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Assessing the Impact of Makerspace Workshops on Breaking Academic Silos Through Cross-Disciplinary Collaboration

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I. Introduction

As the world confronts increasingly complex global challenges from climate change and public health crises to rapid technological advancements, academic institutions worldwide are recognizing that preparing future engineers requires more than traditional, siloed curricula [1], [2]. Contemporary engineers must possess an expanded skill set that combines deep technical expertise with strong communication, ethical reasoning, and collaboration skills, enabling them to address multifaceted issues effectively [3]. These changing demands have fueled a shift toward more holistic, cross-disciplinary approaches in engineering education, prompting educators to explore alternative pedagogical frameworks capable of breaking down disciplinary barriers and foster real-world problem-solving [4].

Within this landscape, academic makerspaces have emerged as significant platforms for such reform. By providing hands-on environments, specialized equipment (e.g., 3D printers, laser cutters), and faculty- and peer-led learning opportunities, these spaces encourage experimentation, iterative design, and interaction among students from diverse majors [5], [6]. Research has shown that participation in makerspace activities can enhance creativity, technical proficiency, and teamwork [7]- [9]. However, the degree to which student-run workshops within makerspaces specifically cultivate interdisciplinary competencies remains underexplored. This gap is especially relevant given the evidence that peer-to-peer learning can play a formative role in shaping students' collaborative mindsets and willingness to work outside their primary disciplines.

Recent initiatives, such as the Future-Ready Engineering Ecosystem (FREE) Workshops conducted by the American Society for Engineering Education (ASEE), emphasize the urgency of this question [1]. The FREE Workshops developed a Competency Taxonomy that spans technical, professional, and personal domains, ranging from advanced manufacturing and machine learning skills to ethical responsibility and inclusive communication [1], [2]. By mapping these competencies, ASEE shows the imperative for an education model that goes beyond conventional coursework, urging institutions to adopt flexible, student-centric experiences that prepare engineers to tackle emerging societal and technological challenges [1].

In this paper, we examine student-run makerspace workshops at a mid-sized research university to understand whether-and how-they advance the interdisciplinary skills and collaborative behaviors aligned with the FREE Competency Taxonomy. Over eight academic terms, a total of 996 undergraduates participated in these peer-led sessions, which covered a wide range of topics such as Soldering, Laser Cutting, and Advanced 3D Printing. To capture attitudinal changes, we administered an adapted 18-item Interdisciplinary Education Perception Scale (IEPS) to a subgroup of roughly 150 participants, of whom 101 completed valid pre-post surveys across three two-term windows (C23–D23, A24–B24, C24–D24). The IEPS specifically gauges students' comfort seeking advice outside their major, appreciation for other disciplines, and willingness to collaborate-domains arguably increased in makerspaces [10], [11].

We also complemented these quantitative measures with a qualitative component, using inductive coding informed by Braun & Clarke's framework to analyze semi-structured interview data. By triangulating item-level IEPS results (revealing shifts in specific attitudes or behaviors) with thematic insights from interviews, we provide a nuanced perspective on how even brief, peer-led makerspace experiences can shape cross-disciplinary project impetus and skill transfer.

Our mixed-methods approach thus seeks to (1) analyze workshop attendance and makerspace usage patterns across different academic majors, (2) measure item-level changes in students' interdisciplinary perceptions, and (3) explore, via qualitative analysis, the mechanisms by which these workshops promote "future-ready" competencies. Ultimately, we offer evidence-based recommendations for integrating peer-led makerspace programming into broader engineering reforms aimed at producing engineers equipped with both technical depth and cross-disciplinary agility.

II. Literature Review

A. The Imperative for Cross-Disciplinary Engineering Education

A growing consensus holds that modern engineers require more than disciplinary knowledge in mechanical, electrical, or civil engineering; they must also demonstrate problem-solving acumen, ethical awareness, and adaptability [8]. Accreditation bodies and academic frameworks have shifted to outcomes-based criteria, stressing skills such as communication, teamwork, and lifelong learning [9]. Similarly, global efforts identify "21st-century skills" encompassing creativity, collaboration, and digital literacy as essential for navigating technological disruption [12], [13].

Implementing these broad competencies often clashes with traditional engineering curricula, which are structured around rigid disciplinary silos [4], [14]. Yet complex real-world problems ranging from sustainable resource management to biotechnology demand collaborative, multifaceted solutions that integrate not only engineering disciplines but also insights from social sciences and policy [2], [16]. This tension has fueled interest in project-based approaches, community-engaged learning, and other experiential pedagogies that encourage cross-disciplinary interactions [6].

B. Makerspaces as Platforms for Interdisciplinary Learning

Within higher education, makerspaces have gained prominence as innovative venues for hands-on learning that mirrors real-world engineering processes [5]. By offering diverse fabrication tools and flexible, student-led programming, makerspaces encourage rapid prototyping, design thinking, and peer-to-peer mentorship [17], [18]. Studies show that regular engagement in makerspaces can increase students' self-efficacy, technical proficiency, and motivation across various engineering and non-engineering domains [5]– [9].

One emerging model is the student-run workshop, wherein trained student instructors deliver topic-specific sessions on tools (e.g., laser cutting, electronics) or processes (e.g., design thinking, prototyping). Such workshops potentially reduce faculty load, encourage agency among student leaders, and introduce newcomers to a wide range of technologies [7]. Although prior research has linked makerspace use to skill growth and confidence-building, relatively few studies have examined how these workshops might develop the holistic, cross-disciplinary competencies that engineering graduates now require.

C. Insights from the ASEE Future-Ready Engineering Ecosystem (FREE) Workshops

The FREE Workshops organized by ASEE sought to identify the key competencies that the future engineering workforce will need- both technical (e.g., AI, robotics, advanced manufacturing) and non-technical (e.g., ethics, empathy, diversity awareness) [1]. The resulting FREE Competency Taxonomy frames these capabilities in three overlapping domains of technical, professional and personal competence.

Alongside this taxonomy, the FREE Workshops produced a Framework and Rubric for Action that encourages institutions to embrace flexible, student-driven educational models, real-world collaborations, and novel assessments (e.g., e-portfolios). These recommendations echo calls for engineering programs to partner with industry and communities, focusing on experiential projects and competency-based curricula [1]. Makerspaces exemplify such experiential spaces, yet empirical data are needed to verify whether student-led workshops indeed promote these “future-ready” competencies in tangible, measurable ways.

D. Bridging the Research Gap

While literature increasingly affirms the value of makerspaces for improving student engagement and technical proficiencies, questions persist regarding their impact on key interdisciplinary outcomes. These questions include whether makerspace workshops draw students from multiple majors, whether participants actually acquire cross-disciplinary mindsets, and how these outcomes align with recognized competency frameworks [1], [5], [7].

Moreover, integrating makerspace workshops into institution-wide curricular structures (and measuring broader impacts) can be challenging because conventional metrics like exams or GPAs may not capture multi-faceted skills like empathy, collaborative leadership, or ethical reasoning [11], [12]. By systematically studying student-run workshops and analyzing item-level IEPS results alongside qualitative interview insights, this research adds to the body of knowledge on effectively “breaking silos” to align local educational practices with large-scale competency-based reforms.

III. Methods

This study employed a mixed-methods approach to evaluate how student-run makerspace workshops influence interdisciplinary collaboration at a mid-sized research university. Data collection spanned eight academic terms from Spring 2023 to Fall 2024, organized into three pre-post “windows,” each covering two consecutive terms. Quantitative measures included workshop attendance and usage logs, as well as repeated Interdisciplinary Education Perception Scale (IEPS) surveys. Qualitative insights were obtained through semi-structured interviews with a subset of workshop participants.

A. Context and Timeline

The Worcester Polytechnic Institute (WPI) Makerspace serves as a hub for hands-on learning and creative exploration at WPI. From Spring 2023 through Fall 2024, encompassing eight academic terms (C Term 2023, D Term 2023, A Term 2023, B Term 2023, C Term 2024, D Term 2024, A Term 2024, and B Term 2024), a total of 996 undergraduate students participated in at least one makerspace workshop, while 2,202 students used the makerspace to work on an academic or personal project. These undergraduate students represented a variety of majors, including Mechanical Engineering, Electrical and Computer Engineering, Robotics, Computer Science, Business, and Arts and Science, among others. Although graduate students, faculty, and staff also used the makerspace, only undergraduates participated in the survey component of this study.

B. Data Collection Windows

To reach a broad audience of makerspace users, the pre-survey was included as an optional add-on to the basic makerspace orientation trainings offered online. Students completing orientation for the first time could opt into the survey. Additionally, the survey link was shared with academic courses that integrated makerspace activities into their curricula, such as project-based design courses in Engineering and cross-disciplinary arts-technology electives. This approach ensured that both frequent and first-time makerspace users were invited to participate. To capture changes in interdisciplinary perceptions over time without imposing undue participant burden, the research employed three distinct pre-post survey windows, each lasting two consecutive terms. The first window spanned C Term 2023 to D Term 2023 and included 33 undergraduates who completed the IEPS at the beginning of C23 and again at the end of D23. The second window took place from A Term 2024 to B Term 2024, during which 44 undergraduates provided pre-survey responses at the start of A24 and post-survey responses by the conclusion of B24. The third window was conducted from C Term 2024 through D Term 2024, involving 24 undergraduates who completed a pre-survey at the start of C24 and a post-survey at the end of D24. Some students appeared in more than one window, but most were unique to a single pre-post cycle.

Within each two-term window, participants were categorized into focus and control groups based on workshop attendance. Focus group members attended at least one workshop and actively used the makerspace for an academic or personal project, while control group members did not attend any workshops during that window but still utilized the makerspace's resources.

C. Data Collection and Survey Instrument

Data collection integrated quantitative records of workshop attendance, tool usage/ checkout logs, and pre-post survey responses, alongside a series of semi-structured interviews. Makerspace logs documented each student's name, email, and major, as well as workshop topics and dates. A unique identifier, derived from each student's email, unified these records with their survey responses.

The Interdisciplinary Education Perception Scale (IEPS) served as the primary quantitative tool for measuring how students' perceptions of cross-disciplinary collaboration evolved over time.

Adapted from its original health professions context, the IEPS was modified to include items relevant to an academic makerspace setting. This adaptation replaced the term “profession” with “field of study” and incorporated references to makerspace projects, workshop attendance, and interactions with peers outside one’s major.

The IEPS was selected as the primary instrument for this study due to its proven effectiveness in measuring interdisciplinary attitudes and collaboration in educational settings, particularly its focus on constructs such as appreciation for other disciplines, cross-disciplinary communication, and willingness to collaborate-skills that align closely with the objectives of makerspace workshops [16,17]. The scale consisted of 18 items rated on a six-point Likert scale (1 = Strongly Disagree to 6 = Strongly Agree) and demonstrated strong internal consistency (Cronbach’s alpha > 0.80) in pilot testing.

D. Semi-Structured Interviews

Following each survey window, a subset of participants from the focus group volunteered to participate in individual, semi-structured interviews. These discussions probed deeper into how workshop experiences influenced their attitudes toward interdisciplinary collaboration and project-based teamwork. Participants were asked to reflect on any new skills gained, whether they interacted with peers from other majors, and whether attending a workshop had prompted them to venture beyond the confines of their own discipline. The interview transcripts were analyzed using an inductive coding strategy, following Braun and Clarke’s (2006) framework for thematic analysis [18]. This process involved starting without a predefined coding scheme, allowing themes to emerge organically from the participants’ words and experiences.

E. Analytical Procedures

Quantitative analyses were conducted using SPSS. Descriptive statistics characterized workshop attendance by major and tool usage patterns. Repeated-measures ANOVA and paired t-tests were chosen as they effectively capture within-subject changes over time, accounting for individual variability. Given the moderate sample size and repeated observations, these methods provide a reliable way to assess whether workshop participation influenced interdisciplinary perceptions. Effect sizes (Cohen’s d) further contextualize the magnitude of observed changes.

Self-selection bias is a potential limitation, as students who voluntarily attend workshops may already possess higher intrinsic motivation for interdisciplinary collaboration. To mitigate this, we included a control group consisting of makerspace users who did not attend workshops, ensuring that comparisons were made within a similarly engaged population. Future studies could employ randomized interventions or matched-group designs to further control for self-selection effects.

The semi-structured interview transcripts were coded thematically using NVivo. We independently reviewed the data to identify themes related to disciplinary openness, collaborative confidence, and the perceived impact of workshop attendance. Discrepancies were resolved by consensus, and these qualitative findings were subsequently joined with the survey results to enrich the overall interpretation of how makerspace engagement might foster interdisciplinary collaboration.

IV. Results

A. Quantitative Findings

The quantitative results suggest that participation in student-led makerspace workshops positively influences interdisciplinary attitudes, as measured by IEPS scores. The following sections explore (1) participant demographics, (2) workshop attendance and tool usage trends, (3) pre-post changes in IEPS scores, and (4) item-level insights.

A.1. Descriptive Overview of Participants

Across the three study windows, 101 undergraduates completed valid IEPS pre- and post-surveys. While some participants appeared in multiple windows, most were unique to a single pre-post cycle. Participants were categorized into two groups: Focus Group, which attended at least one workshop and actively used the makerspace, and Control Group, which used the makerspace but did not attend any workshops. Table I summarizes participant distribution across study windows.

Table I. Participants by Window and Group

Window	Total (n)	Focus (n)	Control (n)
C23–D23 (W1)	33	19	14
A24–B24 (W2)	44	25	19
C24–D24 (W3)	24	14	10
Total	**101**	**58**	**43**

A.2. Workshop Attendance and Tool Usage

Analysis of workshop attendance logs revealed that engineering students made up approximately 70% of all participants, with the remaining 30% distributed among Business, Computer Science, and Arts disciplines (Figure 1). This distribution suggests that makerspaces attract a diverse mix of students, facilitating interdisciplinary interaction.

Tool usage data further reinforces this trend: 3D printers and laser cutters were the most frequently used tools, while additional resources like belt sanders, drill presses, and vinyl cutters saw significant engagement. Chi-square analysis ($p < 0.05$) indicated that Focus Group participants accessed a broader range of tools compared to the Control Group, suggesting that workshop attendance encourages students to explore beyond their familiar toolsets (Figure 2).

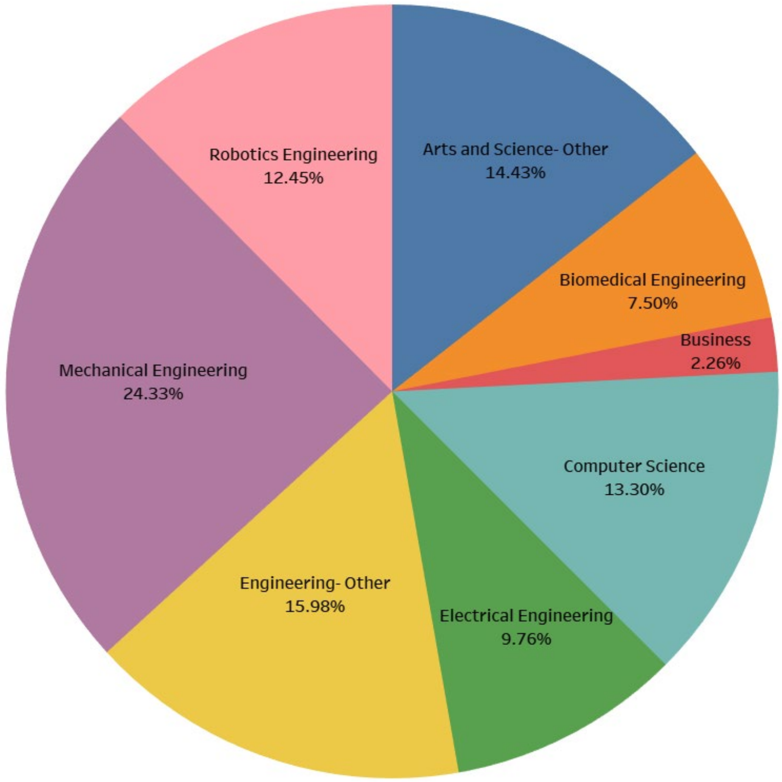

Figure 1. Major Field of Study Distribution of Workshop Participants

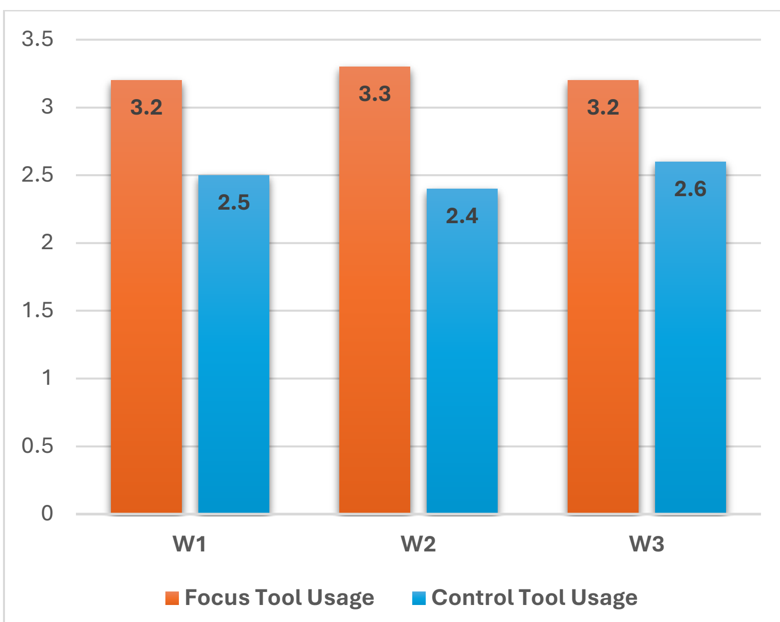

Figure 2. Chi-square test for Tool Utilization

A.3. IEPS Pre-Post Changes per Window

Table II. Mean (SD) IEPS Scores by Window, Group, and Time

Window	Group	Pre-IEPS M (SD)	Post-IEPS M (SD)	p-value (RM-ANOVA) *	Cohen's d**
W1 (C23–D23)	Focus (n=19)	3.72 (0.52)	4.04 (0.48)	0.049	0.53
	Control (n=14)	3.78 (0.49)	3.89 (0.50)	0.11 (n.s.)	—
W2 (A24–B24)	Focus (n=25)	3.80 (0.51)	4.10 (0.53)	0.043	0.47
	Control (n=19)	3.77 (0.50)	3.88 (0.48)	0.13 (n.s.)	—
W3 (C24–D24)	Focus (n=14)	3.68 (0.55)	4.00 (0.49)	0.058	0.44
	Control (n=10)	3.71 (0.56)	3.83 (0.54)	0.21 n.s.)	—

*p-value for the Group × Time interaction from repeated-measures ANOVA or equivalent test.
** Cohen's d effect size for pre–post change in the Focus Group; "—" indicates non-significant changes in the Control Group.

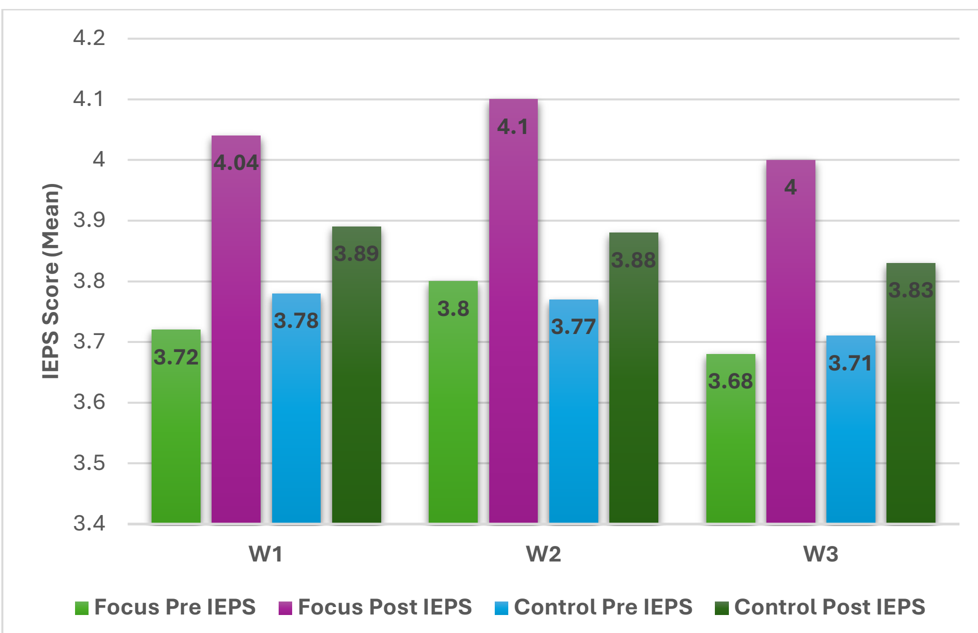

Figure 3. Pre Vs Post IEPS Mean Scores

Table II presents pre- and post-survey results, showing that the Focus Group exhibited statistically significant gains in IEPS scores across all three study windows (Cohen's d = 0.44–

0.53). The Control Group, in contrast, showed smaller, statistically non-significant changes, suggesting that makerspace engagement alone is not sufficient to drive interdisciplinary perception shifts, active participation in structured workshops is a key factor.

A.4. Item-Level Results

To capture specific attitudinal shifts, Table III displays item-level means for all 18 IEPS items (aggregated across windows). Focus participants generally reported moderate to significant improvements on most items referencing cross-major collaboration, project idea generation, or openness to unfamiliar tools. Control group changes were typically smaller and statistically non-significant.

Table III. Item-Level IEPS Results

IEPS Item	Focus Pre M (SD)	Focus Post M (SD)	p-value (Focus)	Cohen's d (Focus)	Control Pre M (SD)	Control Post M (SD)	p-value (Control)
1. "I am comfortable seeking advice from students in other majors…"	3.64 (0.50)	4.08 (0.48)	0.028	0.44	3.72 (0.52)	3.84 (0.51)	0.19
2. "My knowledge/skills in my own field are sufficient…" (Reverse-coded)	3.58 (0.51)	3.92 (0.47)	0.035	0.40	3.62 (0.49)	3.68 (0.52)	0.24
3. "Collaborating with peers from different academic backgrounds…"	3.80 (0.54)	4.12 (0.50)	0.041	0.36	3.77 (0.55)	3.90 (0.49)	0.16
4. "I often share ideas or offer assistance to students in other majors…"	3.62 (0.56)	3.98 (0.49)	0.026	0.45	3.67 (0.57)	3.74 (0.54)	0.31
5. "I feel confident contributing my disciplinary expertise…"	3.69 (0.51)	4.05 (0.45)	0.033	0.43	3.70 (0.50)	3.79 (0.48)	0.27
6. "Attending a makerspace workshop helped me discover new project ideas."	3.46 (0.52)	3.94 (0.50)	0.021	0.46	3.50 (0.58)	3.57 (0.56)	0.34
7. "Students from other fields of study have valuable insights…"	3.79 (0.53)	4.10 (0.49)	0.039	0.38	3.76 (0.52)	3.85 (0.50)	0.14
8. "I prefer to rely solely on tools/techniques from my major…" (Reverse-coded)	3.54 (0.55)	3.91 (0.50)	0.030	0.40	3.59 (0.53)	3.66 (0.52)	0.22
9. "Working with students from different majors in the makerspace has increased my interest…"	3.67 (0.59)	4.02 (0.47)	0.025	0.44	3.68 (0.58)	3.75 (0.55)	0.28

10. “Makerspace workshops are not particularly helpful…” (Reverse-coded)	3.60 (0.57)	3.89 (0.52)	0.034	0.39	3.62 (0.56)	3.67 (0.54)	0.23
11. “I appreciate learning about unfamiliar tools or techniques, even if not directly related…”	3.88 (0.50)	4.15 (0.48)	0.045	0.34	3.86 (0.51)	3.94 (0.49)	0.20
12. “I plan to collaborate with classmates from other majors in future course/personal projects…”	3.66 (0.58)	4.01 (0.47)	0.029	0.42	3.68 (0.56)	3.76 (0.53)	0.26
13. “My perspective on problem-solving has broadened through discussions outside my field…”	3.73 (0.52)	4.06 (0.48)	0.037	0.38	3.70 (0.51)	3.82 (0.50)	0.15
14. “I find it challenging to see how other majors’ skills apply…” (Reverse-coded)	3.57 (0.54)	3.88 (0.49)	0.032	0.41	3.58 (0.52)	3.63 (0.51)	0.29
15. “Makerspace workshops make me feel more open to methods used by other disciplines.”	3.62 (0.56)	3.98 (0.50)	0.020	0.46	3.64 (0.55)	3.73 (0.53)	0.26
16. “Engaging in cross-major teams in the makerspace is a valuable way to learn about real-world challenges.”	3.85 (0.49)	4.12 (0.46)	0.048	0.33	3.86 (0.48)	3.90 (0.47)	0.17
17. “I rarely interact with students from other majors in the makerspace…” (Reverse-coded)	3.61 (0.53)	3.92 (0.50)	0.027	0.43	3.65 (0.51)	3.70 (0.50)	0.25
18. “Having a peer-led workshop introduced me to potential collaborators outside my academic circle.”	3.45 (0.57)	3.94 (0.51)	0.016	0.47	3.49 (0.58)	3.56 (0.55)	0.36 (n.s.)

Some items are reverse-coded (noted in parentheses). Higher post-survey scores on these items indicate a stronger endorsement of cross-disciplinary attitudes (once reversed).

Examining individual IEPS items reveals specific attitudinal shifts. Focus Group participants reported greater openness to seeking advice from students in other majors (Item 1, $p = 0.028$, $d = 0.44$) and increased confidence in contributing their disciplinary expertise to cross-major projects (Item 5, $p = 0.033$, $d = 0.43$). These item-level trends reinforce the role of makerspace workshops in breaking disciplinary silos by encouraging knowledge-sharing and mutual reliance among students from different fields.

B. Qualitative Findings

While the quantitative findings demonstrate measurable improvements in interdisciplinary attitudes, the qualitative interviews provide rich insights into how these shifts manifest in student experiences. The thematic analysis identified five key drivers behind these changes: (1) cross-discipline skill transfer, (2) increased confidence, (3) peer networking, (4) project impetus, and (5) cumulative effect of repeated participation (Table IV).

Table IV. Thematic Analysis of Interview Transcripts

Theme	Count of Mentions	Definition
Cross-Discipline Skill Transfer	24 references	Participants discovered new tools/techniques outside their own major and applied them in various contexts.
Confidence	21 references	Students described increased self-efficacy and a willingness to tackle unfamiliar challenges.
Peer Networking	18 references	Workshops facilitated meeting peers from different disciplines, leading to collaborative relationships.
Project Impetus	16 references	Workshop experiences (tools, ideas) directly triggered or accelerated the start of an interdisciplinary project.
Cumulative Effect	10 references	Attending multiple workshops over time led to incremental skill-building and broader project involvement.

B.1. Cross-Discipline Skill Transfer

Many participants reported discovering a technique, tool, or approach typically associated with another major. For instance, computer science students learned basic woodworking, while mechanical engineering students explored vinyl cutting. This exposure encouraged them to integrate these newly acquired skills into ongoing or future projects. An Electrical Engineering Sophomore commented: *"I'm an EE [Electrical Engineering] major, so I never expected to do anything with sewing or vinyl cutting. But after going to that beginner workshop, I ended up adding custom decals to my circuit enclosure. It made the project more polished and interesting."*

B.2. Confidence

A recurrent pattern was the boost in confidence participants gained from attending a relatively short, peer-led workshop. Several students described initially feeling out of place or intimidated by unfamiliar equipment. However, a single workshop often demystified the process, leading them to feel more adventurous and resourceful. A Robotics Engineering Junior said: *"I'd been* *too nervous to try the laser cutter. Seeing another undergrad junior show me step by step made it seem so doable. Now I'm cutting parts for my robotics lab, no problem."*

B.3. Peer Networking

In nearly every workshop setting, participants encountered peers from other majors who shared similar interests or complementary skill sets. These informal networking opportunities sometimes evolved into small project teams or ongoing collaborations. Students noted that the peer-led structure created a low-pressure environment to connect and exchange ideas. Some also claimed these ad-hoc partnerships were more impactful than formal group assignments in their courses. A CS Major said: *"I sat next to an ECE student in the Soldering Basics workshop, and we found out we both like wearable tech. We ended up partnering on a project for a WPI hackathon, blending my code and his product pitch."*

B.4. Project Impetus

A significant subset of the interviews also highlighted how attending a single workshop led participants to start or accelerate an interdisciplinary project. Often, trying out a novel tool or brainstorming with diverse classmates sparked creative solutions or new directions. Some students cited immediate applications, such as designing a small device for a community outreach program. A Business sophomore mentioned: *"I had this half-formed idea for an assistive device, but it was just a concept…. After seeing how easy it was to mold plastic in the Vacuum Forming workshop, I started right in. Suddenly, it felt real and doable."*

B.5. Cumulative Effect

Although fewer participants attended multiple workshops, those who did described a compounding benefit. Each session added a new skill or contact, gradually expanding their interdisciplinary toolkit. Over time, these participants displayed greater resourcefulness and a broader network, sometimes even mentoring new workshop attendees. A Mechanical Engineering Senior said: *"I was hooked after the first two workshops- basics of 3D printing and laser cutting. By the third workshop, I felt like could help someone else, and applied to be an instructor. I've combined these techniques in a [final year capstone] project that has students from three majors."*

These findings suggest that makerspaces serve as natural "collaboration incubators," fostering both technical and relational networks that extend beyond immediate workshop contexts. Even brief, peer-led training can instill enough confidence for students to try out unfamiliar tools or partner with peers from different majors. This synergy of skill transfer and collaborative networking is often multiplied when participants attend multiple workshops, reinforcing the moderate gains observed in the quantitative IEPS data.

C. Integrating Quantitative and Qualitative Findings

The convergence of quantitative (IEPS improvements) and qualitative (student narratives) evidence supports the assertion that student-led workshops create a structured yet exploratory space for interdisciplinary learning. This dual perspective strengthens the argument for formal curricular integration of makerspace activities, ensuring that these benefits are accessible to a broader student population beyond self-selected participants.

D. Curricular Integration of Makerspace Workshops

Given these results, institutions should consider embedding structured makerspace workshops into core curricula to reinforce interdisciplinary collaboration. Three key strategies emerge:

1. **Reinforcement of Fundamental Concepts:** Makerspace projects can complement science and engineering courses by providing tangible applications of theoretical principles. Constructivist learning theory [22] suggests that interactive, hands-on experiences enable students to break down complex threshold concepts [23] through experimental iteration.
2. **Prototyping in Design Education:** Integrating makerspace workshops into senior capstone and laboratory courses ensure that students have practical prototyping skills to support their design objectives. Early interdisciplinary exposure in makerspaces can also help students navigate design constraints across multiple domains.
3. **Formal Recognition & Incentives:** Implementing badging systems or micro-credentials could incentivize broader participation and help students track interdisciplinary competencies gained through makerspace engagement.

Institutions should engage department faculty in co-developing workshop content that complements existing course objectives. Cross-listed electives that count toward major or minor credit could incentivize participation, while faculty mentorship of peer instructors would ensure alignment with academic standards. Embedding workshops into first-year seminar or capstone courses also supports early and late-stage exposure.

These strategies position makerspaces as both technical resources and structured learning environments, reinforcing their pedagogical role in breaking disciplinary silos.

VI. Conclusion

This study provides empirical evidence that student-run makerspace workshops play a vital role in fostering interdisciplinary collaboration. Across three study windows, workshop attendees consistently exhibited moderate but significant gains in interdisciplinary attitudes, while qualitative findings illustrated how these experiences translated into real-world collaborations.

Key takeaways include (1) the value of curricular integration, (2) the impact of peer-led facilitation, and (3) the cumulative benefits of repeated engagement. These insights support the broader case for leveraging makerspaces as hubs for cross-disciplinary learning and innovation.

These findings align with the FREE Competency Taxonomy, demonstrating that student-led makerspace workshops effectively cultivate technical, professional, and personal competencies critical for engineering graduates.

Future research should explore longitudinal tracking of workshop participants to assess whether interdisciplinary mindsets persist beyond graduation, as well as multi-institutional studies to validate these findings across different educational settings. Additional questions remain about the depth of discipline achieved, the specific competencies most impacted, and how these experiences influence career pathways or entrepreneurial pursuits. Addressing these gaps will strengthen the case for integrating makerspaces into national STEM strategies.

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