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The Impact of Makerspace within STEM Domains on Creative Confidence, Problem-Solving, and Student Engagement in Elementary Schools in Jerusalem

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Abstract

Objectives: K–12 makerspaces are widely promoted as environments that foster twenty-first-century competencies, yet rigorous causal evidence at the elementary level—particularly across multiple learning outcomes—remains limited. This study examined whether sustained makerspace participation improves elementary students' creative confidence, problem-solving skills, and engagement during STEM instruction. It was hypothesized that students working in a makerspace would outperform peers following the same curriculum in a conventional classroom.

Methods: Sixty sixth-grade students from schools in Jerusalem were selected through simple random sampling and randomly assigned to an experimental makerspace group or a control classroom group. Both groups completed 15 STEM design challenges over a 12-week after-school program during the first semester of the 2024/2025 academic year. Post-test data were collected using three validated questionnaires measuring creative confidence, problem-solving skills, and engagement.

Results: MANOVA revealed a statistically significant multivariate effect ($p < .05$). Follow-up ANOVAs showed significantly higher scores for makerspace students across the measured outcomes. Discriminant function analysis indicated that problem-solving skill was the strongest contributor to group differentiation ($\beta = .852$), followed by creative confidence ($\beta = .510$) and engagement ($\beta = .441$).

Conclusions: Elementary makerspaces provide supportive environments that strengthen students' confidence in their creative abilities, enhance strategic reasoning, and sustain engagement in STEM tasks. Integrating makerspaces into early curricula may accelerate engineering education outcomes, while longitudinal studies are needed to examine the durability of these gains and their influence on later academic achievement.

Keywords: Makerspace, creative confidence, problem-solving skill, student engagement, STEM education

أثر مساحة الصناع على الثقة الإبداعية، وحلّ المشكلات، و انخراط الطلبة في المدارس الابتدائية في مدينة القدس ضمن منحنى STEM

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ملخّص

الأهداف: هدفت هذه الدراسة إلى فحص ما إذا كان الانخراط المستمر في مساحة الصناع يُحسّن لدى طلبة المرحلة الابتدائية: (1) الثقة الإبداعية، (2) مهارة حل المشكلات، و(3) الانخراط أثناء تعلم مجالات STEM. وقد افترض الباحثان أن الطلبة الذين يعملون في مساحة الصناع، سيتفوقون على نظرائهم الذين يتبعون المنهاج نفسه في صف تقليدي.

المنهجية: تم اختيار ستين طالبًا من الصف السادس في مدارس مدينة القدس بطريقة العينة العشوائية البسيطة، ثم جرى توزيعهم عشوائيًا إلى مجموعتين: تجريبية تعمل في مساحة الصناع، وضابطة في صف دراسي تقليدي. أنجز كلا المجموعتين 15 تحديًا في التصميم ضمن مجالات STEM خلال برنامج بعدي، استمر 12 أسبوعًا في الفصل الدراسي الأول من العام 2025/2024. جُمعت بيانات ما بعد الاختبار باستخدام ثلاث استبيانات مقننة لقياس الثقة الإبداعية، وحل المشكلات، والانخراط.

النتائج: أظهرت نتائج تحليل التباين المتعدد (MANOVA) وجود أثر دال إحصائيًا ($p < .05$)، كما أظهرت تحليلات ANOVA اللاحقة أن طلبة مجموعة مساحة الصناع، حققوا درجات أعلى دلالة إحصائيًا في جميع المتغيرات الثلاثة. وأشار تحليل الوظيفة التمييزية إلى أن مهارة حل المشكلات كانت المساهم الأقوى في التمييز بين المجموعتين ($\beta = .852$)، تلتها الثقة الابتكارية ($\beta = .510$)، ثم الانخراط ($\beta = .441$)، مما يشير إلى أن حل المشكلات قد يكون العامل الأساسي وراء الأثر المتعدد الملحوظ.

الخلاصة: توفّر مساحات الصناعة في المرحلة الابتدائية بيئات تعليمية داعمة للاحتياجات تُنمّي إيمان الطلبة بقدراتهم الإبداعية، وتصقل تفكيرهم الاستراتيجي، وتحافظ على انخراطهم الفعّال في مهام STEM. إن دمج مساحات الصناع في المناهج المبكرة يُسهم في تسريع تطوير مخرجات التعليم الهندسي؛ وينبغي أن تتناول البحوث الطولية القادمة مدى استدامة هذه المكاسب، وأثرها على التحصيل الأكاديمي اللاحق.

الكلمات الدالة: مساحة الصناع، الثقة الإبداعية، مهارة حل المشكلات، انخراط الطلبة، منحنى STEM..

INTRODUCTION

Recent educational research emphasizes that meaningful engagement with physical and digital materials supports cognitive development and fosters creativity in learning environments (Patterson et al., 2023). Makerspaces, built upon constructionist learning theory, leverage these tools to facilitate project-based learning, collaboration, and creative problem solving, particularly within STEM (science, technology, engineering, and mathematics) education (Ching & Jones, 2021; Shively & Rutstein, 2023; Alshunnaq & Kraishan, 2020). These developments occur within the broader context of the Fourth Industrial Revolution, characterized by the convergence of digital, physical, and biological technologies (World Economic Forum, 2023). As artificial intelligence, robotics, and smart systems become central to daily life and work, learners are increasingly expected to master a set of future-focused competencies, including critical thinking, innovative confidence, and self-regulated learning (UNESCO, 2022; OECD, 2023). Contemporary educational frameworks thus call for pedagogies that emphasize adaptability, interdisciplinary thinking, and real-world application.

Research shows that educational engagement, defined across behavioral, emotional, and cognitive dimensions, is a key predictor of academic success and skill acquisition (Fredricks et al., 2019; Shernoff et al., 2020; AlShabnuti et al., 2024). In makerspace settings, engagement is often driven by the authenticity of tasks, learner autonomy, and the opportunity to create personally meaningful products (Khan & Rehmat, 2022). These environments also foster the development of innovative confidence, defined as the belief in one's ability to generate and implement creative ideas (Alvarez-Huerta et al., 2021).

Makerspace integration in Arabic-speaking educational systems remains limited. In Palestine, while vocational education has expanded at the secondary level (Palestinian Ministry of Education, 2022), there has been minimal implementation of hands-on, technology-enhanced learning environments in elementary schools. This gap is particularly concerning given Palestine's performance in international benchmarks such as TIMSS 2023, where student scores in mathematics and science remain significantly below the global average (IEA, 2023). Recent evidence highlights that early development of problem solving and creative thinking skills is strongly associated with improved STEM achievement and long-term academic outcomes (Garcia & Smith, 2021; Alissa & Ejbara, 2020).

This study addresses this gap by examining the impact of makerspace on sixth-grade students in Jerusalem. Specifically, it investigates the program's effect on three key outcomes: problem-solving ability, creative confidence, and educational engagement. The makerspace was embedded within regular instructional time and aligned with the national STEM curriculum. By focusing on a previously under-researched context, this study contributes to the global discourse on how makerspaces can serve as transformative environments for developing essential cognitive, affective, and behavioral competencies in elementary education.

LITERATURE REVIEW

Makerspaces have emerged as fertile ground for cultivating these abilities: systematic reviews show significant gains in problem-solving, collaboration, and digital fluency when students engage in hands-on design work (Becker et al., 2016). Experimental studies further report sharp improvements in creative thinking after even short maker interventions (Saorín et al., 2017). International evidence links early proficiency in problem solving and creativity to higher math and science achievement (Leung, 2018; OECD, 2021). Drawing on firsthand experience directing an elementary makerspace in Jerusalem, controlled makerspace studies examining multiple learner outcomes in Arabic-speaking elementary contexts remain limited. This study investigates whether a semester-long, curriculum-embedded makerspace program can enhance sixth-grade students' problem-solving skills, creative confidence, and engagement, outcomes that remain largely untested in Arabic-speaking contexts and in controlled designs.

Makerspace in Education

Within makerspace settings, learning outcomes appear to be shaped less by the mere presence of tools and more by the mechanisms through which learners interact with them. Constructionist and project-based pedagogies position students as

active designers, requiring them to externalize ideas, test assumptions, and iteratively refine solutions. This process has been associated with gains in problem-solving ability, creative confidence, and sustained engagement, as students receive continuous feedback from both materials and peers and experience repeated cycles of success and productive failure. In schools, makerspaces function as incubators of creativity, innovation, and technical fluency. When embedded within curricular goals, they provide students with structured opportunities to explore personal interests, solve real-world problems, and develop self-efficacy through hands-on learning (Martinez & Stager, 2019). Teachers serve as facilitators, guiding exploration and fostering autonomy, collaboration, and critical thinking. Empirical research supports the cognitive and motivational benefits of these environments. Capel (2023), in a study of Australian secondary schools, found that girls participating in makerspace activities reported increased motivation, collaboration, and creative output. Similarly, Peppler and Bender (2020) synthesized experimental studies demonstrating that maker-based learning enhances young learners' problem-solving skills, innovative confidence, and sense of agency. In the Gulf region, Hadad (2020) showed that integrating 3D printing and virtual reality into makerspace tasks improved students' computational thinking and programming skills. Alshaya (2019) found that enrichment programs grounded in makerspace pedagogy significantly boosted creative thinking and academic achievement among gifted female students in Riyadh. These findings suggest that makerspaces, when supported by thoughtful instructional design and adequate resources, can be powerful vehicles for advancing twenty-first-century skills in diverse educational settings.

The Need for Makerspaces in Elementary Schools

Early and sustained exposure to hands-on design is increasingly viewed as a prerequisite for cultivating the dispositions and skills that modern engineering demands. Developmental research shows that the primary years are a sensitive period for building confidence in one's ability to "shape the material world," a belief that predicts later selection of elective STEM courses and persistence in open-ended problem solving (Hira & Hynes, 2021). Cognitive neuroscience studies demonstrate that iterative manipulation of physical objects strengthens spatial reasoning pathways that underpin success in mathematics and science (Newcombe, 2017). By offering tool-rich environments where students can prototype, test, and revise, makerspaces provide a practical venue for leveraging these developmental windows.

Makerspaces supply infrastructure such as 3D printers, laser cutters, microcontrollers and, equally important, a culture that privileges experimentation over rote completion (Resnick, 2017). When such spaces are integrated with project-based curricula, measurable benefits emerge: randomized trials in Spain and China have reported medium-to-large gains in creative confidence, strategic problem solving, and STEM identity among 9- to 12-year-olds who engaged in maker activities for a single semester (Ruiz Viruel, Sánchez Rivas, & Ruiz Palmero, 2025; Li, He, & Zhang, 2023). Equity considerations add another layer of urgency. Achievement gap studies show that underrepresented and economically marginalized students tend to disengage from STEM pathways before adolescence; early access to maker experiences has been linked to higher STEM interest and a stronger sense of belonging, particularly for girls and minority learners (Vossoughi, Hooper, & Escudé, 2016).

Interventions for enhancing creative confidence, problem-solving, and engagement

Research on problem-solving reveals a parallel pattern. Inquiry sequences such as predict–observe–explain and productive failure tasks produce medium effect sizes on strategic transfer (Loibl, Roll, & Rummel, 2017). Makerspace teachers operationalize these ideas by withholding expert tips until after an initial prototype and by using digital scaffolds, block-based coding and augmented reality force visualizers, to link abstract concepts to concrete outcomes (Sullivan & Bers, 2019). Nevertheless, most studies examine problem-solving in isolation, leaving its interaction with creative confidence and day-to-day engagement underexplored.

Makerspaces support engagement by embedding autonomy, opportunities for competence development, and collaborative interaction within authentic design tasks (Ryan & Deci, 2020). Design-choice menus, tool-mastery badges, and community-oriented projects raise on-task behavior (Ching, Hsu, & Baldwin, 2018; Vossoughi, Hooper, & Escudé,

2016). Gamified elements, timed "sprints" or collaborative boss levels, inject excitement without diluting rigor (Plass, Homer, & Kinzer, 2015). Yet engagement is often treated as an endpoint rather than a mediator linking makerspace participation to cognitive gains.

We still lack (a) rigorously controlled studies tracking creative confidence, problem-solving, and engagement simultaneously; (b) evidence from Arabic-speaking elementary schools; and (c) analyses testing whether engagement is the engine driving deeper cognitive growth. Addressing these gaps is critical for understanding how makerspaces translate hands-on activity into lasting STEM proficiency.

Rational of the present study

Few makerspace studies span an entire semester, assess multiple outcomes, and include a control group, particularly in Arabic-speaking elementary schools. This investigation fills that gap by comparing two cohorts of sixth-graders: one completed a 12-week, curriculum-integrated makerspace program, while the control group tackled identical design challenges in a conventional classroom. Drawing on the Palestinian Ministry of Education's STEM Challenge Workshop Manual, the makerspace condition fused digital fabrication with structured project-based cycles. Each of the 15 challenges required students to design, prototype, test, and refine a real-world solution, embedding mastery experiences, productive failure, and peer critique, elements known to elevate creative confidence, strategic problem-solving, and engagement. For instance, students iteratively optimized a small-scale water filtration system to address local freshwater scarcity.

The present study randomly assigned sixth-grade students either to this makerspace experience or to a conventional classroom that completed the same challenges with basic craft materials. By administering validated post-tests of creative confidence, problem-solving skill, and engagement to both groups, we aim to produce the first causal, multi-outcome evidence from an Arabic-speaking elementary setting. The research question that we addressed is the following:

RQ: What is the impact of makerspaces on developing problem-solving skills, creative confidence, and engagement among elementary students in Jerusalem within STEM domains?

Method

This study employed a true experimental design. To mitigate the risk of testing effects, a post-test only control group design was employed. This is due to the fact that pre-tests might heighten participants' sensitivity and alter their subsequent responses (Campbell & Stanley, 1963). The independent variable was the instructional approach, operationalized as participation in a makerspace-based learning environment versus conventional classroom instruction. The dependent variables were students' post-intervention scores on problem-solving skills, creative confidence, and engagement. The random assignment of students to groups established baseline comparability, allowing any discrepancies in post-test results to be attributed to the intervention itself (Shadish, Cook, & Campbell, 2002). A total of 60 sixth-grade students were selected via simple random sampling from the limited number of elementary schools in Jerusalem equipped with both standardized STEM curricula and functioning makerspaces. Due to the scarcity of such facilities in the region, the sample size reflects the total accessible population under conditions of curricular and infrastructural equivalence. Students were randomly assigned to one of two instructional settings:

1. **Control Group** (n = 30), which completed the 15 STEM challenges in a conventional classroom using paper, cardboard, tablets, and teacher-facilitated discussion.
2. **Experimental Group** (n = 30), which engaged in the same challenges within a dedicated makerspace equipped with desktop 3D printers, diode laser cutters, microcontroller kits, and hand tools.

Participants

The study was conducted in two Arabic medium elementary schools in Jerusalem that share a district STEM curriculum and identical class sizes. According to the 2024 municipal census, 1,753 sixth grade students attend schools equipped with operational makerspaces (Jerusalem Municipality, 2024). Using simple random sampling, 60 students were drawn from this population and then randomly allocated to one of two groups: 30 students followed the regular STEM syllabus in a conventional classroom, while the remaining 30 completed the same syllabus in the school's makerspace.

Sixth graders were chosen because, in Piagetian terms, they are entering the formal operations stage, a developmental window associated with emerging abstract reasoning and an increased capacity for systematic experimentation (Piaget, 1972). Prior teaching experience also suggested that students at this age can handle digital fabrication tools safely and collaborate without the behavioral volatility sometimes observed in early adolescence. Randomization was executed with Excel's RAND function to ensure an unbiased draw (Fraenkel, Wallen, & Hyun, 2019). Ethical approval for this study was obtained from An-Najah National University (IRB #Fgs/Hum.Feb.2025/4) on February 2, 2025. Written informed consent was obtained from the parents of all participating students, and assent was obtained from the students themselves prior to inclusion in the study. Participation was voluntary, and confidentiality was maintained throughout the research process.

Instruments

Three post-test instruments were adapted for the local context.

- Problem-Solving Questionnaire. The 35-item questionnaire by Heppner and Petersen (1982) was translated into Arabic, back-translated, and reviewed by seven STEM-education specialists for wording clarity. Factor analysis on a 40-student pilot sample yielded a Kaiser–Meyer–Olkin (KMO) value of .64 indicating marginal sampling adequacy (Kaiser, 1974). A three-factor solution—problem definition, response generation, and solution monitoring—that explained 54.4 % of the variance. Cronbach's alpha for the full questionnaire was .97, indicating excellent reliability.
- Creative Confidence Questionnaire. Thirteen items from Zhou and George (2001) were localized using the same translation protocol. A KMO of .85 supported factorability, and a single-factor solution accounted for 90.6 % of the variance. Internal consistency was high ($\alpha = .95$).
- Student Engagement Questionnaire. The 20-item measure developed by Ozhan and Kocadere (2020) assesses cognitive and affective engagement. Pilot analysis produced a KMO of .89 and a two-factor structure (cognitive, affective) explaining 83.8 % of total variance. Reliability for the full questionnaire was $\alpha = .95$. Across all three instruments, item-level content-validity indices were above .77 and modified kappa values exceeded .60, satisfying Polit and Beck's (2006) criteria for excellent agreement among content experts.

Procedure

This study was grounded in Kolb's Experiential Learning Cycle, which conceptualizes learning as a dynamic process involving four interconnected stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 1984). The intervention followed a ministry approved guide titled *STEM Challenge Workshop Manual* (Ministry of Education, 2022). From its 21 activities, a panel of ten STEM teachers selected 15 projects that could be completed within the 12-week study window. Each session lasted 90 minutes. In each project, students were asked to design, build, and test an artefact, such as a bridge, lifting device, or simple vehicle, using either classroom craft supplies (control) or makerspace tools (experimental). Content validity for each activity was checked with Lawshe's (1975) CVR, Polit and Beck's I CVI, and modified kappa; only tasks meeting all three thresholds (CVR > 0.62, I CVI > 0.77, k* > .60) were retained (Table 1). Sessions ran once a week after school, and trained observers confirmed that teachers in both conditions adhered to the same instructional script, differing only in the materials available.

Table 1 Content Validity Indices

Experiment	N	CVR	I-CVI	K*	Decision
1	9	0.82	0.91	0.83	Accepted
2	8	0.63	0.86	0.64	Accepted
3	9	0.81	0.92	0.82	Accepted
4	8	0.63	0.86	0.62	Accepted
5	7	0.42	0.71	0.41	Rejected
6	9	0.83	0.92	0.82	Accepted
7	8	0.63	0.82	0.64	Accepted
8	7	0.41	0.71	0.41	Rejected

Experiment	N	CVR	I-CVI	K*	Decision
9	8	0.64	0.82	0.63	Accepted
10	9	0.85	0.92	0.82	Accepted
11	8	0.66	0.86	0.63	Accepted
12	7	0.43	0.71	0.41	Rejected
13	9	0.88	0.91	0.84	Accepted
14	8	0.67	0.86	0.62	Accepted
15	9	0.89	0.91	0.84	Accepted
16	6	0.21	0.61	0.21	Rejected
17	8	0.69	0.88	0.64	Accepted
18	9	0.88	0.92	0.83	Accepted
19	7	0.41	0.71	0.41	Rejected
20	8	0.66	0.86	0.62	Accepted

N= number of experts who rated the experiment as "essential."

Data Analysis

Prior to conducting the multivariate analysis of variance (MANOVA), assumption checks were performed to ensure the validity of the statistical inferences. The assumption of multivariate normality was assessed using the Shapiro–Wilk test for each dependent variable across both instructional groups. The results indicated no significant deviation from normality (all $p > .05$), with specific values reported for problem-solving skill ($p = .406$ for the classroom group; $p = .892$ for the makerspace group), creative confidence ($p = .150$; $p = .511$), and engagement ($p = .753$; $p = .506$). These findings confirm that the data distributions meet the normality assumption. Additionally, Box's M test for homogeneity of covariance matrices was non-significant ($p = .562$), supporting the use of MANOVA. Bivariate Pearson correlations among the dependent variables ranged from $r = .30$ to .45, indicating moderate intercorrelations without multicollinearity, thereby satisfying the assumption of appropriate multivariate structure. Furthermore, the use of simple random assignment ensured baseline equivalence between groups, reinforcing the internal validity of the design (Shadish, Cook, & Campbell, 2002).

Result

Table 2 summarizes the post-test means and standard deviations for the three outcome variables. Across creative confidence, problem-solving skill, and engagement, students who learned in the makerspace outperformed their peers who completed the same challenges in a conventional classroom.

Table 2 Descriptive statistics for the three outcomes

Outcome	Group	n	Mean	SD
Problem-solving skill	Classroom	30	3.53	0.09
	Makerspace	30	4.5	0.09
Creative confidence	Classroom	30	3.42	0.12
	Makerspace	30	4.46	0.17
Engagement	Classroom	30	3.51	0.13
	Makerspace	30	4.47	0.13

As shown in Table 2, students who participated in the makerspace scored notably higher on all three post-test measures than students in the conventional classroom. For problem-solving skill, the makerspace group ($M = 4.50$, $SD = 0.09$) exceeded the classroom group ($M = 3.53$, $SD = 0.09$). A similar pattern emerged for creative confidence, with means of 4.46 ($SD = 0.17$) and 3.42 ($SD = 0.12$), respectively. Finally, engagement was higher in the makerspace group ($M = 4.47$,

SD = 0.13) than in the classroom group (M = 3.51, SD = 0.13). The small standard deviations across groups indicate relatively homogeneous scores within each condition, while the sizeable mean gaps suggest a substantial makerspace advantage even before inferential testing (Hair et al., 2019; Ryan & Deci, 2020).

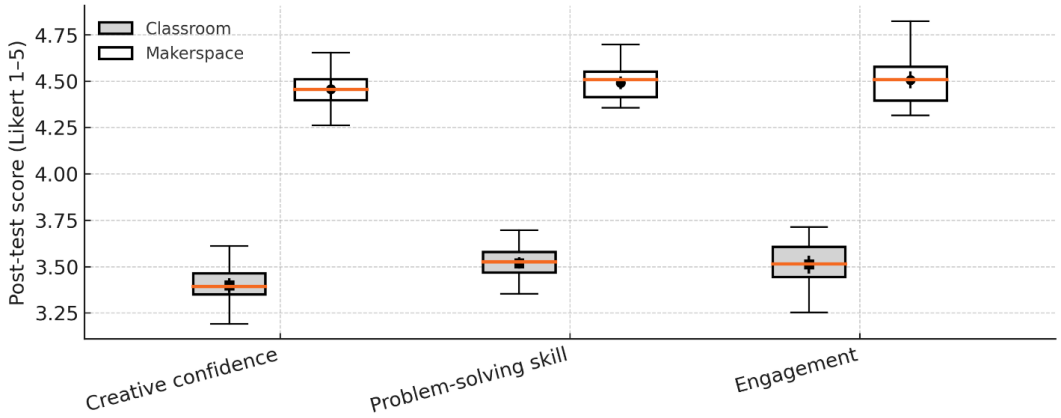


Figure 1 Distribution of post-test scores with 95 % CIs

Figure 1 displays the full score distributions for the three outcomes, with box plots and 95% confidence interval markers, illustrating the consistently higher performance of the makerspace group across all measures.

A one-way MANOVA was conducted with instructional setting (makerspace vs. classroom) as the independent variable and the three post-test scores as dependent variables. Assumption checks were satisfactory: Shapiro–Wilk tests were non-significant for all variables (all $p > .15$), and Box's M indicated homogeneity of covariance matrices ($p = .562$) (Hair et al., 2019).

Table 3 The Effect of Instructional Setting on the Combined Dependent Variables

Test Statistic	Value	F	df	p	η^2
Pillai's Trace	0.98	1126.16	56	< .001	0.98
Wilks' Lambda	0.01	1126.16	56	< .001	0.98
Hotelling's Trace	62.56	1126.16	56	< .001	0.98
Roy's Largest Root	62.56	1126.16	56	< .001	0.98

Table 3 shows the multivariate effect was highly significant, Wilks' $\lambda = 0.01$, $F(1, 56) = 1126.16$, $p < .001$, partial $\eta^2 = .98$. This indicates that 98% of the variance in the combined outcome measures is explained by the instructional setting.

To examine the effect of instructional setting (makerspace vs. classroom) on each of the three dependent variables individually, one-way analyses of variance (ANOVAs) were conducted (Table 4).

Table 4 One-Way ANOVA Results

Outcome Variable	Source	SS	df	MS	F	p	η^2
Problem-solving skill	Between	13.35	1	13.35	1644.41	< .001	0.967
	Within	0.46	56	0.008			
Creative confidence	Between	15.85	1	15.85	797.43	< .001	0.934
	Within	0.46	56	0.008			
Engagement	Between	13.24	1	13.24	739.16	< .001	0.93
	Within	0.49	56	0.009			

Note. All effects are significant at $p < .001$. Partial η^2 values > .90 indicate large effect sizes (Cohen, 1988).

As shown in Table 4, all three univariate tests revealed statistically significant differences between the instructional settings. Specifically, the makerspace group outperformed the classroom group on problem-solving skill, creative confidence, and engagement, with $F(1, 56)$ values ranging from 739.16 to 1644.41, all $p < .001$. The corresponding partial η^2 values, ranging from .93 to .97, indicate that over 90% of the variance in each outcome was attributable to the instructional condition, representing large effect sizes (Cohen, 1988).

A discriminant function analysis was conducted to determine the relative contribution of each outcome variable in distinguishing students based on instructional setting (makerspace vs. classroom). Standardized canonical discriminant function coefficients revealed that problem-solving skill contributed most strongly to group differentiation ($\beta = .852$), followed by creative confidence ($\beta = .510$), and engagement ($\beta = .441$). These findings indicate that problem-solving skill was the most powerful discriminator between the two instructional conditions, suggesting it may be the primary driver of the observed multivariate effect.

The results suggest a positive effect of the intervention on the outcomes of interest. Participation in the semester-long makerspace condition led to statistically significant and substantively large improvements in sixth-grade students' problem-solving skills, creative confidence, and engagement, relative to peers who completed identical STEM challenges in a conventional classroom. The instructional setting accounted for approximately 93% to 97% of the variance in each outcome, reflecting exceptionally large effect sizes. Among the three constructs, problem-solving skill emerged as the most strongly differentiated variable, as confirmed by discriminant analysis.

Discussion

This study investigated whether a makerspace program could outperform the conventional classroom curriculum in enhancing sixth-grade students' problem-solving skills, creative confidence, and engagement. The observed outcomes align closely with the principles of Kolb's Experiential Learning Cycle, providing a theoretical explanation for the marked gains among makerspace participants. Each design challenge in the experimental group was structured to engage students in all four stages of experiential learning, concrete engagement through hands-on tasks, structured reflection, conceptual discussion, and iterative redesign. This recursive process is known to deepen learning by connecting physical experiences with abstract understanding. In contrast, students in the control group worked with more limited materials and less opportunity for iteration or revision, likely curbing their ability to complete the full learning cycle. The significant advantage observed in problem-solving skill particularly underscores the importance of active experimentation and iterative refinement, core tenets of Kolb's model. These findings affirm that experiential learning environments, when thoughtfully aligned with curricular goals, can substantially enhance both the cognitive and affective dimensions of student learning. The results provide a strikingly clear answer: across all three constructs, students in the makerspace condition achieved significantly higher post-test scores, with effect sizes in the very large range (partial $\eta^2 \approx .93–.97$). The following sections interpret these findings in relation to prior research and key affordances of the learning environment.

Problem-Solving Skill

Students who worked in the makerspace demonstrated higher level of performance compared to their peers in the conventional classroom. This pattern echoes earlier reports that hands-on, technology-rich settings strengthen analytical and strategic reasoning (Rouse & Rouse, 2022; Loertscher et al., 2016; Martin, 2015). Three characteristics of the local makerspace likely account for the magnitude of the gain:

Authentic challenges, each task required learners to design artefacts that addressed real constraints, filtration systems for water-scarce regions, for example, forcing them to integrate science and mathematics concepts rather than apply them in isolation (Herrington & Oliver, 2000). Iterative experimentation, rapid access to 3-D printers and laser cutters enabled multiple prototype cycles inside a single session. Iteration is known to deepen students' mental "problem schemata," expanding the range of strategies they can deploy (Halverson & Sheridan, 2014). Collaborative troubleshooting, students worked in fluid teams, sharing tools and debugging protocols, which mirrors professional engineering practice and has been shown to enhance collective problem framing (Loertscher et al., 2016).

Creative Confidence

The makerspace also produced a pronounced lift in creative confidence. Prior studies attribute such gains to the chance to see one's idea materialize in a tangible object (Choi et al., 2022; Davies et al., 2013; Tan et al., 2019). In the present setting, students had freedom to stand, move, and manipulate high-end tools, conditions that contrast sharply with the seat-bound routines of the traditional classroom. The experience of success with advanced fabrication equipment seems to have strengthened the students' confidence in their resourcefulness. According to the social cognitive theory of Bandura, mastery experience, successful completion of difficult tasks, is the most influential source of self-efficacy development (Bandura, 1997). In this study, opportunities to design and create functional objects using maker-friendly tools were likely to provide repeated practice experiences, which contributed to the observed increase in creative confidence, especially in a local context where conventional classrooms usually lack opportunities for open fabrication.

Engagement

Engagement showed the same pattern, rising from 3.51 in the classroom to 4.47 in the makerspace. Dewey's (1938) learning-by-experience paradigm predicts that practical, consequential activity will heighten involvement; recent STEM-specific work confirms the point (Martin, 2015; Gravel & Puckett, 2023). Classroom observations indicated high levels of student enthusiasm, as learners were able to move freely, negotiate tool use, and see their ideas materialize into tangible artefacts. From the perspective of Self-Determination Theory, learning environments that support choice, skill development, and social interaction are likely to satisfy students' basic psychological needs for autonomy, competence, and relatedness, which are central to sustained engagement (Ryan & Deci, 2020). In the makerspace context, opportunities to make meaningful decisions, successfully construct functional artefacts, and collaborate with peers appeared to align closely with these needs, offering a plausible explanation for the heightened behavioral and emotional engagement observed in this study.

Explaining the Magnitude of the Effects

The unusually large effect sizes observed in this study likely reflect the synergistic influence of several contextual and pedagogical factors:

- Novelty and Resource Contrast: For many students, the makerspace represented their first encounter with industrial-grade tools such as 3D printers and laser cutters. In contrast, the control group operated with rudimentary materials (e.g., cardboard and glue). Such stark contrasts in technological affordances may amplify cognitive engagement and motivation, as suggested by prior research on novelty effects and material richness (Resnick, 2017).
- Curricular and Task Alignment: While both groups engaged with identical STEM challenges, the makerspace context enabled implementation at a level of fidelity and realism not achievable with basic classroom resources. This fidelity likely deepened conceptual understanding and sustained effort, consistent with theories of situated cognition and embodied learning.
- Expert-Led Implementation: The intervention was facilitated by a trained makerspace educator (the lead author), ensuring high implementation fidelity. Each session included structured reflection, peer feedback, and safety protocols, which minimized disruption and maximized productive iteration—factors known to enhance learning outcomes in hands-on environments (Halverson & Sheridan, 2014).

These interacting factors likely contributed to the substantial between-group differences, emphasizing that the makerspace effect is not solely attributable to the physical tools, but to the integration of pedagogy, environment, and facilitation.

Implications for Practice

Results underscore that well-structured makerspaces can serve as effective platforms for developing core twenty-first-century competencies in elementary education. Schools considering investment should note that impact depends on more than hardware; expert facilitation, authentic challenges, and iterative feedback loops are critical. For policy makers in Palestine and similar contexts, the findings justify scaling makerspace access beyond pilot programs, provided that teacher professional development accompanies equipment deployment.

Limitations and Future Directions

This study offers robust evidence for makerspace benefits in elementary STEM, yet several constraints temper its generalizability. Contextual scope is narrow: the intervention occurred in one well-resourced school, potentially limiting relevance to under-resourced settings or other cultures. Statistical power is modest; a sample of 60, though randomly assigned, may miss subtle interactions tied to prior experience or teacher–student dynamics. Novelty effects could inflate outcomes, as many participants encountered laser cutters and 3-D printers for the first time. Data breadth is restricted to quantitative post-tests; interviews, journals, or video analysis might clarify the cognitive and emotional mechanisms underlying gains. Facilitator dependence is another concern: results were achieved by a highly trained maker educator, raising scalability questions for generalist teachers. Finally, all measures capture short-term change; it remains unknown whether boosts in problem-solving, creative confidence, and engagement persist into middle school or shape STEM career trajectories. Future research should employ mixed methods, larger and more diverse samples, longitudinal tracking, and explicit tests of facilitator expertise to build a nuanced, generalizable model of how makerspaces influence early STEM learning.

Conclusion

Engaging sixth-grade students in a twelve-week makerspace yielded large, statistically robust improvements in problem-solving skill, creative confidence, and engagement relative to conventional project-based instruction. These outcomes align with global evidence yet fill a critical regional gap by providing causal data from an Arabic-speaking elementary context. For educators and policy makers seeking to cultivate the next generation of creative, strategic, and motivated engineers, makerspaces offer a powerful, though resource-intensive, path forward. Crucially, the intervention was not only effective but also theoretically grounded: its design was closely aligned with Kolb's Experiential Learning Cycle, offering students structured opportunities for hands-on construction, reflective observation, conceptual synthesis, and iterative redesign. By situating makerspace learning within a robust pedagogical framework and integrating it with national STEM guidelines, this study demonstrates how experiential education can meaningfully elevate both the cognitive and motivational dimensions of elementary STEM learning in culturally and linguistically diverse contexts.

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