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Design and Implementation of an Electrical and Computer Engineering Makerspace to Bridge a Hands-On Learning Gap

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Abstract

Makerspaces are increasingly used in engineering education to create hands-on, collaborative environments that complement formal coursework and support students' development as creative problem-solvers and self-directed learners. However, "opening a lab room after hours" does not, by itself, produce the access model and sustainability mechanisms that characterize effective makerspaces; particularly for Electrical and Computer Engineering (ECE), where test instrumentation, soldering, and electronics prototyping introduce distinct workflow and supervision needs. This paper presents the design and rollout of a dedicated ECE makerspace at a large public university created to address a departmental gap: ECE students lacked a proximate, appropriately equipped space to tinker, prototype, and collaborate outside scheduled laboratories. The new makerspace was designed with purposeful zoning, electronics-focused equipment, equipment tracking, and operating policies that balanced open access for students with safety and organization for staff. Initial observations indicate that the new space is well utilized and supported teamwork and prototype development. Findings show that lack of perceived need and lack of awareness are leading barriers, suggesting that curricular integration and early-program messaging are essential to equitable utilization. Finally, we provide recommendations for other ECE programs to design and implement their own makerspace.

1. Introduction

Electrical and Computer Engineering (ECE) education requires students to translate abstract theory into functioning artifacts, including circuits, embedded systems, printed circuit boards, and integrated prototypes. While formal laboratory courses play a critical role in developing foundational technical skills, they are typically structured around predefined experiments, fixed schedules, and narrowly scoped objectives. As a result, opportunities for open-ended exploration, iterative prototyping, and independent skill development are often limited. This constraint creates a persistent hands-on learning gap, particularly for students seeking to explore electronics beyond coursework, efficiently iterating on capstone designs, or independently learning emerging technologies.

At the same time, engineering graduates are expected to enter the workforce prepared to continually acquire new knowledge and skills as technologies evolve. This expectation is reflected in accreditation criteria emphasizing graduates' ability to acquire and apply new knowledge using appropriate learning strategies[1]. Educational research commonly frames this capability through the lens of self-directed learning, which underpins lifelong learning and professional adaptability[2]–[4]. However, traditional ECE curricula, while technically rigorous, do not consistently provide environments that cultivate self-directed learning behaviors, particularly for students who do not already identify as independent learners[5].

Makerspaces have emerged in engineering education as one potential response to this gap. Prior literature positions makerspaces as environments that support learning through making, peer collaboration, experimentation, and informal mentorship, drawing on constructionist learning principles and the maker movement [6]–[8]. Importantly, research emphasizes that makerspaces are not merely rooms with tools; rather, they are spaces that promote peer interactions to increase student engagement and learning experiences [9], [10]. Nevertheless, empirical evidence linking makerspace participation to outcomes such as self-directed learning readiness remains mixed, and adoption is uneven across student populations[11], [12].

Notably, prior studies have shown that many students, particularly those early in their academic careers, do not use makerspaces, citing lack of perceived need, lack of awareness, or time constraints rather than lack of interest or ability[13], [14]. These findings suggest that barriers to makerspace use are often structural and curricular rather than motivational. As a result, simply making tools available or opening instructional laboratories after hours does not address the factors that influence equitable adoption or sustained engagement.

These challenges are especially pronounced in ECE. Electronics prototyping involves benchtop instrumentation, soldering, small-part organization, and varying levels of user expertise, all of which complicate open-access models and safety oversight. As a result, an effective ECE makerspace must be intentionally designed to support electronics-centered workflows while also reducing intimidation, lowering barriers to entry, and promoting sustained, voluntary use. Prior work has emphasized that discipline-specific makerspaces can better align tools, workflows, and cultural norms with students' learning needs than centralized, multidisciplinary spaces [15].

At a large public institution in the northeast, ECE students historically relied on scheduled laboratory sessions, limited open-lab hours, or portable "lab-in-a-box" kits to complete coursework. While sufficient for meeting course requirements, these options did not provide a proximate, appropriately equipped space for collaboration, iterative debugging, or independent project work. A centralized, multidisciplinary campus makerspace existed but was underutilized by ECE students, reflecting trends reported in the literature when spaces are distant from departments or lack discipline-specific infrastructure[13], [16]. These limitations became particularly evident during capstone projects and personal prototyping efforts, where students needed short, frequent access to instruments, soldering, and components rather than prolonged, scheduled lab blocks.

Motivated by both local needs and insights from prior research on makerspace adoption and self-directed learning, the ECE department undertook the design and implementation of a dedicated

ECE makerspace located within the department. The space was intentionally framed not as another instructional laboratory, but as a shared, informal environment supporting coursework, capstone projects, and student-initiated exploration. Design decisions were informed by benchmarking at peer institutions, engagement with national ECE makerspace initiatives, stakeholder feedback from students and faculty, and empirical evidence identifying barriers to makerspace use[17]. Particular attention was given to proximity, electronics-focused zoning, access and safety policies, stewardship mechanisms, and culture-setting practices that normalize experimentation and learning through iteration [9], [10]. This paper presents the design process, rollout, and early outcomes of the ECE makerspace. Early evidence includes departmental observations of student collaboration and project activity and decisions to expand the space based on utilization demand.

Design and Implementation Approach

The design and implementation of the Electrical and Computer Engineering (ECE) makerspace was guided by the premise that effective makerspaces are sociotechnical systems rather than collections of tools. Prior research emphasizes that makerspaces function through the interaction of physical infrastructure, access policies, safety practices, cultural norms, and peer interaction, all of which jointly shape student engagement and learning[9], [10]. Accordingly, the development process emphasized not only physical layout and equipment, but also proximity, workflow alignment, stewardship mechanisms, and culture-setting practices that influence adoption and sustained use. These considerations were informed by benchmarking at peer institutions, engagement with national ECE makerspace initiatives, stakeholder input from students and faculty, and empirical evidence identifying common barriers to makerspace utilization[17].

A central design decision was the selection of location. Rather than expanding ECE capacity within an existing centralized, multidisciplinary makerspace, two underutilized rooms within the ECE department suite were repurposed to create a dedicated makerspace (Figure 1). These rooms, previously used as graduate student work and study areas, had become largely vacant following shifts in work patterns after the COVID-19 pandemic. Their location near ECE laboratories, faculty offices, and electronics supplies made them well suited for conversion into a shared prototyping and collaboration space. This proximity was intentional: prior research and local experience indicate that distance from the department significantly reduces spontaneous and short-duration use, particularly for electronics workflows that involve incremental debugging, solder rework, or brief instrument checks[13], [16]. Locating the makerspace within the department reduced friction for frequent, low-commitment visits and supported closer alignment with laboratory and capstone activities.

The physical layout was organized around electronics-centered workflows rather than traditional instructional laboratory configurations. Electrical and computer engineering prototyping typically involves rapid cycles of build–test–modify, requiring flexible access to instrumentation, soldering, and small components. As a result, space was zoned to support multiple concurrent activities while maintaining safety and usability. Dedicated electronics bench areas were equipped with benchtop instrumentation and ESD-conscious work surfaces to support circuit development and testing. A separate soldering and rework area was established to manage heat, fumes, and tool control while enabling students to develop hands-on fabrication skills. Open collaboration areas supported capstone team meetings, documentation, and system integration, while organized storage and consumables areas reduced project delays caused by missing small components. These design choices align with prior work emphasizing the importance of workflow-aware layouts in academic makerspaces[15].

Access and safety policies were designed to balance openness with responsibility. Rather than restricting the space to scheduled use or limiting access to advanced students, a tiered access model was adopted in which onboarding and training aligned with equipment risk and user experience. Entry-level access emphasized approachability and avoided intimidating gatekeeping, reflecting research indicating that perceived barriers, fear of misuse, and lack of confidence can deter novice users [14], [17]. Higher-risk tools and activities require additional orientation or sign-off, allowing broad participation while maintaining safety and accountability. Equipment tracking and consumables management were implemented to support long-term sustainability and reinforce shared ownership of the space [9].

Cultural considerations were treated as integral to the design rather than as secondary outcomes. Prior studies emphasize that makerspaces support learning not only through tools, but also through social interaction, psychological safety, and norms that encourage experimentation and iteration[7], [8]. Visual design choices, signage, and space norms were intentionally selected to reduce intimidation and normalize learning through trial and error. The makerspace was explicitly framed as distinct from graded laboratory environments, supporting coursework, capstone projects, and student-initiated exploration. Peer interaction and informal mentoring were encouraged through open layouts and shared work areas, aligning with constructionist learning principles commonly associated with makerspace environments [6], [10].

Throughout the design and implementation process, particular attention was paid to adoption barriers identified in prior research, including lack of perceived need and lack of awareness[17]. While the physical space addressed access and tooling gaps, the implementation strategy acknowledged that sustained utilization depends on curricular pathways, early exposure, and clear communication about the purpose and value of the makerspace. As such, the design intentionally preserved flexibility for future pedagogical integration and targeted interventions aimed at supporting broader and more equitable participation.

Collectively, these design and implementation choices reflect an approach that treats the ECE makerspace as an evolving system shaped by student behavior, institutional context, and educational goals. Rather than prescribing a fixed blueprint, the process emphasized adaptability, evidence-informed decision making, and alignment with the specific workflows and learning needs of Electrical and Computer Engineering students.

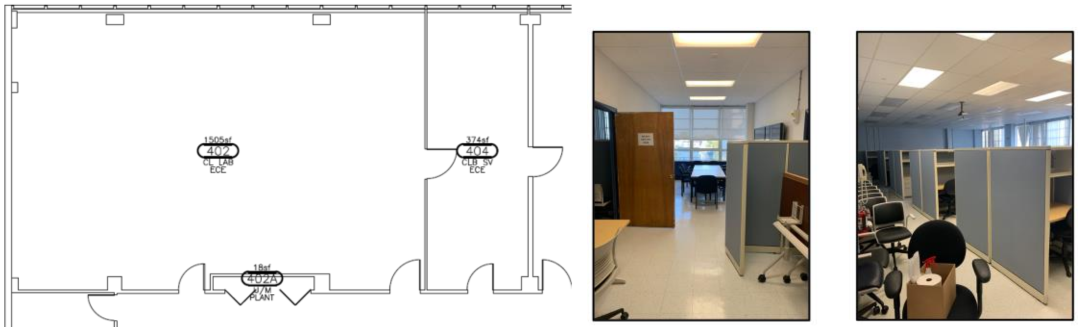

Figure 1– Blueprint Showing ECE Makerspace Rooms (402 and 404) which were underutilized rooms

Outcomes and Early Evidence of Impact

Because the ECE makerspace was recently implemented, evidence of impact is necessarily preliminary and consists of a combination of operational indicators and departmental observations. While this paper does not claim causal learning outcomes attributable to the makerspace alone, these early indicators provide insight into adoption patterns, space effectiveness, and alignment between design intent and student behavior.

The makerspace was launched using a “soft opening” approach, allowing initial design assumptions to be tested and refined based on observed use. During this period, sustained student activity was observed across multiple use cases, including capstone project development, coursework-related prototyping, and personal electronics projects. Informal collaboration among students was frequently evident, including peer-to-peer troubleshooting, shared use of instrumentation, and spontaneous mentoring interactions. These behaviors are consistent with prior literature characterizing makerspaces as environments that support collaboration, experimentation, and social learning [7], [8]. Importantly, these activities occurred outside scheduled laboratory hours, reinforcing the distinction between the makerspace and traditional instructional laboratories.

Operational demand provided an additional early signal of impact. The makerspace employs an electronic check-in system that logs each entry. Table 1 provides recorded data from across the semester window analyzed in the dissertation study,

Table 1: Makerspace Usage and Adoption Indicators (Semester Analyzed)

Indicator	Value	Notes
Makerspace check-ins (total)	5,990	Total check-ins recorded during the semester window analyzed
Unique individuals (total)	354	Distinct users captured by the check-in system
Association between self-reported weekly hours and check-in counts	$r = .659$, $p < .001$	Pearson correlation (semester-wide); alignment between self-report and log-based usage

Table 1 provides a basic utilization footprint. In addition, self-reported weekly makerspace hours and check-in counts were strongly aligned (semester-wide $r = .659$, $p < .001$), suggesting that student self-reports were directionally consistent with access logs. Demand also exceeded initial capacity assumptions during peak periods, and the department-initiated plans to expand the makerspace footprint (an adjacent-room expansion concept is described in the facilities plan) to accommodate additional students and activities.

Utilization levels during the soft opening exceeded initial capacity assumptions, prompting plans to expand the makerspace into adjacent space to accommodate additional users and activities. This decision was driven by observed crowding, competition for bench space, and increased demand during peak periods. Similar growth patterns have been reported in prior studies, which note that makerspace usage often increases as awareness spreads and peer norms around participation develop[13], [14]. While expansion alone does not constitute evidence of educational impact, it does indicate that the makerspace is addressing a previously unmet need within the department.

Student adoption patterns observed in the makerspace are consistent with findings reported in the broader makerspace literature. Informal feedback and observational data suggest that nonuse is more often associated with lack of perceived need, limited awareness, or competing time demands rather than lack of interest. These barriers align with those identified in prior studies examining why students do not engage with academic makerspaces [14], [17]. Such findings reinforce the importance of implementation strategies that clarify the purpose of the space, reduce intimidation, and create low-barrier entry points for novice users.

Usage trends also appeared to vary by academic stage, with more frequent and sustained use observed among upper-division students working on capstone or integrative projects. This pattern mirrors prior work showing that voluntary makerspace engagement tends to increase as students' progress through their programs and encounter more open-ended design challenges.

These observations highlight the role of curricular structure in shaping when and how students perceive value in makerspace participation.

With respect to learning-related behaviors, the makerspace environment supported activities commonly associated with self-directed learning, including independent problem solving, peer learning, iterative testing, and exploration beyond prescribed coursework. While these behaviors were not formally assessed using validated learning instruments within the scope of this paper, their presence aligns with prior studies linking makerspace participation to conditions supportive of self-directed learning and learner autonomy[10], [11]. In this context, the makerspace is best understood as providing enabling conditions rather than directly producing specific learning outcomes.

Taken together, these early outcomes suggest that the ECE makerspace is functioning as intended: providing a proximate, electronics-focused environment that supports collaboration, iterative prototyping, and informal learning outside scheduled laboratories. The combination of observed student behavior, demand-driven expansion, and alignment with known adoption patterns reinforces the central premise of this work and that effective makerspaces require intentional design and implementation strategies focused on access, culture, and curricular alignment. These early indicators also motivate ongoing assessment efforts aimed at more systematically characterizing usage patterns, project outcomes, and the impact of targeted interventions designed to broaden participation.

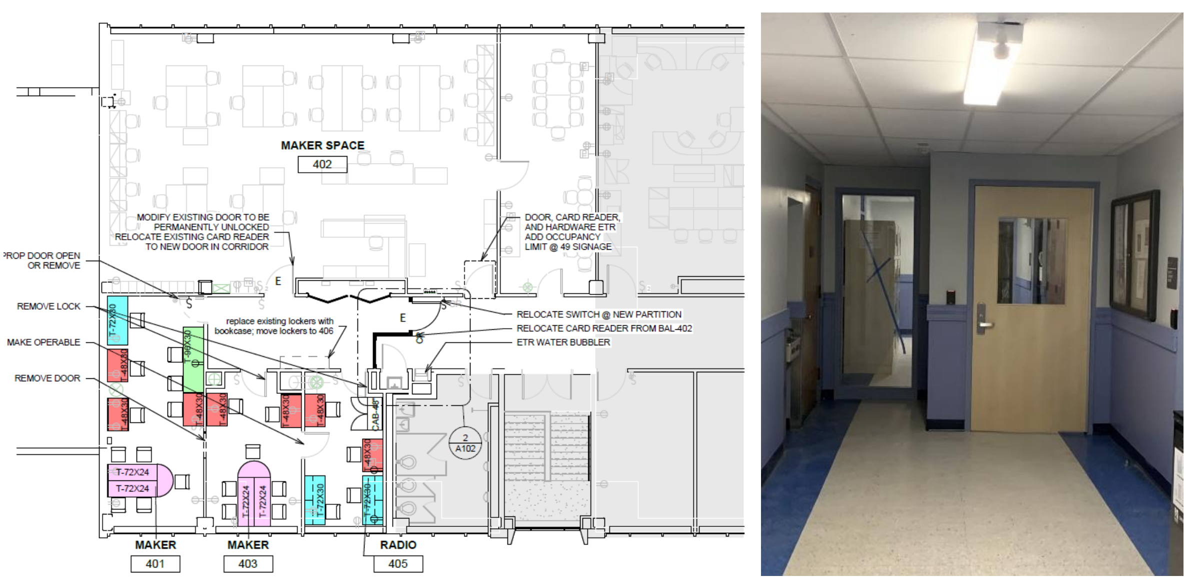

Figure 2 – Blueprint Showing ECE Makerspace Rooms (402 and 404), and the new additional rooms (401, 403, and 405).

Discussion: Lessons Learned and Design Implications

The design, implementation, and early use of the ECE makerspace yielded several lessons that extend beyond local context and inform broader efforts to develop effective discipline-specific makerspaces. Collectively, these lessons reinforce the idea that makerspaces succeed not simply by providing access to tools, but by intentionally addressing adoption, workflow alignment, and cultural factors that shape how students engage with informal learning environments.

A primary lesson is that proximity and disciplinary specificity matter for adoption. Locating the makerspace within the ECE department, near laboratories, offices, and electronics supplies, reduced friction for short, iterative work sessions and encouraged frequent, low-commitment use. This finding aligns with prior studies showing that distance from a student's academic home and misalignment between available tools and disciplinary workflows can significantly reduce makerspace utilization[16]. For ECE students, prototyping often involves incremental debugging, solder rework, and brief instrument access rather than prolonged fabrication sessions. Designing these patterns supported spontaneous use and helped distinguish the makerspace from scheduled laboratory environments.

A second lesson is that adoption barriers are primarily structural rather than motivational. Observed usage patterns and informal feedback suggest that students who did not engage with the makerspace were more often constrained by lack of perceived need, limited awareness, or time pressures than by lack of interest. This mirrors findings in the literature indicating that nonuse of makerspaces frequently reflects curricular and informational gaps rather than student disposition[14]. As a result, making space available, even one that is well equipped and centrally located, is insufficient to ensure broad participation. Design and implementation strategies must therefore extend beyond infrastructure to include intentional communication, onboarding, and curricular pathways that help students recognize when and why the makerspace is relevant to their learning.

The distinction between a makerspace and an "open lab" also emerged as critical. Traditional instructional laboratories, even when accessible outside scheduled class times, are optimized for controlled experiments, fixed workstations, and course-driven supervision. In contrast, the ECE makerspace supported mixed-use activity, informal collaboration, and iterative workflows that allowed students to define their own goals and timelines. This distinction reinforces prior arguments that makerspaces should be understood as socio-technical systems rather than simply shared facilities [9], [10]. Without explicit attention to norms, access models, and stewardship, open labs risk reproducing the same constraints that limit self-directed exploration within formal coursework.

Cultural design choices also played a significant role in shaping early outcomes. Visual cues, layout decisions, and access policies were intentionally selected to reduce intimidation and normalize experimentation and learning through failure. Prior research has emphasized that psychological safety and peer interaction are central to makerspace learning, particularly for students who may not initially view themselves as "makers" [7], [8]. Observed peer mentoring and collaborative problem solving suggest that these cultural elements contributed to an environment where students felt comfortable engaging beyond prescribed assignments.

Another important implication concerns scalability and growth planning. Initial capacity assumptions proved conservative as awareness and demand increased, prompting plans for expansion. This experience highlights the difficulty of accurately predicting makerspace utilization prior to launch and underscores the value of modular layouts and adaptable infrastructure. Prior studies similarly note that successful makerspaces often evolve over time as patterns of use emerge and community norms develop [14]. Designing with flexibility in mind enables programs to respond to growth without requiring wholesale redesign.

Finally, these lessons point to the importance of curricular alignment as a lever for equitable participation. While voluntary use increased among upper-division students working on capstone projects, earlier-stage students were less likely to perceive an immediate need for a makerspace. This pattern reinforces findings that makerspace engagement is strongly influenced by course structure and project requirements[13]. Introducing low-stakes, makerspace-connected activities early in the curriculum may help normalize use, reduce uncertainty, and support broader participation over time. Importantly, such integration should preserve the informal and exploratory character of the makerspace rather than converting it into another scheduled laboratory.

Taken together, these lessons suggest that effective ECE makerspaces require intentional alignment among space design, access policies, cultural norms, and curricular pathways. The outcomes observed here support a shift away from viewing makerspaces as optional add-ons and toward understanding them as integrated learning environments that must be designed, launched, and sustained with adoption in mind.

Recommendations for ECE Makerspace Implementation

Based on the design, implementation, and early outcomes of the ECE makerspace described in this paper, a series of recommendations is proposed to guide other Electrical and Computer Engineering programs seeking to develop or refine discipline-specific makerspaces. It is important to note that makerspaces are constantly moving and evolving by design and are shaped by physical infrastructure, institutional context, and student behavior. Thus, rather than prescribing a fixed blueprint, a sequence of considerations is recommended that can be adapted to local constraints, resources, and curricular structures.

First, it is recommended that programs should evaluate their existing facilities and explicitly define what students are unable to do within existing laboratories, open-labs, or portable-kit models, such as limited opportunities for iterative prototyping, informal collaboration, or independent exploration. Aligning the makerspace design with departmental goals such as capstone quality, student retention, community building, or ABET-relevant competencies helps establish shared purpose and administrative support. At this stage, potential adoption risks, including lack of awareness, lack of perceived need, and time constraints, should be acknowledged.

Next, it is recommended to design the makerspace as a complete, well-supported learning environment. Location should be selected which is convenient to students and faculty, with proximity to ECE laboratories, faculty offices, and electronics supplies if possible. Physical layout should be organized around electronics-centered workflows rather than instructional laboratory configurations. This would support rapid build–test–modify cycles, soldering and rework, collaboration, and small-parts access. Access and safety policies should be designed to align training requirements with equipment risk and stewardship mechanisms, such as consumables management, equipment tracking, and shared norms, are essential for sustainability and organization of the space.

Launching the makerspace with adoption in mind is as important as the physical build. Early communication should explicitly address what the space is for, who it is intended to serve, and how students can begin using it without fear of misuse or failure. Low-barrier onboarding experiences, particularly early in the curriculum, can help normalize makerspace use and reduce intimidation. On example is to create initial exposure by integrating at least one makerspace-connected experience in early coursework, without converting the space into another scheduled laboratory. It is also useful to display visible examples of student work, such as capstone demonstrations or personal project showcases.

Ongoing instrumentation and iterative improvement are also essential. It is recommended to collect lightweight utilization metrics, such as check-ins or observed peak usage periods. Periodic short surveys or informal feedback can also help identify emerging barriers, bottlenecks, or unmet needs. This data can be utilized to improve space layout, equipment availability, and update policies. Importantly, programs should plan for growth from the outset by adopting modular layouts, scalable infrastructure, and flexible storage solutions.

Limitations and Future Work

The findings presented in this paper are subject to several limitations that should be considered when interpreting early outcomes. First, the ECE makerspace described here is recently implemented, and the evidence of impact is based primarily on operational indicators and departmental observations rather than long-term, systematic assessment. As a result, conclusions regarding learning outcomes, persistence, or professional skill development cannot yet be drawn. The early-stage nature of the makerspace also means that usage patterns may continue to evolve as awareness increases and curricular connections mature.

Second, observed adoption patterns reflect the local institutional context, including program structure, student demographics, and departmental culture. While many of the design principles and implementation lessons are transferable, specific outcomes such as utilization levels or growth rates may differ at institutions with different constraints, resources, or curricular models.

Third, while behaviors associated with self-directed learning such as independent problem solving, peer mentoring, and iterative experimentation were observed, these behaviors were not formally measured using validated instruments within the scope of this work. As a result, the paper does not claim direct effects of the makerspace on self-directed learning or lifelong learning outcomes. Instead, the makerspace is positioned as an enabling environment whose educational impact depends on how it is integrated into broader curricular and institutional systems.

Future work will focus on more systematic assessment of makerspace use and impact. Planned efforts include the collection of lightweight utilization metrics over multiple semesters to characterize patterns of repeat use, peak demand, and activity types (e.g., coursework, capstone, personal projects). Short recurring surveys may be used to capture student perceptions of value, barriers to participation, and perceived learning gains. In addition, structured evaluations of project outcomes such as prototype iteration cycles, time-to-debug, or capstone integration may provide more direct insight into how makerspace access influences engineering practice.

Future research will also explore targeted interventions designed to reduce adoption barriers identified in this work. These may include early-program onboarding activities, low-stakes makerspace-connected assignments, or explicit messaging within core courses to clarify the purpose and relevance of the makerspace. Longitudinal studies examining how patterns of makerspace engagement evolve across students' academic trajectories would further illuminate the relationship between access, curriculum, and informal learning environments.

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