RESEARCH PRIORITY BRIEF—

IMPACTS OF MAKERSPACES ON STUDENT ENGAGEMENT

Introduction

A Hanover Research partner is currently working to maximize the use of a newly acquired educational makerspace facility and understand the impacts this facility may have on improving student outcomes. The facility is a state-of-the-art co-learning facility serving as a functional resource for hands-on learning and transition programming. The space offers high-end learning experiences with fully equipped science labs, industrial kitchens, performing arts studios, computer labs, textiles and sewing labs, and more. To support this initiative, the partner has partnered with Hanover Research (Hanover) to examine the impacts that this type of makerspace could have on improving student outcomes.

In this brief, Hanover reviews academic literature and practical resources on the impacts that makerspaces have on student outcomes, particularly for students in special education, transition programs, or career and technical education (CTE) programs. This report aims to provide partners with a foundation of knowledge to support in future project work with Hanover.

Key Findings

- **Makerspaces improve student learning by developing skills that contribute to their personal growth and engagement.** Makerspaces provide students a safe space to experiment, innovate, and acquire new skillsets through hands-on instruction. Through making and hands-on education, students acquire design thinking and 21st Century skills along with service learning experiences. Makerspaces provide new approaches to instruction in which teachers are not the sole conductors of knowledge that students receive passively. Instead, students are encouraged to be active participants in their learning through experimentation, creative thinking, problem-solving, and collaboration. While the skills acquired through hands-on education improve student engagement, they also support students' transitions into postsecondary life.
- **Makerspaces are particularly beneficial for special education students.** Makerspaces help students with special learning needs to learn at their own pace and develop practical and vocational skills, creative thinking, problem-solving, and collaboration. Makerspaces also provide an environment that allows students with special needs to express themselves without fear of failure, helping them to feel empowered and take control of their learning. Much of the literature on transitional programming addressing the impacts makerspaces have on promoting positive outcomes for special needs students. However, one empirical study reveals that makerspaces can help emancipated emerging adults to gain entrepreneurial skills and develop a sense of belonging in their communities.
- **The inclusion of makerspaces in CTE programs may support institutions in providing qualified candidates to fill local skill gaps.** Makerspaces offer unique opportunities to collaborate with local job-training programs to include makerspace practices in their curricula and build pipelines of skilled makers at all grade levels.
- **Schools should train teachers to connect classroom instruction with makerspace practices.** Teachers must understand how makerspaces work so they can play an active role in designing and implementing maker activities into day-to-day instruction. Teachers should consider the school context and students' needs to implement maker learning **practices** and continuously reinforce students' confidence to keep them engaged in makerspace learning.

Overview of Makerspaces

Makerspaces, a growing trend in education, offer hands-on learning opportunities for students to design or create projects using a variety of physical and digital tools. Although the term "makerspace" is relatively new, reflecting a recent educational trend, it aligns with well-established instructional principles. These principles include experiential education, which emphasizes "learning by doing," as well as allowing students to solve problems and take ownership of their learning.[1] Hackerspaces, which denotes an emphasis on creating and exploration, or fab labs are other terms one may use to refer to makerspaces.[2]

Makerspaces provide new approaches to instruction in which teachers are not the sole conductors of knowledge that students receive passively. Instead, students are encouraged to be active participants in their learning through experimentation, creative thinking, problem-solving, and collaboration. Thus, makerspaces provide new educational opportunities, especially for those students who thrive in nontraditional learning environments.[3]

Makerspaces equip students with skillsets through hands-on instruction. Most of the available literature comprises anecdotal studies rather than empirical studies measuring the impact of makerspaces on standardized test scores, and certain authors note the difficulties of these types of tests to accurately demonstrate the impacts of participation in a makerspace on student achievement.[4]

Makerspaces improve student learning by developing skills that contribute to their personal growth and engagement. Given the difficulty of identifying the effect of makerspaces on students' learning in standardized test scores, scholarly literature highlights the skill sets acquired by students to argue for the positive impact of makerspaces on student success. For instance, "it is the combination of the design thinking processes, service-learning experiences, and 21st-century skills being developed in makerspaces that are positively impacting student learning."[5] The table below summarizes each of these three indicators and provides examples of how makerspaces develop these skillsets.

Indicators of Student Learning in Makerspaces

Design Thinking	
Definition	A problem-solving framework that helps learners define problems, empathize with those facing or addressing those issues, develop prototypes of possible solutions, and hone those prototypes through multiple iterations until they have generated a viable solution to the challenge at hand.
Makerspace Implementation	In a makerspace, students carefully plan their designs and record their thinking before diving into the creation phase. After completing the initial design prototype, students reflect on their creation and make plans to iterate for improvement, and the design cycle begins again.
Service Learning	
Definition	An instructional approach in which students apply academic knowledge and skills to address genuine community needs.
Makerspace Implementation	In the Round Rock Independent School District in Austin, Texas, Grade 8 students identify a need in their community, develop a plan and solution to address that need, and then utilize the makerspace to implement their solution.
21st Century Skills	
Definition	The World Economic Forum's Future Jobs Report includes a list of the top 10 skills needed to thrive in the workforce by 2025, which include analytical thinking, active learning, creativity, leadership, resilience, and the ability to use technology.
Makerspace Implementation	Makerspaces help students develop most of these 10 skills, including problem-solving, critical thinking, creativity, innovation, active learning, and technology use.

Source: EdSurge and World Economic Forum[6]

Similarly, makerspaces engage students to learn by providing opportunities to have unique experiences and develop the following skills:

Student Engagement Through Skills Development

- Develop 21st-century employment skills through solving problems and thinking creatively.
- Learn through play at their own pace by developing self-confidence through designing and creating objects.
- Deepen what is learned in STEAM classes by making connections with real-life tasks and problems.
- Explore their interests and develop creative solutions to real-world problems.
- Develop intergenerational relationships and build communities.
- Develop collaboration skills and teach others what they learn.
- Develop fine motor skills through using manual tools.
- Learn by trial and error, take risks, and persevere.

Source: EdCan Network[7]

Schools adopting makerspace programs for science, technology, engineering, arts, and mathematics (STEAM) education use innovative technology tools to keep students engaged and motivated. For instance, the following figure shows examples of two innovative makerspace practices that provide students a familiar environment to learn.

Innovative Technology Inclusion Practices

Introduction of Robotics	Themed Labs
The use of kid-sized robots such as Sphero and littleBits offer K-12 classroom integration. For instance, younger students can use draw programming to direct their bots, while older kids can design mazes and other challenges.	Montour School District (PA)'s Brick Makerspace partnered with LEGO to use LEGO education activities to enhance children's spatial, fine motor, social, language, and creative skills.

Source: EdTech and Montour School District[8]

Impacts of Makerspaces on Elementary School Students

Makerspaces can be effective in developing cognitive and technological skills in elementary school students. A research study on makerspaces in primary school settings conducted by an Australian university revealed that makerspaces could effectively develop children's creativity, critical thinking, design thinking, and digital skills.[9] The study examined 500 students in Grades K-2 at three public schools who participated in maker activities using 3D design and printing technology.[10] The following table shows examples of the study's findings in terms of the skills that students learn when undertaking maker activities.

Skills Developed Through Maker Activities

Skill	Observed Example
Creativity	Plans, solutions, and artifacts students created clearly reflected original thinking. For instance, a teacher noted that students rapidly ideated 180 designs in a single lesson.
Problem Solving	A teacher noted that students "are quick to identify a problem and determined to find a solution."
Critical Thinking	In one of the lessons, critical thinking was evident when students were required to think carefully about decisions like how to best customize the design of their keyring to meet the needs and interests of the teacher they interviewed.
Inquiry	Teachers highlighted the increased capacity of students to conduct open-ended questions. A teacher noted that students become better at asking more specific questions.
Collaboration	Teachers commonly referenced how students engaged with and helped their peers during assignments. For example, student collaboration included "sharing resources, taking turns, and peer-reviewing work."
Autonomy	Teachers noted high levels of student autonomy and self-directed learning. Students also referenced how much they enjoyed having a degree of control over what they were doing and creating.
Literacy	Teachers highlighted how maker activities improved students' language skills through the acquisition of new vocabulary. They also noted strong gains for students who had historically been weak at reading and writing because they could engage in the language tasks in a highly applied way.
Numeracy	Teachers identified how numeracy and mathematical skills were intrinsically developed during the design activities. For instance, with relation to 2D and 3D shapes, students developed an applied understanding of size and proportion.
Scientific Understanding	Researchers observed in some classrooms how addressing scientific problems such as making a boat float, designing shadow puppets, and developing a habitat for hermit crabs could promote deep and rich scientific understanding.
Technical Capabilities	Researchers observed improvements in students' technical and technological capabilities when they demonstrated the capacity to create, position, resize, rotate, and join the 3D objects within the Makers Empire 3D app.
Real-World Connections	Researchers observed how maker activities helped students addressing authentic problems. Students discussed the connections that they had made between their designs and the real world.
Communication Skills	Teachers noted that students learned how to give and receive feedback and express their ideas clearly using correct terminology.
Reflective Thinking	A teacher noted that the students were very reflective about their learning designs and were able to identify what worked, what did not, and what they would have to do to make it work.
Resilience	Teachers noted increasing students' perseverance and resilience. For instance, students were not intimidated when finding issues in their designs or when dealing with technical issues with the 3D printer.

Source: Macquarie University[11]

However, educators should provide ongoing emotional support to keep students motivated and confident in their abilities. A study of the impact of makerspaces on 100 elementary school students' learning experiences notes that, although hands-on learning can trigger student interest in STEM activities, the iterative aspect of these activities can lead to a decline in students' motivation. At the start of the semester, the study found that students show high levels of interest and self-efficacy, which refers to students' beliefs about their ability to complete a design project that effectively solves an identified problem. However, at the mid-point of the semester, many students reevaluated what they could feasibly do for their projects given time and ability constraints, and generally showed a decreased sense of self-efficacy and interest. Therefore, educators must encourage students' self-confidence and provide continued support to convince students of their abilities.[12]

Impacts of Makerspaces on Middle and High School Students

In the following section, Hanover examines the impacts of makerspaces on special education students, students in transition programs, and students in CTE programs in the secondary grades.

Special Education Students

Makerspaces are particularly beneficial for students with special learning needs. Makerspaces provide an environment that allows students with special needs to express themselves without fear of failure, helping them to feel empowered and take control of their learning.[13]

Empirical evidence suggests that makerspaces help special education students develop problem-solving, creative thinking, communication, and vocational skills. The Watson Institute, which operates several special education schools and programs in Pennsylvania, includes makerspace education in its curriculum and notes the following skills developed by the students through this program:

Skills Developed at Makerspaces

Practical and vocational skills	Problem-solving	Creative thinking	Working with peers cooperatively

Source: Watson Institute[14]

Likewise, school administrators and empirical studies highlight the importance of makerspaces to bring STEM and STEAM education to students with intellectual, emotional, and physical challenges. The following table displays anecdotal experiences of two schools in Pennsylvania that use makerspaces to teach STEM courses to special education students. The table also summarizes the findings of an empirical study of makerspace experiences for STEM classes in four different middle schools across the county and their implications for students with disabilities. These case studies align with the Watson Institute's perceived benefits of makerspaces on special education student success.

Case Studies and Perceived Benefits

Case Study	Perceived Benefits
Mon Valley School, PA	• **Practical and vocational skills:** STEAM education through makerspace can provide skills that lead to jobs in post-secondary education programs. For instance, the use of computers can help students fill in online job applications. • **Problem-solving:** Makerspaces allow special education students to master complex academic concepts, improving their confidence, teaching them how to regroup after failure, and improving communication skills.[15]
Cross-Case Study at Four Middle Schools	• **Student engagement**: Teachers reported that the maker activities' hands-on nature facilitated student engagement, as they relied less on students using reading or math skills compared to traditional instruction. • **Student collaboration**: Teachers noted student collaboration across different activities. A teacher mentioned that students were encouraged to reach out to their peers before asking questions to the teacher during a class activity, thus helping them realize that they can help each other with troubleshooting processes.[16]
Colonial High School, PA	• **Practical and vocational skills**: The IU1 FabLab at CHS provides opportunities for students with learning disabilities and behavioral issues to get STEM-related career and technical training, which helps them to rethink future education choices. For instance, a student noted a desire to pursue more education or training in the areas of carpentry, laser cutting, and 3-D design or printing after participating in the Lab. • **Mental and emotional health**: School administrators note the role of the Lab as an educational resource and a calming environment that helps students focus while providing an emotional outlet. For instance, a student who had been suspended multiple times before participating in the program stopped showing behavioral problems as he focused his energy on his work at the Lab.[17]

Source: Various sources quoted in the table.

Transition Program Students

Publicly-available information about the use of makerspaces in transition programs and their impact on students is limited. Most of the available secondary literature touches on how makerspaces can help special education students transition to post-school life through vocational skills, as developed in the previous section.

Makerspaces can provide technical skills and community engagement opportunities to emancipated emerging adults (EEAs), or young adults who have aged out of the foster care system. An empirical study of the participation of emerging adults in a community makerspace notes that makerspaces serve as safe places to learn, explore identities, build relationships, and become entrepreneurs, as described in the following figure.[18]

Makerspaces Benefits for EEAs

Community engagement

EEAs create connections with makerspace staff and the local community. For instance, makerspace staff actively encouraged EEAs to participate in activities related to their interests.

Skills and knowledge development

Makerspace participants can explore different activities to develop various skills and competencies (i.e., arts and crafts, t-shirt design, painting) and have access to new tools (i.e., digital tools).

Community-member identity

Engagement with the maker community of practice and learning the skills and knowledge of makers support the development of a maker identity.

Entrepreneurship

Some EEAs expressed interest in commercializing the products they produced in the makerspace. For instance, one participant planned to sell self-designed silk-screening t-shirts.

Source: *Journal of Health Psychology*[19]

Career and Technical Education Programs

Makerspaces in Career and Technical Education (CTE) programs can help close local middle-skill gaps. The California Community College (CCC) Maker Initiative offers an example of makerspaces CTE programs. According to CCC, the Maker Initiative aims to close California's middle-skill gap that has resulted from the inability of California's education pipeline to keeping pace with the skills and education required by employers. Therefore, CCC's initiative seeks to prepare students in STEM and STEAM careers that demand 21st Century skills through a network of makerspaces.[20]

According to a CCC report, the CCC makerspace network comprises facilities at 24 locations across the state, serving 64,310 students.[21] The report, which contains a series of case studies, highlights the following impacts of makerspace in CTE education.

Makerspaces Benefits for CTE Programs

Benefit	Case Study
Community Engagement	The **Central Coast Makerspace** is operated through a partnership with the community college, a public library, and a children's museum, providing an opportunity for cross-generational collaboration within the community. Although the makerspace is set up primarily to appeal to children, it also to offer opportunities for families to make together.
Equity	The **makerspace at Cabrillo College** cultivates a culture of diversity. The makerspace is a safe place for students to "experiment, play, fail, collaborate, and grow." The diverse staff strive to offer inclusivity and support student agency, and encourage students to serve as mentors for their peers.
Innovation	**Orange Coast College Makerspace** celebrates all forms of making and innovation. For instance, the makerspace team added video, audio, and DJ equipment and a surfboard-shaping machine to contribute to local market needs.
Work-Based Learning	**The College of Canyons Makerspace** provides work-based learning through industry internship opportunities. For instance, students participate in the NASA High-Altitude Student Platform program and the City of Santa Clara's Green Streets project.
Entrepreneurship	In **Butte College Makerspace,** several students have used the makerspace to create merchandise, such as custom T-shirts, shoes, and 3D-printed phone cases, which they then market and sell on online platforms like Etsy, as well as in local stores and the campus bookstore.
Access	**Moorpark College's Makerspace** ensures that students from all disciplines can access it. The makerspace is in the Campus Center, and the makerspace staff hosts ongoing workshops and outreach events to invite people to use the makerspace.
Curriculum	**Sierra College Makerspace** offers professional development workshops for faculty to teach them how to incorporate hands-on projects in their curriculum.

Source: California Community College[22]

Makerspaces in CTE programs can also support sector-based training. For instance, OpenWorks, a makerspace in Baltimore, serves a growing base of local advanced manufacturers and smaller craft-based maker businesses that need skilled woodworkers, seamstresses and tailors, and metal artisans. The program collaborates with local job-training programs to include makerspace practices in their curricula, and aims to build a pipeline of skilled makers who begin in elementary school and engage through high school and college.[23]

Best Practices for Makerspace Implementation

Incorporating makerspaces into the curriculum requires educators' active participation in the design and implementation process. The National Science Teachers Association proposes a three-pronged approach to integrate makerspaces into day-to-day instruction. As described in the following figure, teachers play an active role throughout this model's three stages.

Makerspace Implementation: Three-Pronged Approach

Aligning Goals with Mission

- Aligning the goals of the makerspace with the school's overall mission helps teachers better understand how implementing activities could benefit their students.
- Teachers must identify skills that align with the school's mission and draft learning objectives related to each of these skills.

Designing and Implementing Activities

Teachers can implement maker-based activities through the maker sprint model, which include the following three steps:

1. Exploration, teachers build excitement around a topic and activate students' prior knowledge.
2. Skill-build, teachers instruct students on developing proficiency with a particular tool or material and how to make connections to learning content objectives.
3. Challenge, teachers pose and open-ended problem in which students can use their new knowledge.

Teacher Awareness of the Importance of Makerspaces

Teachers should participate in professional development programs to better understand how they can connect classroom instruction with makerspace activities.

Source: National Science Teachers Association[24]

Educators must consider the context of their students when aligning makerspaces with school curricula. The three considerations included in the following figure can help teachers build and sustain makerspaces that effectively empower students to take ownership of their own learning.[25]

Implementation Considerations

Consider the School Context

When integrating making into schools, it is essential to begin with the context by asking, "What might making mean and look like here, in this school, with these resources, for these students?"

Consider Student Comfort Levels

Educators should consider that some students, especially those accustomed to concrete instructions, might feel disoriented with maker activities.

Educators should find ways to ease students into becoming confident makers.

Consider Alternative Assessment Tools

Open-ended projects do not lend themselves to standardized evaluations. Therefore, educators should create alternate assessments that give teachers clearer pictures of student learning.

Source: Phi Delta Kappan[26]

Makerspace Implementation in Special Education

Educators must incorporate specific instructional strategies to serve special education students in makerspaces. Besides the physical characteristics that makerspaces must have to support special education students, teachers should include the following safety and instructional strategies.

Special Education Instructional Strategies in Makerspaces

Strategy	Description
Supervision	Teachers should consider that students with disabilities require some form of supervision and assistance regardless of age.
Modifications	The instructor should determine, along with the student's IEP case manager, what equipment is safer to use based on the student's abilities and behavioral trends.
Shaped and Color-Coded Signs	Developing color-coded signs with unique shapes can help students quickly recognize hazards.
Tactile Prototyping Tools	Providing tactile prototyping tools, such as clay, allows students with visual impairments or who lack fine motor skills to share their design ideas.
Scaffold Instruction	Students with attention deficits will benefit from scaffolded instruction (i.e., e-text or QR codes linked to safety protocols).
Universal Design for Learning (UDL)	UDL harnesses the power of technology-enhanced, high-leverage practices to enhance instruction for all students. An example is allowing students to choose which learning pathway they will take to demonstrate mastery of an objective.

Source: International Technology and Engineering Educators Association.[27]

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