Maker Space Innovations to increase the Student Success

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Abstract

Makerspaces have become an integral part of higher education, providing experiential learning environments that support hands-on design, fabrication, and problem-solving. Prior studies have shown positive impacts on student engagement, confidence, and skill development; however, fewer investigations examine how operational innovations within makerspaces contribute to student success, particularly in rural university contexts. This paper presents a case study of iMakerSpace, an innovative university makerspace at a rural state institution, highlighting how intentional design and operational strategies enhance student learning experiences. Two complementary surveys were conducted during the Fall 2025 semester: a workshop-based survey following a hands-on metal casting activity and a semester-wide survey assessing overall makerspace usage and impact. Survey results and utilization metrics indicate high levels of student satisfaction, confidence development, and sustained engagement. Key innovations, including a web-based fabrication management system, industry-led workshops, diversified access to equipment, and structured design support, emerged as significant contributors to scalable, inclusive experiential learning. The findings demonstrate that a well-integrated makerspace ecosystem can effectively support student learning, workforce preparedness, and interdisciplinary collaboration within resource-constrained academic environments.

1. Introduction

Makerspaces have become an increasingly important component of higher education, offering experiential learning environments where students engage in hands-on design, fabrication, and problem-solving. These spaces typically combine digital fabrication tools, electronics prototyping resources, and collaborative work areas that support project-based and interdisciplinary learning [1]. Prior research has shown that makerspaces positively influence student engagement, creativity, self-efficacy, and persistence by enabling students to translate theoretical concepts into physical artifacts through iterative design processes [2], [3], [4].

Within engineering and technology education, makerspaces are closely associated with active learning pedagogies and workforce preparation. Structured making activities support the development of technical competencies and professional skills, such as teamwork, communication, and problem-solving, all of which are critical for preparing students for modern engineering careers [5]. Studio-based, hands-on instructional models aligned with additive manufacturing (AM) have been shown to reduce skill gaps between academic preparation and industry needs effectively [6], [7].

Makerspaces also play a significant role in workforce development by exposing students to emerging manufacturing technologies and authentic industrial workflows. Innovations in AM education, remote laboratory access, and studio pedagogy have been shown to enhance student learning outcomes and career readiness [8], [9]. Best-practice studies further emphasize inclusive access, diversified equipment, and structured operational models as key contributors to student success [10].

Despite this growing body of work, most studies focus on large research-intensive or urban institutions. Fewer investigations examine how makerspaces in rural or resource-constrained universities can be designed to maximize access, scalability, and student success. In particular, limited work has examined how operational innovations, such as web-based fabrication management systems and industry-led workshops, directly affect student learning experiences.

This paper addresses these gaps by presenting a case study of iMakerSpace, an innovative makerspace at a rural state university. Using two surveys, one focused on a Foundry in a Box metal casting workshop and another assessing overall makerspace usage, this study demonstrates how iMakerSpace's environment and innovations contribute to student success.

2. Innovations of iMakerSpace and Its Environment

iMakerSpace functions as a central hub for hands-on learning, interdisciplinary collaboration, and creative manufacturing across academic semesters. The space supports a wide range of educational activities, including structured hands-on workshops, course-based instructional engagements, recurring student organization meetings, and open-access fabrication through the MakerTrack system. In addition, iMakerSpace provides customized design and fabrication support for institutional initiatives, enabling students to apply technical skills in authentic, real-world contexts while contributing to broader university activities.

2.1 MakerTrack: Web-Based Fabrication Support System

A key operational component of iMakerSpace is MakerTrack, a web-based platform for managing student-initiated fabrication requests. Through MakerTrack, students upload their design files in STL format, which may represent either single components or larger assemblies intended for AM. Upon submission, designs are reviewed by trained iMakerSpace student assistants, who evaluate printability and manufacturability. Submissions are either approved for fabrication or returned with detailed feedback that identifies design issues and guides students toward more manufacturable solutions. Once a design enters the production workflow, its status can be tracked on the web platform at each stage, including pending, approved, printing, and completed. During the printing stage, the assigned printer is explicitly indicated, allowing students to monitor where their parts are being fabricated. In addition to real-time status tracking on the platform, students receive automated email notifications at key stages, enabling continuous awareness and transparency throughout the fabrication process. Table 1 summarizes MakerTrack-supported fabrication activity during the Fall 2025 semester. Structured fabrication workflows such as

MakerTrack align with best practices in makerspace and AM education, improving reliability and scalability while supporting iterative learning [10].

Table 1. MakerTrack Utilization Metrics (Fall 2025)

Metric	Value
Print submissions completed	149
Individual students served	78
Logged printing hours	~800
Additional printing hours (estimated)	~100

These data demonstrate sustained student demand and effective scaling of makerspace resources.

2.2 Workforce Training

In addition to on-demand fabrication support, iMakerSpace hosts multiple hands-on workshops designed to immerse students in real industrial processes. Through direct, practice-oriented engagement, these workshops enable students to develop core maker skills and gain practical experience with manufacturing tools, materials, and workflows. Delivered by professionals with industry experience, the workshops expose students to authentic production environments and professional perspectives, helping broaden their technical vision and understanding of engineering practice. This combination of hands-on learning and industry-informed instruction helps students become more confident, competent, and better prepared for industrial and professional settings.

Workshops conducted during 2025 are summarized in Table 2.

Table 2. 2025 iMakerSpace Workshops and Attendance

Workshop	Date (2025)	Attendance
Casting the Night Away (Foundry in a Box)	Jan 29	26
Introduction to Modern Shipbuilding	Feb 26	27
Introduction to Laser Engraving	Mar 12	21
Creative Technology – A Contemporary Artist's Toolset	Apr 2	26
Advanced Manufacturing Trends	Apr 26	22
Design for Additive Manufacturing	Sep 10	18
Casting the Night Away (Foundry in a Box)	Sep 25	44
Introduction to Laser Engraving	Oct 22	17
Holiday Decoration Making	Nov 19	13

Studio-based and industry-informed workshops such as these align with workforce-oriented pedagogies that have been shown to improve student confidence, preparedness, and alignment with ABET student outcomes [6], [8].

2.3 Equipment Infrastructure and Access Philosophy

iMakerSpace maintains a diverse suite of equipment supporting digital fabrication, electronics prototyping, creative manufacturing, and introductory industrial processes. This includes multiple FDM and SLA 3D printers, 3D scanners, laser cutting and engraving systems, benchtop CNC machining, vinyl cutting, and heat pressing [11], sewing machines [12], food 3D printers [13], vacuum forming, plastic injection molding [14], and post-processing techniques [15], full electronics testing suite [16], CAD and simulation software [17], and the Slicer software [18] needed for AM. Representative images of the iMakerSpace workshop area illustrating this fabrication environment are shown in Figure 1.

This breadth of capability supports the makerspace's guiding philosophy: to accommodate any student project, thereby increasing inclusivity and participation across disciplines and experience levels [10].

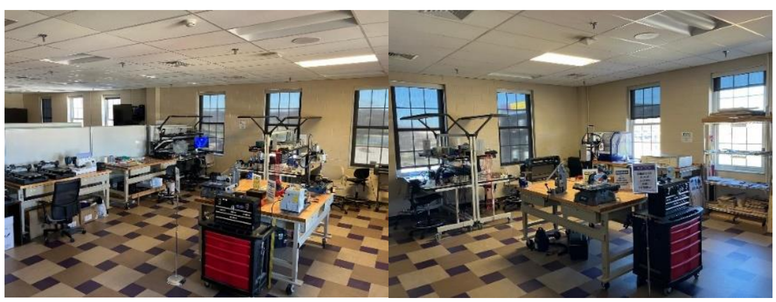

Figure 1. iMakerSpace workshop area and fabrication environment.

2.4 Design Support

iMakerSpace provides design support to students with innovative ideas but limited experience in digital design or computer-aided modeling. Through one-on-one guidance and iterative feedback, student assistants and staff help translate conceptual ideas into manufacturable digital models, lowering entry barriers to making and prototyping. This support enables students from diverse academic backgrounds to participate in fabrication activities without requiring prior advanced design skills.

In addition to digital modeling assistance [19], iMakerSpace provides access to 3D scanning technologies [20] to further support the design process. Physical objects, hand-built prototypes, or reference components can be digitized and refined, allowing students to move efficiently from physical concepts to digital fabrication. By combining design guidance with 3D scanning capabilities, iMakerSpace supports inclusive participation, accelerates idea-to-prototype workflows, and fosters confidence in students' design and creative abilities. Examples of 3D-scanned components used to support the design and fabrication process are shown in Figure 2.

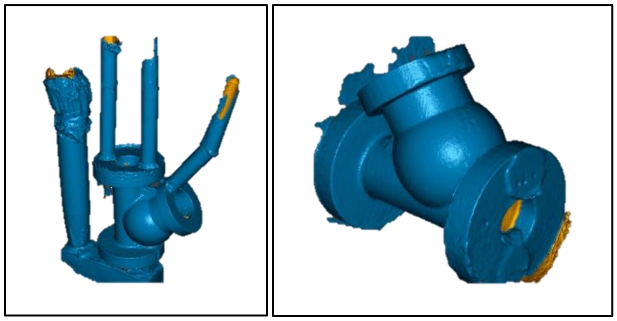

Figure 2. Examples of 3D-scanned components used in iMakerSpace to support design refinement and fabrication.

2.5 Extracurricular Activities

Beyond formal instruction and fabrication support, iMakerSpace serves as a shared environment for extracurricular activities that promote collaboration, knowledge exchange, and interdisciplinary interaction. The space regularly hosts meetings for student organizations such as the IEEE Student Chapter and Students for the Exploration and Development of Space (SEDS), providing a venue for students to gather, discuss technical topics, and exchange ideas in engineering, technology, and design. These recurring meetings support informal learning and peer-to-peer knowledge sharing outside traditional classroom contexts.

In addition to student organizations, iMakerSpace also supports programmatic and institutional engagement by hosting meetings and events for initiatives such as the Tennessee Tech University Grand Challenge Scholars Program (GCSP) and departmental advisory activities, including Mechanical Engineering and Manufacturing and Engineering Technology Advisory Board meetings. As part of the community-oriented activities, students also design and fabricate custom apparel, including baby-sized garments, to support continued student–alumni connections, as shown in Figure 3. By accommodating a diverse range of extracurricular and institutional groups, iMakerSpace strengthens its role as a collaborative learning hub, fostering communication, interdisciplinary awareness, and community building across academic and professional boundaries [21].

Figure 3. Representative activities conducted in iMakerSpace: (a) Design for Additive Manufacturing workshop, (b) student-designed and fabricated baby apparel supporting student–alumni engagement, (c) "Casting the Night Away" hands-on casting event, and (d) virtual reality (VR) workshop illustrating experiential and interdisciplinary learning activities.

2.6 Research and Capstone Projects

iMakerSpace provides critical support for student research and capstone design projects by offering access to fabrication tools, technical guidance, and prototyping resources throughout the project lifecycle. Students engaged in undergraduate research, senior design, and capstone courses utilize the makerspace to develop prototypes, test design concepts, and iterate on functional components [22]. This access enables students to move beyond theoretical design and engage in hands-on problem-solving aligned with real engineering challenges. Representative examples of student research and capstone projects developed within iMakerSpace, including functional prototypes made from PLA and PETG Filaments [23], [24], and experimentally validated components, are shown in Figure 4.

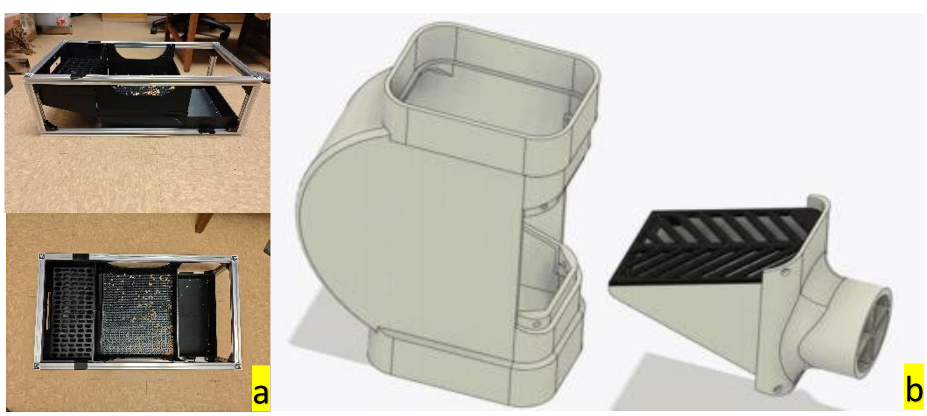

Figure 4. Example of a student research project conducted in iMakerSpace: a) 3D reconstruction process of corn root samples using a 6-DOF robotic arm, b) Rain barrel water diverter

3. Evaluation of the iMakerSpace Activities

Two structured surveys were administered during the Fall 2025 semester to evaluate the educational impact and operational effectiveness of hands-on training activities and makerspace services. Both surveys were designed to collect student feedback using a combination of Likert-scale, multiple-choice, and open-ended questions, allowing for both quantitative and qualitative analysis.

The first survey focused on a Foundry in a Box hands-on metal casting workshop. This workshop-oriented survey was distributed immediately following the training session to capture participants' immediate perceptions and experiences. The survey evaluated key dimensions, including clarity of workshop objectives, relevance and organization of instructional content, effectiveness of hands-on activities, adequacy of training materials, instructor preparedness, development of confidence in basic sand-casting tasks, and overall satisfaction with the workshop. Responses were primarily measured using a five-point Likert scale ranging from Strongly Disagree to Strongly Agree, with additional open-ended questions included to gather qualitative feedback on strengths, areas for improvement, and future training recommendations.

The second survey assessed broader student experiences with iMakerSpace services and resources. This survey examined patterns of makerspace usage, accessibility, equipment availability and reliability, staff and student assistant support, fabrication turnaround time, workshop communication effectiveness, and the perceived contribution of iMakerSpace to students' learning and maker skill development. Questions were organized into thematic sections covering usage frequency, facilities and equipment, staff support and training, user experience, and overall impact. The survey employed multiple-choice and Likert-scale questions to facilitate quantitative analysis, alongside open-ended questions that allowed respondents to elaborate on challenges, suggestions, and complementary resources used outside the makerspace.

Participation was voluntary, and responses were collected anonymously to encourage honest and unbiased feedback. Collected responses were manually coded and aggregated into structured Excel datasets for analysis. Descriptive statistics were used to summarize response distributions, while open-ended responses were reviewed thematically to identify recurring trends and insights. Together, these surveys provided complementary perspectives on both targeted workshop-based learning outcomes and the broader educational role of iMakerSpace in supporting student-centered, hands-on engineering and design experiences.

3.1 Workforce Training Evaluation

Over the last two years of iMakerSpace activities, the 'Casting the night away' activity has been very well received by participants. To understand the effectiveness and impact of this wellattended training activity, the author team decided to conduct a survey to identify the basis of this success, so that other activities can be transformed into similar ones.

A total of 33 responses were collected following the Foundry in a Box sand casting workshop. Overall, results demonstrate strong learning outcomes, with mean scores exceeding 4.5 out of 5 across all instructional and experiential metrics (Table 3).

Participants reported high agreement that the workshop objectives were clear (M = 4.73) and the content was relevant and useful (M = 4.88). Scores related to hands-on learning effectiveness (M = 4.70) and confidence improvement (M = 4.55) indicate that the workshop not only delivered content effectively but also enhanced participants' practical competence, a key component of student achievement in experiential engineering education. Instructor effectiveness received the highest mean score (M = 4.94), underscoring the importance of expert facilitation in achieving these outcomes.

Overall satisfaction was high (M = 4.58), and 100% of respondents indicated they would recommend the workshop, suggesting that the training model provides meaningful educational value and measurable learning gains. Table 3 summarizes key quantitative results.

Table 3. Foundry in a Box Workshop Survey Summary (N = 33)

Item	Mean (1–5)	Top-Box (%)
Objectives clearly stated	4.73	90.9
Content relevant/useful	4.88	97.0
Workshop organization	4.79	93.9
Hands-on learning effectiveness	4.70	90.9
Instructor effectiveness	4.94	97.0
Confidence in performing sand casting	4.55	87.9
Overall satisfaction	4.58	93.9
Would recommend the workshop	5.00	100

The authors found that participants highlighted the following points:

- The instructor is available throughout the entire workshop, from start to finish, and provides continuous guidance to help participants achieve successful casting outcomes.
- Students enjoy producing their own final cast pieces and appreciate the opportunity to take them home.
- The activity is entirely hands-on, keeping participants actively engaged at all times.
- Comprehensive safety training is provided at the start of the workshop, ensuring a smooth, safe execution of the activity.

- Upon completion of the training, all participants receive certificates of completion in recognition of their effort and participation.

3.2 Student Satisfaction Survey

The iMakerSpace survey yielded 20 responses. Results indicate a consistently positive relationship between iMakerSpace engagement and student learning outcomes. The survey was conducted in the last month of the Fall 2025 semester, and only students who used the facility during the semester were asked to complete it (Table 1). A substantial majority of respondents (85.0%) reported that iMakerSpace contributed positively to their learning objectives and/or curricular needs. In comparison, 90.0% stated that they would recommend the space to other students and colleagues (Table 4).

Operational factors supporting student achievement were also rated favorably. Easy access to iMakerSpace was reported by 90.0% of respondents, and 90.0% expressed satisfaction with equipment availability. Staff support remained a key strength, with 85.0% of respondents rating staff or student assistants as excellent or good. In terms of project support efficiency, 94.0% of respondents reported fabrication turnaround times of one week or less, indicating generally adequate workflow support for academic projects.

Collectively, these results suggest that iMakerSpace provides an accessible, well-supported environment that facilitates hands-on learning, timely project completion, and enhanced student achievement. Table 4 summarizes key outcomes.

Table 4. iMakerSpace Survey Results (N = 20)

Category	**Result (%)**
Positive contribution to learning and maker skill development	85.0
Would recommend iMakerSpace to other students	90.0
Access to iMakerSpace	90.0
Satisfied with equipment availability	90.0
Satisfied with equipment maintenance and reliability	85.0
Staff rated excellent or good	85.0
Fabrication turnaround time ≤ 1 week	94.0

The authors' team found that participants highlighted the following points:

- Students emphasized the importance of having a large, built-environment 3D printer to fabricate large-scale components.
- The tools and equipment should be well organized and clearly structured to allow convenient access and ease of location.
- Students suggested using modern design software, such as Rhino modeling, to support complex and advanced design requirements.

- The makerspace's centralized location is highly valued by students, as it provides convenient access for majors across campus.
- Students expressed appreciation for the availability and helpfulness of the student support staff in addressing design and fabrication needs.
- Students also conveyed that iMakerSpace should be accessible 24/7 to support their fabrication and project requirements.

5. Discussion

The combined survey findings and utilization metrics indicate that the innovations implemented within iMakerSpace positively contribute to student success, engagement, and overall learning experience. High levels of satisfaction and strong recommendation rates observed across both the semester-long and workshop-based surveys align with prior makerspace research emphasizing the educational value of hands-on, informal learning environments [2], [3], [4]. These results reinforce the role of maker spaces in fostering students' technical competence, confidence, and motivation across diverse academic backgrounds.

Beyond confirming previously reported benefits, this study highlights the importance of operational innovations that extend beyond traditional open-access makerspace models. Systems such as MakerTrack and industry-led workshops play a critical role in supporting scalable, inclusive learning opportunities. MakerTrack not only streamlines fabrication workflows but also provides iterative design feedback that supports design-for-manufacturability and reduces barriers for students with limited prior fabrication experience. Similarly, industry-led workshops expose students to authentic manufacturing practices, contributing to immediate learning gains and increased confidence, consistent with findings in experiential and practice-oriented engineering education literature [8], [10].

Student feedback further emphasizes the importance of infrastructure, accessibility, and support in maximizing the educational impact of makerspaces. Participants noted the need for larger build-volume 3D printers to accommodate large-scale or complex projects, particularly for capstone and research applications. Suggestions for improving the organization of tools and equipment highlight the role of effective space management in reducing friction during fabrication and enhancing the user experience. These observations align with the broader understanding that makerspace effectiveness depends not only on equipment availability but also on thoughtful operational design.

Students also expressed interest in access to more advanced design software, such as Rhino, to support complex modeling needs. This feedback reflects an evolving user base that increasingly engages in sophisticated design tasks, underscoring the need for makerspaces to adapt their digital tool ecosystems alongside their physical fabrication capabilities. At the same time, students consistently identified iMakerSpace’s centralized campus location as a significant advantage, underscoring the importance of physical accessibility in promoting interdisciplinary participation and sustained engagement.

Finally, strong appreciation for the availability and helpfulness of student support staff reinforces the critical role of human support systems within makerspaces. Design guidance, fabrication assistance, and responsive communication were repeatedly cited as strengths, suggesting that peer-supported models can effectively enhance learning outcomes. Suggestions for extended operating hours, including potential 24/7 access, further indicate high levels of student demand and reliance on the makerspace for academic and creative work. While such access presents logistical and safety considerations, it highlights the central role iMakerSpace plays in students' academic workflows.

Collectively, these findings suggest that iMakerSpace's impact is shaped not only by access to tools but also by an integrated ecosystem that combines operational innovation, instructional support, and responsive infrastructure. By continuously evolving to meet student needs, makerspaces can better support experiential learning, equitable access, and workforce readiness in engineering and related disciplines.

6. Limitations

This study primarily relies on responses from Fall 2025 semester student participants, which provide valuable insight into students' experiences, perceptions, and reflections on learning in the makerspace environment. Such perception-based measures are particularly well-suited for capturing dimensions such as confidence, engagement, and satisfaction that are not readily observable through traditional assessments. While these responses may not directly quantify objective performance outcomes, they offer an essential complement to utilization metrics and contextual observations of makerspace engagement.

The study is also based on data collected within a single academic semester and includes modest sample sizes, providing a focused examination of iMakerSpace operations within a specific institutional context. These characteristics present clear opportunities for future work. Subsequent studies can build on these findings by incorporating additional measures such as project-based performance evaluations, longitudinal tracking of student engagement across multiple semesters, and broader institutional comparisons. By extending this work with complementary quantitative and longitudinal approaches, future research can further strengthen the understanding of how makerspace innovations contribute to sustained learning, skill development, and workforce readiness.

7. Conclusions and Future Work

This study demonstrates that an intentionally designed, well-supported makerspace can play a meaningful role in enhancing student success in a rural state university context. The findings show that iMakerSpace functions not only as an open-access fabrication facility but also as an integrated learning ecosystem that combines operational innovation, instructional support, and experiential learning opportunities. Innovations such as the MakerTrack system, industry-led workshops, and broad access to fabrication technologies support students at all levels of experience, enabling them to engage confidently in design, prototyping, and manufacturing. Together, the survey results and utilization metrics indicate that these elements contribute to positive learning experiences, increased confidence, and sustained engagement.

Beyond documenting positive student perceptions, this work highlights the value of pairing structured instructional experiences with flexible, student-driven making environments. Short-format, industry-informed workshops facilitate immediate skill development and exposure to authentic manufacturing practices, while continuous access to makerspace resources supports long-term learning, autonomy, and interdisciplinary collaboration. As makerspaces continue to evolve within higher education, the iMakerSpace model illustrates how thoughtful integration of digital infrastructure, human support, and physical resources can advance inclusive and scalable experiential learning. Future work will build on these findings by expanding large-format AM capabilities and implementing longitudinal assessment strategies to further examine the impact of makerspace engagement on student learning, persistence, and professional readiness.

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