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Board 171: Project-Based Learning Using NASA Design Concepts for 3D Printing Makerspace Development to Support Pre-college STEM Education

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Project Based Learning Using NASA Design Concepts for 3D Printing Makerspace Development to Support Pre-College STEM Education

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Abstract

One of the most important aspects of STEM education is the engineering design process. When it comes to the design process, however, STEM education from kindergarten through 12th grade frequently overlooks the significance of modeling. The quick reproduction capability of 3D printers can be used to support modeling during the engineering design phase. This research will investigate the usefulness of incorporating 3D printing technology into STEM project-based learning activities in terms of improving STEM learners grasp of the engineering design process, particularly modeling. Six categories are defined and presented because of research into the application of 3D printing in classrooms settings: a) teaching STEM learners about 3D printing;
b) teaching practitioners about 3D printing; c) as a support tool during teaching; d) producing artifacts that aid learning; and e) supporting outreach efforts. Evidence of 3D printing-based teaching techniques can be discovered in each of these six areas, and recommendations for further research and policy are given.
Keywords: Project based learning, Design Concepts, 3D Printing Makerspace Development, Support Pre-College STEM Education, Engineering, Engineering Technology

Introduction

STEM education has been challenged with identifying the next generation of learners to advance technology and development. In this study, we have identified key performance measures to align pre-college STEM education with industry for innovation. The objective is to prepare learners for STEM careers and to connect industry through academia. In higher education, the critical learning skills are necessary to STEM education and degree completion. There are retention efforts provided for the curricular support program that scholars have contribute to motivation and outcomes of STEM interdisciplinary degree completion. Our efforts to support pre-college STEM education includes an understanding of college readiness and the learning environment using project-based learning (PBL). Hands-on experiences are general found to be successful when integrated using PBL methods with industry. According to recent study, both intrapersonal and interpersonal skills in PBL has been vital with a connection to industry careers [1]. The partnership with industry to achieve a learning engagement community through personal learning experiences to enhance skills and reveal critical factors of our learners. These factors include barriers for recruitment and retention into STEM fields because the lack of experiential learning and cohort building. The pre-college STEM education encourages learners to engage with professionals that addresses imposter phenomenon and other barriers in the learning community. To encourage learners, the National Aeronautics and Space Administration (NASA) design concepts for 3D printing makerspace development can offer innovative learning pedagogies, practical design solutions, and support to pre-college STEM students.

Overview

Underrepresented groups in STEM gives a benefit to pre-college STEM education initiatives using PBL as a tool for at learning and scientific innovation. Mentorship provides opportunity for accessibility, increase self-efficacy and STEM degree completion of learners. In STEM professions, the mentorship practices allow for a transformative STEM interdisciplinary mindset for industry careers. For students in the STEM fields, mentoring is essential for matriculation, retention, and graduation. Mentoring in STEM promotes the formation of a STEM identity and offers knowledge of industry trends, technical expertise, and professional networking. Mentoring provides STEM students with setting goals and expectations, building effective communication, and strengthen collaboration efforts.

PBL is extremely beneficial in developing problem solving skills for the future workforce in STEM professions. Problem solving is crucial because the development of problem-solving skills encompasses different teaching strategies to equip students for solving problems and present theoretical ideas to take on more concrete meanings. PBL with hands-on and active participation facilitates problem-solving process. Students study a problem from then curriculum using PBL, which has a positive impact on student attainment of professional skills. The goal of PBL strategies is which instruction encourages STEM students to collaborate to understand concepts. 3D printing affords STEM learners with a practical and experience-based curriculum that benefits the learner and industry.

A viable method for integrating PBL in STEM education is the use of 3D printing in the subject areas of STEM. The significance of 3D printing integrated in PBL and STEM education is a powerful educational tool. 3D printing promotes integrative stem education by connecting engineering, technology, and applications of science concepts. 3D printing can be used in STEM education to engage STEM learners in a wide range of activities. 3D printing can engage STEM learners in PBL learning activities into a design-led process that integrates PBL into STEM education. 3D printing allows STEM educators to develop learning experiences for theoretical constructs that brings valuable lessons about design, theory, and problem-solving techniques are applicable to every profession. The use of 3D printers has the potential to foster collaboration, communication, problem-solving, and the generation of new ideas, especially in the face of complexity.

STEM Learners and 3D Printing

Technology is now frequently used in educational settings. Because technology-based learning environments actively engage students in the learning process and give them the chance to develop thinking, interpretation, and self-expression skills, it has been a crucial topic of discussion to create technology-based processes in teaching design and assist students in developing technology skills [2]. By 2028, it is anticipated that the number of 3D printers shipped worldwide would have increased to 15.3 million [3]. Using 3D printing in educational programs is incredibly advantageous for the learning process. STEM learners obtain tactile feedback of learning concepts that are difficult to represent using only normal learning materials. Many institutions of higher learning are already using 3D printing as a realistic means of preparing STEM learners for their future vocations and teaching them essential skills. It serves as a tool to aid in many areas of education and provides teachers with new ways of engaging the STEM learner. Working on 3D printing projects allows students to hone a variety of abilities, including creativity, technology literacy, problem-solving, self-directed learning, critical thinking, and perseverance. 3D printing will prepare the STEM learner for industry that places a demand on critical thinking and the ability to collaborate with others. There are similarities between the talents that teachers identify and 21st-century skills that are frequently highlighted, which suggests that 3D projects are a viable strategy for preparing students for life and work in the digital age [4].

STEM Practitioners

The versatility of 3D printers makes them ideal for a wide range of applications and activities at the forefront of a wide variety of educational endeavors. Learning subjects like science, technology, engineering, and mathematics can be facilitated significantly using 3D printing in the classroom. Integrating 3D printing in PBL are utilized in enhancing analytical thinking, increase comprehension and collaboration [4]. STEM students can physically study objects, view models of complicated ideas or concepts, or learn a lesson in a new way when a classroom is equipped with this technology. This not only helps students retain what they have learned but also gets their brains thinking in new ways, which in turn increases their interest with the material [2] [1].

The incorporation of 3D printing into the curriculum is an excellent approach to bring cutting-edge technology into the curriculum at a time when many educational institutions are reorienting their curricula to place a greater emphasis on *hard skills* and *trade skills* [3]. This is especially helpful for STEM practitioners that offer lessons in design, architecture, engineering, or manufacturing may employ 3D printing in their classrooms to illustrate prototyping and development workflows. This is especially valuable for practitioners that offer classes in design. STEM students are better prepared to enter the workforce when their curricula integrate 3D printers. Integrating 3D printing allows them to move beyond theoretical concepts and into actual applications.

Engineering Design Process

Although engineering's contributions have been thoroughly documented, there is room for improvement in one area: the inclusion of engineering design in STEM curricula, particularly at the pre-college level [5]. It has been observed, for instance, that participation in such activities can help STEM students cultivate an appreciation and understanding of the various roles that engineering plays in shaping societies, as well as the ways in which it can contextualize the fundamentals of mathematics and science to improve students' achievement, motivation, and ability to solve problems [6].

The engineering design process (EDP) is comprised of a set of processes that are carried out by engineers to arrive at a conclusion or an answer to a question [7]. The steps include methods for problem-solving such as, for example, defining the objectives and constraints, prototyping, testing, and assessment. EDP includes developing a solution to a problem.

Although the design process is adaptive, it nevertheless adheres to a set of predetermined phases, and the STEM learner may have to do some of these steps more than once before moving on to the next one. This design process will vary based on the project, but it will allow for improvements to be implemented and lessons to be learned from previous failures. Before integrating STEM education through EDP can become more prevalent, many factors need to be studied. Especially important are the factors that affect student engagement, which is thought to be closely related to putting the student at the center of the learning process [5]. Student-centered learning has become one of the long-term goals of education reform in the United States.

STEM Education and Innovation

STEM students are given the ability to take meaningful, in-depth looks at problems and build real-world applications for potential answers when STEM education is used as a major component of the innovation equation. STEM innovation is becoming increasingly important as the needs of the world change and as we are faced with new challenges in a post-pandemic world. This is because we need to find economical and sustainable solutions for the problems we face, whether it be improving digital literacy or eliminating world hunger and achieving better food security. Incorporating 3D printing into curriculum is giving STEM students the opportunity to discover how well the technology works in the industry and are providing them an advantage if they choose to pursue a professional career in the STEM field. STEM education and innovation need to collaborate to turn it into a reality.

It is more vital than ever before for the youth of our country to be prepared with the knowledge and skills necessary to solve issues, make sense of information, and know how to acquire and analyze evidence to make decisions, because we live in a world that is always evolving and becoming more complex. These are the kinds of abilities that STEM learners cultivate while studying STEM subjects, including computer science. These subjects are referred to as a collective. Building students' skills, content knowledge, and literacy in STEM fields is essential if we want to create a nation in which our future leaders, neighbors, and workers can understand and solve some of the complex challenges of today and tomorrow. In addition, doing so will allow us to meet the demands of a workforce that is both dynamic and evolving. In addition to this, we have a responsibility to make certain that children, irrespective of the community in which they are raised, have access to appropriate educational opportunities.

Method

For the 3D print models, the authors have worked with groups of students for informal and pilot testing of the models. These include different designing from prosthetics, robotics, wind tunnel, and art. Formal testing of the three 3D printed models was completed with one group of students totaling 14 participants, ages 18-21, at the University of Maryland Eastern Shore. To assess the PBL environment and the learners’ success in using the NASA design concepts for 3D printing, the makerspace development regarding the support of pre-college STEM students included the following categories:

- Learners Ability to Apply NASA Design Concepts for 3D Printing Makerspace Development
- Project Based Learning and the Application to Support Pre-College STEM Education
- Learners Confidence to Engage in the Engineering Design Process
- College Learners Willingness to Support Pre-College STEM Learners
- Learners Confidence about Project Based Learning using NASA Technology

These five (5) categories included a pre and post assessment metric for evaluation to determine the findings according to the proposed method. From our study, the engineering education was vital to the design approach created by the students to correlate PBL to advance industry research in a classroom environment.

Results

The results had offered a linkage to the use of PBL and industry design concepts for 3D printing in regard to the makerspace development to support pre-college STEM education. The engineering learners in the classroom environment had created stations to test the design concepts of the 3D printed components (shown illustration of the created makerspace environment below).

Figure 1. 3D Printing Makerspace Environment to Support Pre-College STEM Education (MakerBot Printers)

One of the distinctive features of all the 3D designs is the way diverse learning arrangements often evolved to support the projects and goals of the students. For example, the AeroPods in which it was invented at NASA Goddard Space Flight Center’s Wallops Flight Facility, can be outfitted with various sensors for aerial imaging and are aerodynamically stabilized, designed to hang from kite string as a simple, low-cost alternative to drone imaging (see figure below).

Figure 2. AeroPod invented by NASA Goddard Space Flight Center's Wallops Flight Facility

The AeroPod was introduced by the AEROKATS and ROVER Education Network (AREN) (2023) to promote NASA technologies and practices in authentic, experiential learning environments. Many people think of NASA as only a space program and are surprised to find out that NASA has done much research on aeronautics (the science of flight), through the use of kites. The 3D print trail run offers (see figure below):

- Testing print quality of 3D printers (MakerBot replicator, +, and mini +)
- Identifying printing errors and estimated print times (7hr)
- Average 2~4 set per day

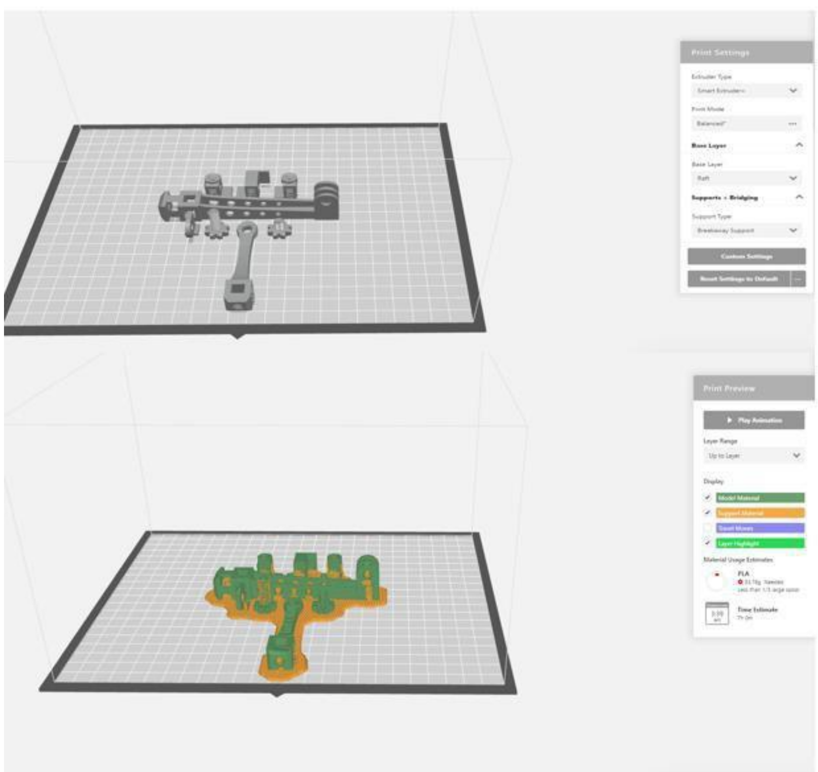

Figure 3. 3D Print Trail Run to Support the NASA Design Concepts

From the print times, the results of the average print times per MakerBot printers yielded outcomes set (2-4 sets – optimal) per the max print time (seven hours). The chart below illustrates the learners results in the classroom environment.

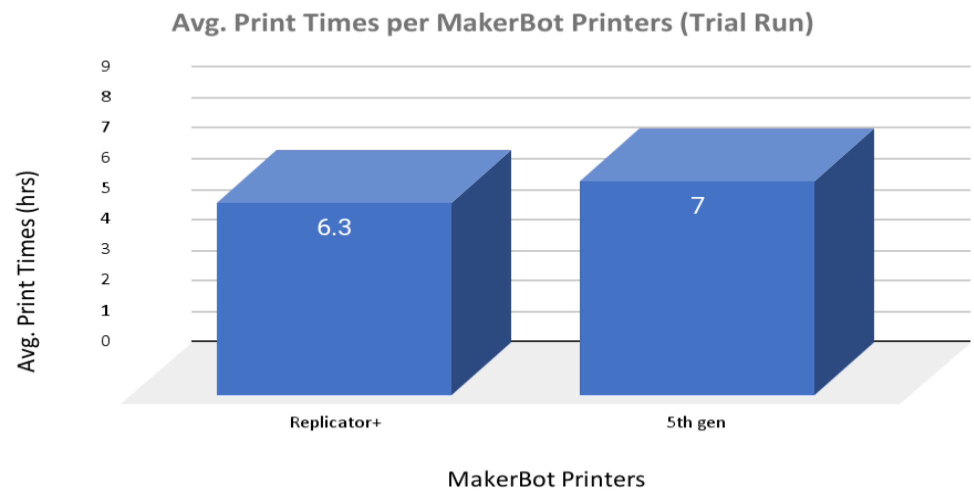

Figure 4. Average Print Times per MakerBot Printers (Trail Run)

Hence, the improvements in production has identified from the practice of printing multiple copies of parts (split production between printers) as a result (five sets were completed per day) (see the evidence below).

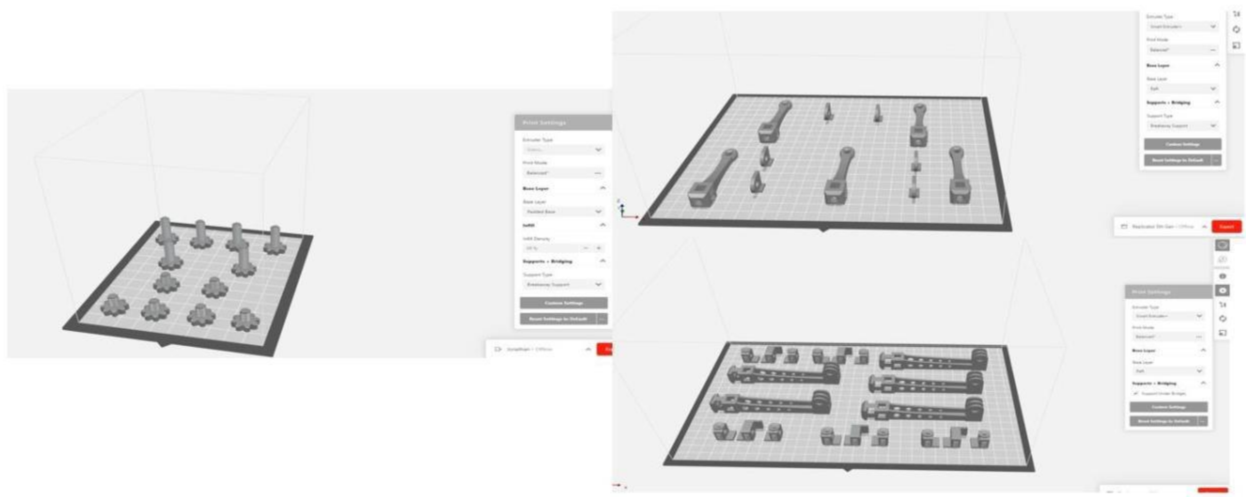

Figure 5. Improvement in Production from the Initial Trail Run of the NASA Design Concepts

Henceforth, the print times had resulted to five (5) sets with a max print time (22.2 hours) as shown in the figure below.

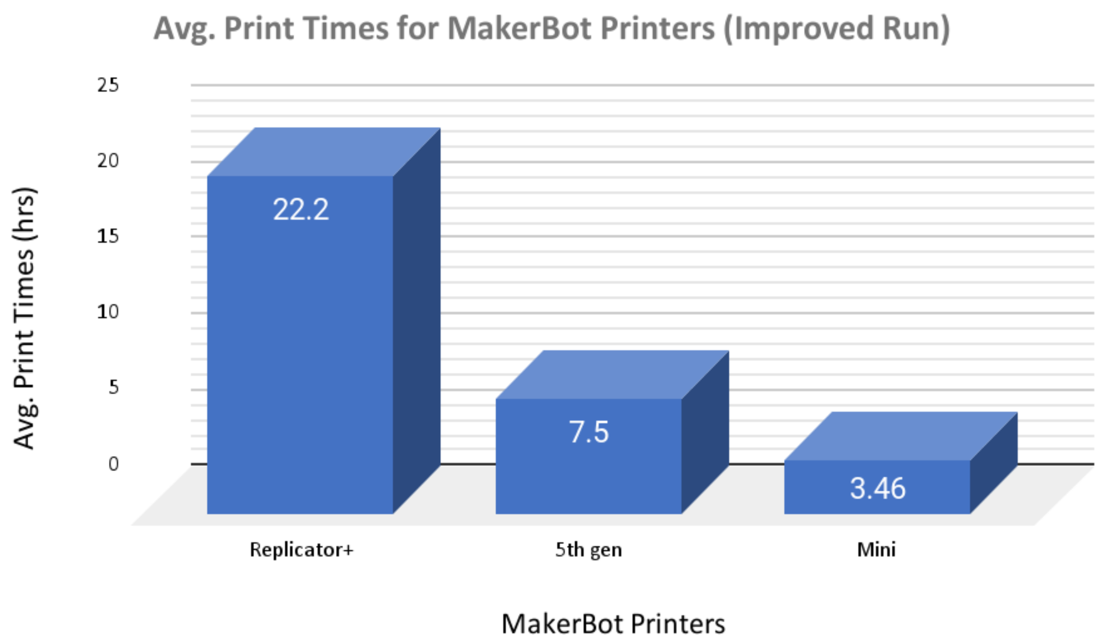

Figure 6. Average Print Times for MakerBot Printers (Improved Run)

Findings and Outcomes

According to the proposed findings, the assessment of the PBL environments and learners' success to integrate NASA design concepts to support the pre-college STEM students create five outcome measures. These findings mapped to the outcomes were previously identified as: a) Learners Ability to Apply NASA Design Concepts for 3D Printing Makerspace Development; b) Project Based Learning and the Application to Support Pre-College STEM Education; c) Learners Confidence to Engage in the Engineering Design Process; d) College Learners Willingness to Support Pre-College STEM Learners; and e) Learners Confidence about Project Based Learning using NASA Technology (shown in the figure below).

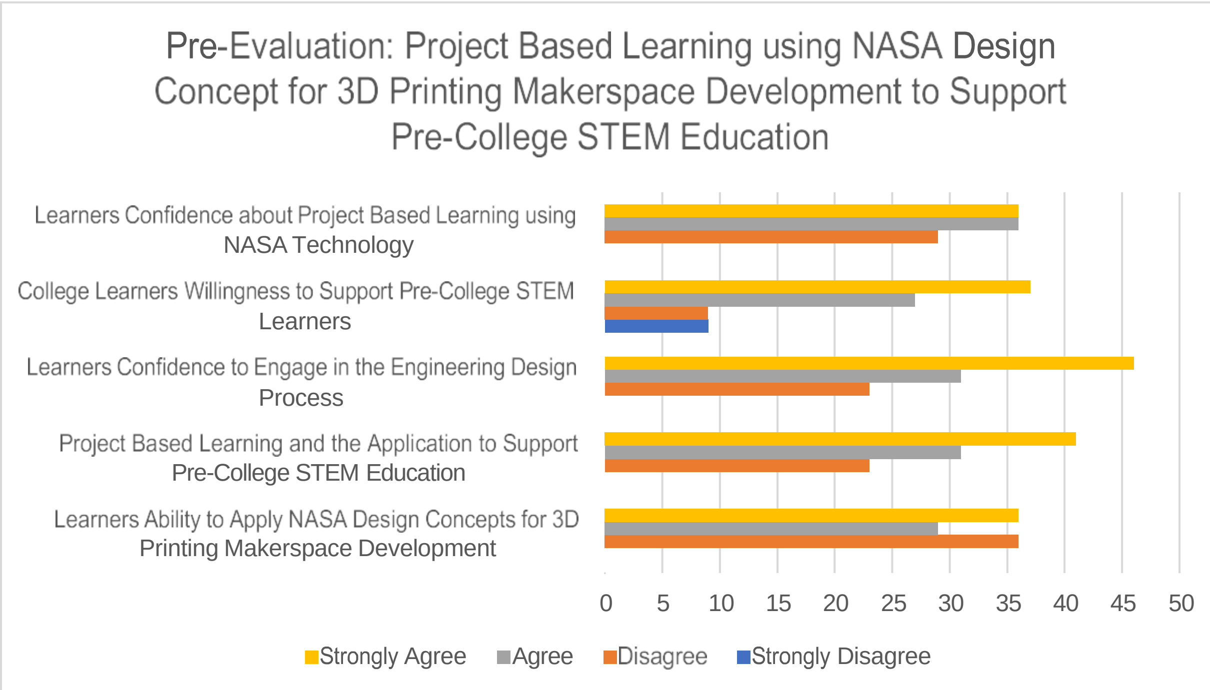

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Figure 7. Pre-Evaluation: Project Based Learning using NASA Design Concept for 3D Printing Makerspace Development to Support Pre-College STEM Education

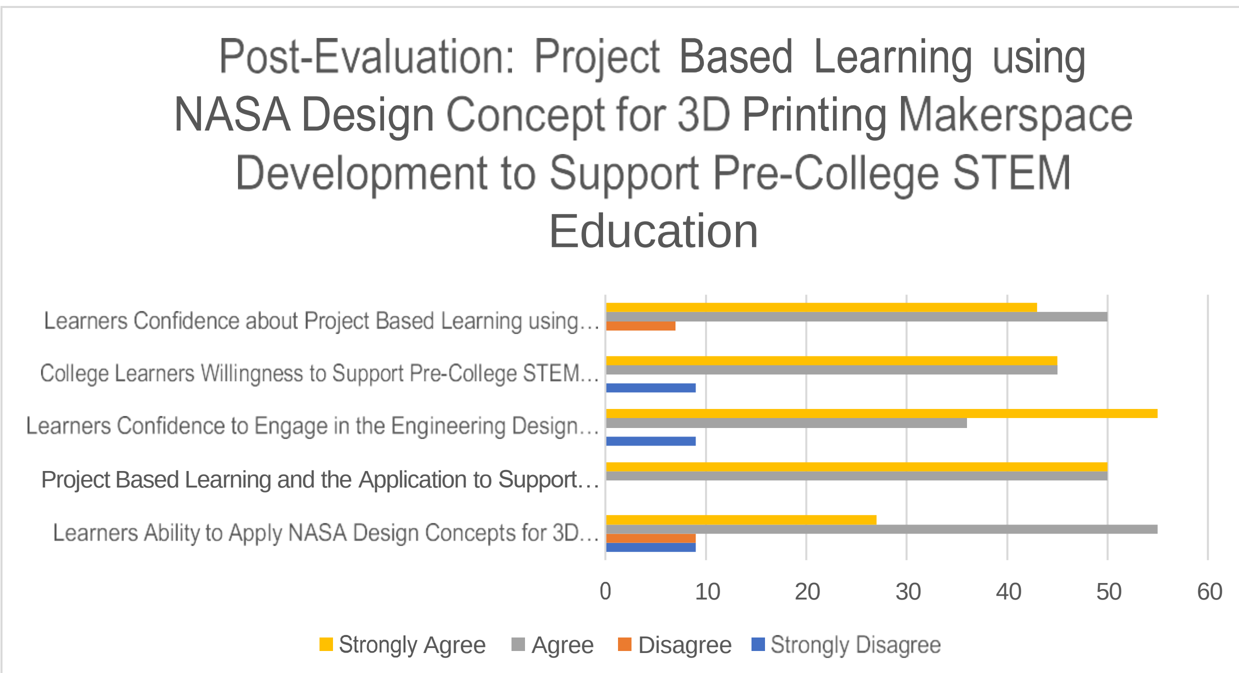


Figure 8. Post-Evaluation: Project Based Learning using NASA Design Concept for 3D Printing Makerspace Development to Support Pre-College STEM Education

The findings included learners' assessment of the PBL using NASA design concept for 3D printing makerspace development to support pre-college STEM education. Both the pre-measures and post-measures had identified a learning community in the classroom environment of engineering and engineering technology students for assessment purposes. The pre-evaluation had identified 11 learners and their involvement in the PBL environments. In comparison, the post-evaluation had identified 14 learners in relationship to the pre-evaluation outcomes.

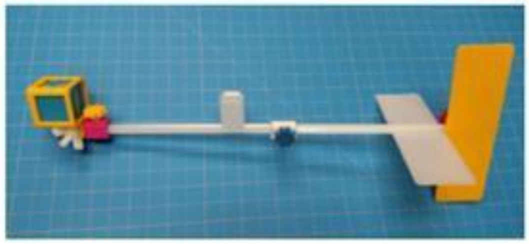
Conclusion and Future Implications

In conclusion, the utilization of 3D printing in the teaching of STEM subjects has recently received a lot of traction, and as technology develops and progresses, the scope of possible applications for it continues to broaden and become more complex. The use of 3D printers may be found in a wide number of professions, including engineering, chemistry, mathematics, biology, and architecture, to name just a few; nevertheless, the real benefits lie in the development of one's imagination and creativity. STEM education can benefit from the explosion of creative potential that is directly caused by the usage of instructional technology. This explosion of creative potential is advantageous to STEM education.

The AeroPod is a passive device that uses aerodynamic forces to stabilize an instrument package suspended from a kite or tethered blimp. It is a low-altitude custom remote sensing platform craft designed for, but not limited to, agricultural and environmental research purposes. AeroPods can be used for a variety of remote sensing and in-situ observations (seen below in NASA's promotional materials).

Figure 9. NASA Design Concepts as a Technology Solution for Innovation

Future implications offer the ability to identify commercial Production of NASA technology with PBL in STEM education. For example, the opportunity to create a formal license method to obtain from NASA to support pre-college STEM education, marketing to advance technology.



Minipod- 100% 3D printed aeropod with a small camera attachment. Good introductory device because of the low cost camera and accompanying kite.

Figure 10. Commercial Production of NASA technology with Project Based Learning in STEM Education

STEM education is the driving force behind accelerated growth, delivering on the future of design potential, and transforming the world into a more conducive learning environment. With the advent of 3D printing, virtually everything a student might imagine can now be brought to life. Using 3D printing, the imaginative process, the creative process, and the function of discovery all become more fruitful.

Currently, 3D printing is used in a variety of fields and professions all around the world. It is not restricted in any way by either culture or language. Education makes use of this sort of technology to bring out the latent abilities of students; if a student has an idea, that idea can be brought to life in the form of a 3D model by the student. The high-tech digital world can now be held in one's hands, giving students of today the opportunity to enhance it for the benefit of future generations.

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