zones for students with learning differences, enhancing problem-solving and design thinking. This paper is an extension of my doctoral study, which was about the educational benefits of makerspaces in a bilingual high school in the Middle East. This study shed light on how cutting-edge makerspace stations can reinforce students' learning outcomes by highlighting a blended model that combines hands-on and technological skills. In particular, it discusses how these spaces aid in building critical thinking, creativity, collaboration, and career readiness among high school students. This paper demonstrates the potential of makerspaces for bridging school learning and real-world application, providing fertile ground for innovation and skill-building to prepare students for the future.

The proposed blended makerspace model, upon which this study is based, is a pedagogical method that combines physical and virtual learning methods for makerspace projects. This model is of special significance in the pandemic context of COVID-19 and evokes the necessity for flexible, hybrid solutions in education. By intertwining online activities, physical access to tools, and face-to-face interactions, blended makerspaces present an adaptive approach for learning organisations grappling with the challenges in education. This study highlights how such a model may overcome learning issues and upgrade the learning process through the sustained involvement of learners and the building of their expertise.

The effects of the blended learning approach on student engagement, although not examined in the context of makerspaces, may be assumed from specific findings associated with blended learning in learning environments. Blended learning, in turn, involves traditional face-to-face and online elements, and it has been proven that it strengthens student engagement in more than one dimension. According to research, it is also evident that the nature of instructional methods used in blended learning conditions may influence student engagement in these conditions [3]. For example, a comparison study conducted between lecture-centred and problem-centred blended learning conditions indicated that students demonstrated higher levels of engagement and spent more time working in the second condition, implying that the particular blended learning method used may impact the levels of engagement [3]. Furthermore, it was stressed in a systematic review that blended learning enhances academic, behavioural, cognitive, and affective student engagement. It was, however, also emphasised that barriers like unequal access to technology may negatively influence levels of engagement in various learning spaces [4].

Liu, Chai, and Wei [5] emphasise that intentionally including Small Private Online Courses (SPOCs) in blended learning environments has significantly increased student motivation. These flexible and personalised modules provide persistent interactivity and accountability, and offer a considerate model for converting makerspace projects to intermix independent digital learning with collaborative, hands-on learning.

Integrating blended makerspace learning that places practical activity alongside digital technologies holds the potential for widely improved student outcomes in schooling. When digital fabrication technologies, such as 3D printing and laser cutting, are included in learning environments, students can engage in

active, hands-on learning in multiple disciplines. However, simple access to these resources is insufficient for effective curricula integration. Researchers indicate that when instructors employ frameworks such as TPACK (Technological Pedagogical Content Knowledge) to organise lesson planning to incorporate these technologies, they engage them more robustly, increasing student engagement and learning outcomes [6].

Moreover, the theoretical groundwork for this study continues to originate in established education research paradigms, for instance, constructionist learning theory, culture of participation, and the 21st-century learning framework. These conceptual models constitute a robust basis for investigating makerspaces' promise in fostering transversal competencies key to students' personal and professional growth. By situating the research in these conceptual lenses, this paper foregrounds the broader relevance of makerspaces for fostering lifelong learning and innovation.

This paper is informed by a mixed-method case study in one bilingual high school with a dedicated makerspace equipped with high-end equipment such as 3D printing, computer numerical control machining, and robotics. The study's findings suggest that these resources facilitate the broad scope of learning outcomes, from enhancing fine motor competence via hands-on activities to acquiring digital literacy via technology-integrated endeavours. This paper describes the nature of blended makerspaces and their transformative power in student learning via qualitative and quantitative data in-depth analysis.

The subsequent section in this paper is on conceptualising and implementing the blended makerspace model, connecting its theory to its practice. With foundations in data from my doctoral dissertation, this thesis aims to contribute to the broader debate around makerspace inclusion in schools and provide insight for schools seeking to implement makerspaces effectively. Ultimately, this paper favours makerspace blended model inclusion as the basis of modern practice in schooling, in preparation for students for a dynamic and complex global world.

2 THEORETICAL FOUNDATIONS

The blended makerspace model is informed by the constructionist learning theory, which focuses on learning by doing. As outlined by Papert [7], sharing and making artefacts enables learners to accumulate knowledge in contextually significant and meaningful ways. This theory-informed approach places learners in an active rather than passive role and prompts exploration, experimentation, and repeated problem-solving. At the makerspace level, this manifests in learners utilising tools, materials, and technologies to see their ideas through to reality and developing an attitude of agency and control of the learning process. The National Library Makerspace Forum [8] exemplifies the growing trend for library-based maker programmes, placing community collaboration, accessibility, and theory-informed practice at the centre ground. Additionally, makerspaces in library contexts have been revealed to positively affect blended learning methods, particularly in the context of Industrial Revolution 4.0. Libraries that evolve to offer makerspace services have the potential to ensure accessibility and flexibility of learning provision [9].

Makerspaces embody the principles of participatory culture, in alignment with Lave and Wenger's [10] idea of communities of practice. Makerspaces are not mere physical spaces but dynamic ecosystems wherein sharing expertise and collaboration lead to proliferation. Makers in such environments actively contribute to the group's expertise while gaining from peer learning and potential mentorship.

Such a culture of cooperation reflects real-world working environments, wherein teamwork and sharing of ideas spark innovation. Makerspaces, in requesting contributions from all members, develop a positive network that enhances both personal and group learning outcomes. Recent literature has showcased the transformative roles of constructionist and participatory learning theories in maker learning, particularly in environments that demand equity, cross-disciplinary knowledge, and digital mastery [11].

The hybrid makerspace model is compatible with the call for 21st-century learning, wherein critical thinking, creativity, communication, and collaboration have been stressed as essential abilities, commonly referred to as the “four Cs.” These skills have gained broader awareness for their critical roles in engagements with the complexity of contemporary life and workplace settings. Makerspaces, in particular, excel in teaching these skills through multidisciplinary projects that compel students to analyse problems, devise solutions, and communicate their thoughts effectively. And through the blended model, these learning experiences are enriched with digital tools and remote collaboration, allowing students to prepare for physical and online settings.

3 RESEARCH CONTEXT AND METHODOLOGY

3.1 Study setting

This study responds to recent calls to explore makerspaces in under-represented educational contexts, particularly beyond Western settings [11], by focusing on a bilingual high school in Kuwait. The research was conducted at a bilingual high school in Kuwait that featured a dedicated makerspace comprising five distinct stations: 3D printing, CNC machining, electronics, robotics, and technology. These stations facilitated various projects that integrated curriculum content with innovative methodologies.

3.2 Data collection

Data was collected using online questionnaires, reflective journals, and observation notes. Seventy-nine high school students and seven teachers participated in the research. This paper’s original study adopted the Tinkering Learning Dimensions Framework [12] and the Reflective Cycle by Gibbs to explore the learning outcomes and experiences.

3.3 Analysis approach

The study adopted a systematic and rigorous data analysis approach, beginning with careful data organisation to ensure accuracy, consistency and confidentiality through safe storage, cleaning, and classification of reflective journals, questionnaires, and observation notes. An inductively and deductively coding approach was adopted, beginning with a theoretical lens (Tinkering Learning Dimensions) to guide preliminary coding and, thereafter, the creation of subsequent themes that arose from the data. NVivo 12 was used for the visualisation, honing and verification of codes and educators’ feedback added to the validity of the coding process.

Further, additional methods like cross-case analysis revealed trends across multiple makerspace stations, and thus, a deeper understanding and theoretical contribution in terms of acquired skills and learning outcomes was made. This multi-faceted approach added to the validity of the findings and allowed the study to connect makerspace learning to 21st-century learning and future work skills.

4 FINDINGS AND DISCUSSION

4.1 Blended makerspace activities

Blended makerspace activities refer to blending in-person and online formats; learning and collaboration are flexible. This model was in the original study of the author's thesis during the COVID-19 pandemic, when it was difficult for the students to approach the physical makerspace. Combining digital and hands-on approaches, blended makerspace activities helped learners develop soft and technical skills, although they could not reach the physical makerspace. For example, breakout rooms in Zoom enabled learners to work in pairs or groups in real-time and helped them collaborate and share ideas while working online.

A key aspect of blended activities is their ability to enable students to access and work on the makerspace tools and machines remotely. For example, this teaching method allowed students to use makerspace machines like 3D printing and CNC equipment without needing physical presence in the makerspace. Faculty members played a crucial role in facilitating this effort, offering teaching to students through online tutorials and recorded videos. This helped them to ensure that designs submitted online were fabricated with accuracy. When finished, students could collect their physical products from the physical makerspace, thus supporting a tactile attachment to their learning products, even in an online setting.

The blended makerspace programmes can provide more opportunities for schools with a low budget in poor countries. Schools without makerspace infrastructure may partner with regional organisations or public makerspaces, allowing learners to create artefacts virtually and, in turn, collect their finished artefacts through mail or other methods. This approach can help schools that can afford to develop makerspace and ensure equitable access to maker learning, thus allowing learners from diverse backgrounds to benefit from these innovative pedagogies. In the future, this might contribute to narrowing down the maker gap, a term coined by the author that refers to the gap between rich and poor countries in having makerspace facilities that support learning. Like many challenges in hybrid learning models, blended makerspaces activities should address digital equity and teacher preparation to ensure equitable access and sustainable use of the makerspace resources [13].

The benefits relating to blended makerspace activities move beyond simple logistical versatility. They, too, develop essential competencies that prepare students for the imperatives of a digitally driven society. Thus, experiential exercises, for instance, refine fine motor skills and initiate innovative thinking, while the online aspect enhances digital acumen and prepares learners for collaboration in virtual environments. Such elements result in holistic learning, allowing students to develop practical and theoretical expertise. Versatility is critical, allowing for the smooth combination of digital and hands-on learning experiences. Effectiveness in hybrid pedagogical methods, including blended and flipped teaching, supports the proposition that combining traditional and digital learning environments may increase academic performance and raise student satisfaction levels. Active, cooperative

pedagogies encourage critical thinking competencies and result in more profound retention of subject content [14].

Education faces many challenges in accommodating the new needs of learners. Mitigating these challenges through reasonable access and digital competency education is critical in ensuring maximum participation. Furthermore, using interactive technologies in blended learning environments has improved student experiences and enthusiasm to engage actively. Furthermore, blended makerspace activities can attract students' attention to work in the makerspace and strengthen their engagement [15].

Participants in the study showed enthusiasm for the blended makerspace activities, indicating that it provided them with active engagement and flexibility. One student suggested, "Being able to design at home and see my work after collecting it from the makerspace was really rewarding." Another student indicated that he was proud of what he designed online and happy when he touched his final artefact. These testimonies reveal the emotional and cognitive advantages that can be added to the intermixing of online and in-person pedagogical methods in the case of maker education. As Ioannou and Gravel [11] indicated, digital technologies remain key to maker pedagogy. Still, their integration in education requires careful consideration to develop real and inclusive learning experiences.

The blended makerspace approach in this study aligns with the ideas highlighted by Mulenga and Shilongo [13], particularly concerning digital platforms for blended teamwork and asynchronous communication. Again, blended activities allowed for continuity of education during the pandemic, ensuring learners could have contact with peers and instructors. For instance, managing the computer desktop remotely enabled learners to use the laser cutter and 3D printers remotely. Furthermore, this helped learners learn engineering skills remotely.

4.2 Hands-on vs. digital activities

Previous research pointed to the merit in balancing hands-on and technological learning to get the benefits of both types. Furthermore, the study of Cheng and Pang [16] indicated that makerspace engagement enhances divergent thinking and digital communication competency. Following the work of Clark and Post [17], students who worked on blended makerspace projects performed better if they started with introductory online sessions or recorded videos, followed by hands-on, synchronous sessions. This is consistent with the blended makerspace model approach, wherein student exposure to digital content or online design upload occurs before working on the physical makerspace machines, such as 3D printers. Blended makerspace activities like these can make students proficient in digital literacy and hands-on problem-solving, thus preparing them for their future jobs. Also, this might help them to fix minor home problems, such as fixing the water tabs. Consequently, they will feel the connection between what they study in school and the real world.

Also, it was noticed that blended makerspace projects promoted teamwork, learning from peers and learning from mistakes. For example, during 3D printing projects, students commonly shared their ideas and methods, thus ensuring an environment of communal learning. It was less visible in digital projects with a more solitary nature. Even so, including collaborative elements in digital projects, for instance, group coding exercises or shared design reviews, could ensure less disparity. However, face-to-face collaboration will be better, as socialisation will be easier, especially for shy students.

The paper highlights the benefits of combining digital and practical activities in makerspaces. Although both methods have advantages, their combination can lead to a holistic learning process that promotes innovation, technological literacy, and socialisation. This balanced approach aligns with makerspaces' primary purposes: preparing learners for their future and meeting their new needs.

4.3 Long-term projects

Long projects, which may continue for weeks or even entire academic semesters, offer students the potential to explore deep issues and build up an in-depth skill set. Long projects are most beneficial in makerspaces, for which long-term use lets students investigate topics of personal interest and build up their skills in small increments. Educators who participated in the research stated that long projects contribute to student-centred learning by making students prepare for student-centred learning and organise their own tasks autonomously.

A primary benefit that is correlated with long-duration projects is supporting co-teaching models. When subject-specific content and maker abilities are paired, educators can provide learners with an interwoven academic experience. For example, an intersection of the science instructor and the makerspace coordinator for a renewable energy project could combine textbook-based instruction in physics with hands-on projects involving the creation of solar-powered products. This approach deepens the curriculum and allows learners to see the practical applications for their academic understanding in the real world.

Long-term projects serve as an effective stimulus for student innovation. With the larger time frame, students can experiment, rework, and refine their ideas, leading to innovative and unique outcomes. Regarding this study, multiple students created innovative products that demonstrated technical competence alongside innovative thinking. For instance, a group working on a robotic arm project revised their blueprint in such a way that it added complementary features, thus demonstrating their potential for innovation in response to the brief.

Long-term projects, on the whole, constitute a defining feature of successful makerspace learning because students can take enough time in the process of making artefacts. Through promoting self-paced learning, collaborative work between students, and incubation of ideas, such projects offer students a complete and consequential learning experience. The dynamic nature accompanying such projects elevates their effectiveness even further, giving students the expertise and perspectives needed for success in the interconnected and complex world. Furthermore, students can learn from mistakes and embrace making mistakes as a way to know during the whole process.

4.4 Variations in learning dimensions across stations

Using the blending makerspace approach, the study highlighted significant differences in learning dimensions across various makerspace stations, demonstrating the impact of hands-on and digital projects upon student achievement. For example, hands-on participants (who used the blended makerspace approach) in 3D printing had higher learning outcomes than their digital project counterparts. This points towards the unique benefits that hands-on activities have in developing innovation and creativity. With activities that involve physical contact with materials and tools,

learners improved their fine motor capabilities, sense of belonging to a group, and deeper understanding of spatial dynamics.

For comparison, learners who engaged in digital projects only, in designing interactive books, had high levels of technological competencies but low levels in working with their hands and interacting with the physical space. While digital projects enhanced digital literacy and content creation-related competencies, they usually could not compete with practical projects regarding participation, personal engagement and socialisation. This comparison points to balancing hands-on and technological learning techniques to seek a more comprehensive learning process. In real life, students need the blended makerspace approach to benefit from working on projects' digital and physical aspects.

The research also indicates that experiential projects effectively improve problem-solving and critical thinking skills, or transferable skills, as some researchers prefer to call them. For instance, when facing challenges in their 3D printing projects, students followed a cyclical design thinking process in solving the problem, learning from their mistakes, honing their designs and experimenting with varying methods before arriving at the desired result. This is a similar practice for innovation exercises in real life, and it prepares students for upcoming challenges in reality. Also, the study proved that combining practical and digital activities enhances interdisciplinarity in education. For example, a robotics project included coding, electronics, and mechanical engineering, making students employ multiple abilities. This combination highlights makerspaces' potential to serve as learning spaces that support holistic learning, allowing students to synthesise knowledge in various disciplines.

Briefly, variations in learning dimensions from station to station emphasise that makerspaces should have a balanced methodology. Incorporating both hands-on and digital activities (through the blended makerspace approach), educators can create innovative learning environments that support multiple learning styles and provide learners with wide competence sets. This fairness not only improves motivation but also prepares students for the multidisciplinary tasks of the modern world.

4.5 Impact on future-readiness

The blended makerspace approach transfers essential skills and dispositions to students (transferable skills), thus enabling them to solve complex problems in the world. Through real-life projects, students develop analytical thinking and problem-solving capabilities through making as they focus on the process, not the final prototype. In addition, they build creativity and flexibility when working within limitations, trying out new ideas, learning from suggestions from their guest speakers, and adjusting strategies based on unexpected outcomes. Besides, students develop essential career-related skills when working with sophisticated tools and hands-on applications, instilling entrepreneurship and professional ambition. For example, two students started their 3D printing company after working on the 3D printing project in the makerspace. The students indicated that working on the makerspace inspired them to start their own company, and they could successfully do it.

The integration of gamification or esports stations in blended learning environments has been linked to high levels of engagement and time management, and has enabled students to learn through playing [18], which are essential in preparing students to manage complex and multidisciplinary tasks in their professional lives ahead. Consistent with Ma's [19] ideal, the makerspace for blended learning combines in-person workshops with AI-facilitated, multimedia-rich tools that support

remote evaluation of designs and immediate feedback. One student noted, “I never thought I’d be interested in engineering until I worked on the 3D printing station. It made me think I might want to make it my career.” Another student reflected, “The makerspace helped me learn to work in teams and think creatively to solve problems, and I know I will use these skills in the future.”

5 RECOMMENDATIONS FOR PRACTICE

Building on the makerspace quadrant framework put forward by Vuorikari et al. [20], the blended makerspace quadrant entwines hands-on engagement with tools and equipment, encourages a sharing- and learning-friendly culture, stresses problem-solving with a sense of flexibility, and integrates both online learning and face-to-face learning modalities to foster a vibrant, innovative environment. Moreover, building on previous research related to hybrid pedagogy, it is recommended to present practical ways for designing makerspace learning environments that are scalable, flexible, and student-centred. Aligning with Mulenga and Shilongo’s [13] vision for the future of hybrid education, this paper emphasises the importance of scalable, adaptable, and student-driven learning environments supported by immersive and digital tools. The following are some recommendations:

1. Schools should integrate online and physical tools, ensuring students benefit from both approaches.
2. Encourage educators to enable students to work on long-term projects to develop transferable skills.

6 CONCLUSION

The blended makerspace model, which the author coins, can increase learning results by combining physical creation with digital design. The combination of experiential learning with virtual interactions on a flexible model places the student at a readiness position to be future-ready. Through the case study of a bilingual high school within Kuwait, this paper proves that blended makerspaces encourage innovativeness, flexibility, and socialisation. This combination makes them crucial components within the learning landscape. In alignment with the IMLS’s focus on connecting scholarly work with implementation, this academic paper encourages establishing formal relationships between learning institutions and public or university libraries for the sustainability and continuity of maker education efforts [21].

Subsequent research endeavours should explore the application of this approach across diverse educational environments and its impact on students’ academic achievement. In addition, more research is required to explore how educators can adopt the blended makerspace model in teaching and learning.

Integrating a blended makerspace model can create a dynamic learning environment with much potential for increasing student learning outcomes and engagement. In growing 21st-century skills, flexibility for responding to varied learning needs, and support for traditional learning constructs, such spaces have a holistic framework for learning to prepare the students for the future. Findings for this study suggest that blended makerspaces are effective for capitalising on and transforming student learning experience and outcomes when adequately implemented and supported. Broadly, student learning outcomes may be improved through the expertise

provided within blended makerspaces due to student engagement, flexibility, and analytical thinking skills they stimulate. Their practical implementation relies on available technological capabilities being adequate, along with available professional learning opportunities for educators.

7 REFERENCES

- [1] S. M. Eldebeky, "How state-of-the-art makerspace stations contribute to differences in students' learning: A mixed methods case study of a bilingual high school in Kuwait," Ph.D. dissertation, ProQuest Dissertations & Theses Global, 2023. [Online]. Available: <https://zilib.idm.oclc.org/login?url=https://www.proquest.com/dissertations-theses/how-state-art-makerspace-stations-contribute/docview/3038633178/se-2>
- [2] S. Tilak, R. Viar, B. Turner, and K. Kennedy, "Situating makerspace curricula for students with learning differences within Vygotsky's cultural historical psychology," *Universal Access in the Information Society*, vol. 24, pp. 1783–1798, 2024. <https://doi.org/10.1007/s10209-024-01177-0>
- [3] Ö. Delialioğlu, "Student engagement in blended learning environments with lecture-based and problem-based instructional approaches," *Educational Technology & Society*, vol. 15, no. 3, pp. 310–322, 2012.
- [4] A. A. Wibowo, "A comprehensive systematic review on effective strategies for student engagement in blended learning environments," *Journal of Blended and Technical Education*, vol. 1, no. 1, pp. 87–101, 2024. [https://doi.org/10.70764/gdpu-jbte.2024.1\(1\)-08](https://doi.org/10.70764/gdpu-jbte.2024.1(1)-08)
- [5] R. Liu *et al.*, "Engaging student engagement in blended learning environments through integration of small private online courses," in *Proc. Int. Symp. Educational Technology (ISET)*, 2024, pp. 274–278. <https://doi.org/10.1109/ISET61814.2024.00061>
- [6] E. Whitewolf, "Activating digital makerspaces for authentic student learning," Ph.D. dissertation, ProQuest Dissertations & Theses, 2022. [Online]. Available: <https://d-scholarship.pitt.edu/43895/1/Whitewolf%20-%20corrected%20version%201-11.pdf>
- [7] S. Papert, *Mindstorms: Children, Computers, and Powerful Ideas*, 2nd ed. New York, NY, USA: Basic Books, 1993.
- [8] K. Koh, R. Teasdale, E. N. Butt, L. Nay, S. Nagle, and L. Regalla, "National library makerspace forum: Working group meetings, research showcase, listening sessions, and white paper drafting," Univ. Illinois Urbana-Champaign, Inst. Museum and Library Services, 2025. [Online]. Available: <https://publish.illinois.edu/librarymakerspaces/files/2024/12/lg-256680-ols-24-full-proposal.pdf>
- [9] R. D. Wilanda, N. Hapsari, and M. Marlina, "Perpustakaan dalam pengembangan makerspace sebagai pendukung metode pembelajaran blended learning di era revolusi industri 4.0," *Info Bibliotheca: Jurnal Perpustakaan dan Ilmu Informasi*, vol. 2, no. 1, pp. 38–47, 2020. <https://doi.org/10.24036/ib.v2i1.81>
- [10] J. Lave and E. Wenger, *Situated Learning: Legitimate Peripheral Participation*. Cambridge, U.K.: Cambridge Univ. Press, 1991. <https://doi.org/10.1017/CBO9780511815355>
- [11] A. Ioannou and B. E. Gravel, "Trends, tensions, and futures of maker education research: A 2025 vision," *Educational Technology Research and Development*, vol. 72, pp. 1–14, 2024. <https://doi.org/10.1007/s11423-023-10334-w>
- [12] B. Bevan, K. Petrich, and M. Wilkinson, *Tinkering Learning Dimensions Framework*. San Francisco, CA, USA: Exploratorium, 2020. [Online]. Available: <https://tinkering.exploratorium.edu/learningdimensions>

- [13] R. Mulenga and H. Shilongo, "Hybrid and blended learning models: Innovations, challenges, and future directions in education," *Acta Pedagogica Asiana*, vol. 4, no. 1, pp. 1–13, 2025. <https://doi.org/10.53623/apga.v4i1.495>
- [14] M. Mushtaq and Z. Iqbal, "Hybrid pedagogies: Assessing the effectiveness of blended and flipped learning in digital learning environments," *Int. J. Emerg. Knowl. Stud.*, vol. 3, no. 9, pp. 662–669, 2024. <https://doi.org/10.70333/ijeks-03-09-034>
- [15] A. S. Ghai, Z. Altinay, F. Altinay, S. Jasola, G. Dagli, and B. Yikici, "Exploring the impact of interactive technologies on student engagement in blended learning environments at higher education institutions," *Int. J. Interactive Mobile Technologies*, vol. 19, no. 5, pp. 233–257, 2025. <https://doi.org/10.3991/ijim.v19i05.52039>
- [16] L. Cheng and W. Y. J. Pang, "Making activities for the competency development of school-age children," *IEEE Trans. Educ.*, vol. 67, no. 6, pp. 846–856, 2024. <https://doi.org/10.1109/TE.2024.3370109>
- [17] C. E. J. Clark and G. Post, "Preparation and synchronous participation improve student performance in a blended learning experience," *Australas. J. Educ. Technol.*, vol. 37, no. 4, pp. 56–67, 2021. <https://doi.org/10.14742/ajet.6989>
- [18] Z. Jing, L. Yongjie, L. Shuhua, and Z. Xin, "Effects of blended learning by gamification on Chinese college students' English learning engagement and foreign language anxiety," in *Proc. Int. Symp. Educational Technology (ISET)*, 2024. <https://doi.org/10.1109/ISET61814.2024.00093>
- [19] N. Ma, "Where AI and multimodal learning will go in 2025," *eSchool News*, 2024. [Online]. Available: <https://www.eschoolnews.com/innovative-teaching/2024/12/13/where-ai-and-multimodal-learning-will-go-in-2025>
- [20] R. Vuorikari, Y. Punie, S. Carretero, and L. Van Den Brande, *Makerspaces for Education and Training – Exploring Future Implications for Europe*. Luxembourg: Publications Office of the European Union, 2019. <https://doi.org/10.2760/12247>
- [21] Institute of Museum and Library Services, "National forum to connect and advance library makerspaces," 2025. [Online]. Available: <https://publish.illinois.edu/librarymakerspaces/>

8 AUTHOR

Dr. Sayed M. Eldebeky is an Assistant Professor at Zayed University, where he serves as a Learning Resources Librarian in the Library and Learning Commons. He is dedicated to fostering innovation and creativity among students. With a strong foundation in technology integration and librarianship, Dr. Mahmoud is committed to bridging the gap between traditional educational methods and the demands of the 21st century through maker-centered learning. Dr. Mahmoud began his educational journey at Cairo University, furthering his studies in ICT and Digital Learning at the University of Newcastle, as well as in Library and Information Science at UCL. His academic path culminated in a PhD in Technology Enhanced Learning from Lancaster University. Dr. Mahmoud focuses on empowering students to develop transferable skills. He provides guidance on effectively utilizing contemporary tools and equipment, thereby enriching their learning experiences and expanding future opportunities. With extensive expertise in 3D printing, laser cutting, and CNC machine operation, Dr. Mahmoud is dedicated to cultivating the innovators of tomorrow within the makerspace environment (E-mail: sayed.mahmoud@zu.ac.ae).