Effective Makerspaces in STEAM Secondary Education:

What Do the Professionals Think?

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Abstract

Makerspaces have the potential to improve the learning outcomes of students in both middle and high schools. They support science, technology, engineering, arts, and mathematics (STEAM) style initiatives, as well as promote natural creativity among students who tend to struggle in expressing it. This study aims to gain significant insight from professionals who are involved in the Makerspaces movement within STEAM secondary education. The findings of the study highlight the critical strategies, effects, and issues behind the implementation of Makerspaces in support of STEAM education at secondary schools. These findings suggest that, for instance, Makerspaces provide students who struggle with school with a means to demonstrate their true knowledge in a way that appeals to them. In addition, in order to utilize Makerspaces properly and effectively, secondary school teachers need professional development experiences that are specific to their needs.

Keywords: Makerspaces, STEAM, secondary education

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The purpose of this study is to investigate professionals' viewpoints on Makerspaces in science, technology, engineering, arts, and mathematics (STEAM) secondary education. These professionals are experts from higher education and enterprise or educators from secondary education who took initiative for Makerspaces implementation in secondary school districts within the States of Pennsylvania and West Virginia in the United States. They have had a significant exposure to Makerspaces particularly in STEAM programs.

The incorporation of Makerspaces into secondary schools has allowed these schools to better integrate STEAM activities into their class lessons. Sousa and Plecki (2013) note that secondary schools in the United States face the challenge of departmentalized schedules. Along with that, the schedules are usually inflexible with unexpected programs that arise and interrupt the entire plan for a school day. This makes it especially challenging for secondary students to work on a STEAM project that typically takes more than one week to complete. Sousa and Plecki recommend STEAM fellow teacher collaboration as a powerful solution to this challenge. For instance, a science teacher and an art teacher can combine two periods together into one extended block class, and a Makerspace can allow an adequate place to support student STEAM projects. This way, the idea of STEAM education is encouraged, and more authentic learning can take place. In addition, Makerspaces allow teachers of one subject to more easily integrate ideas of another, which is the true significance behind the concept of STEAM. Smay and Walker (2015) give an example of the arts being incorporated into science due to the inclusion of a Makerspace. In their example, a science teacher had the secondary students select a scientific theory in the area of physics and then conceptualize it as an artistic, physical model using the school's Makerspace as a resource. Secondary students can *tinker* with real science tools and

processes in their school's Makerspace to make real-world connections with the content being studied.

The power of STEAM education combining Makerspaces can be the key ingredient that can make secondary school a successful experience for students (Sousa and Plecki, 2013). A Makerspace approach of STEAM education offers secondary students an opportunity to gain knowledge through a student-centered environment of doing and creating, as well as to develop their collaboration skills cross-disciplinarily (Maslyk, 2016). For example, in one of the studies Bevan, Gutwill, Petrich, and Wilkinson conducted in 2015, one female secondary student was tinkering with recycled objects to make a created contraption float in a wind tunnel and was struggling in her design. Another female secondary student reached out to her and analyzed her contraption. They discovered together that it was too heavy to float and collaboratively made an adjustment before another test was conducted.

Additionally, Quinn and Bell (2013) share an example of *bio-hacking* where secondary students worked to create synthetic molecules and systems that were unconventional as compared to those that existed naturally. Quinn and Bell claim that the secondary students in their study were not only working in the realm of the biological science field, but also using engineering skills to model and design these creations. Bevan et al. (2015) point out that Makerspace activities help promote a broader understanding of content. In one of their studies, the secondary students tinkered with devices connected to a circuit board. One male secondary student demonstrated parallel circuits in a hands-on fashion with one female secondary student. The female secondary student then vocalized his process while he was doing it to help her gain a further understanding of what was happening. Both secondary students were collaborating and gaining understanding of circuits, but in two unique ways.

The integration of Makerspaces and STEAM education is crucial for middle and high school aged students because it provides students with ideal learning approaches and necessary skills they need in order to succeed in their adult lives. Quinn and Bell (2013) discuss that the processes of making at Makerspaces not only support STEAM education, but also facilitate the learning of other academic subjects. They explain that formal and informal education go hand-in-hand in the areas of STEAM, that informal learning experiences tend to create an interest in disciplinary subjects, and that developing oneself in STEAM areas is a lifelong process that expands beyond the formal classroom setting. Quinn and Bell also convey that there are significant relationships between content standards in math, science, and language arts. They argue that because schools are shifting towards the approach of integrating subjects, schools must progress forward and engage in a *minds-on* and *hands-on* approach to learning. The processes of making at Makerspaces better mirror the processes of real STEAM. Quinn and Bell go further by explaining that the design–make–play approach in STEAM classrooms incorporating Makerspaces can not only provide more valid learning experiences, but also give more context to the relevancy of the lesson, so that secondary students will apply it later in life.

Furthermore, Sousa and Plecki (2013) explore that secondary schools without the incorporation of Makerspaces and STEAM education are not adequately providing students with the necessary skills they need in order to succeed in their adult lives. The extreme focus on standardized testing in the United States eliminates opportunities for innovative and creative instruction within secondary schools. Consequently, as students graduate from middle or high schools, they are not succeeding as much post-graduation when compared to students in other countries. Sousa and Plecki believe that these students need to develop grit by engaging in creative problem solving embedded in the integration of STEAM education and Makerspaces.

They comment that when secondary students are exposed to the creative process, they recognize the importance of persistence—the need to keep on working until the task is done. Once students have passion, they have grit to solve problems.

The Study

This study investigated the first-hand experience of professionals who have implemented ideas from the movement of Makerspaces when teaching STEAM to secondary students. A semi-structured, in-depth interview was conducted to gather and evaluate the opinions of three experts in the field of Makerspaces, as well as three STEAM teachers and one principal in secondary education. The interviewees were selected based on their prior knowledge and extensive backgrounds in education, STEAM, Makerspaces, and technology integration. The interviewees were divided up into two separate groups and were given a particular set of interview questions by their groups. The first group consisted of one specialist from Carnegie Mellon University's Community Robotics, Education and Technology Empowerment Lab (CREATE Lab), one specialist from Pittsburgh Public Studio, LLC, and one specialist from West Liberty University's Center for Arts and Education. These individuals were considered the experts in the incorporation of STEAM and Makerspaces in both higher and secondary education and were given the first set of interview questions (see Appendix A). The interview questions mainly evaluated interviewees' immense knowledge and helped gain insight into the effective strategies for STEAM and Makerspace integration in secondary education.

The second group included one science teacher at Wheeling Middle School, one technology specialist for Ohio County Schools, one art teacher at Wheeling Middle School, and one principal at Warwood Middle School. These professionals all have had experiences in bringing Makerspaces to their current and former secondary schools. They were presented with

the second set of interview questions (see Appendix B). The interview questions ascertained interviewees' experiences and the goals and plans of implementing Makerspaces in their STEAM classrooms.

The interview questions were designed to address the research questions as follows:

- What role do Makerspaces play in a secondary school?
- What spaces can be used in schools to become Makerspaces, and how will they be supportive?
- What resources, besides financial, should be included in a Makerspace?
- What kinds of technology should be brought into a secondary education Makerspace?
- How can STEAM education be incorporated into the Makerspace?

This study utilized the quantitative primary, qualitative first approach into collecting data (Creswell, 2009; Morgan, 1997). A semi-structured, in-depth interview was conducted which yielded a qualitative type of data. Part of the interview questions determined specific numbers in how secondary students improved or did not improve their academic performance and participation in STEAM after they experienced making at Makerspaces. For instance, the interviewees had the opportunity to give examples of student STEAM test scores and enrollment records in STEAM workshops and classes.

The interview data were then compared to one another by the implementation of the casual-comparative type of research. Joyner, Rouse, and Glatthorn (2012) describe casual-comparative research as a way to define the causation of a certain phenomenon after looking at the data collected about something else related. This study evaluated what the interviewees have experienced with secondary students in the integration of STEAM and Makerspaces. It also examined the quantitative data that interviewees have collected about the academic performance

and participation among secondary students. The data collected through the interviews were categorized into the two different groups: 1) experts who work outside of a secondary school, and 2) teachers and administrators who work in secondary schools. Tables were used to document the commonalities among the data within each group. The topics of focus included STEAM education, the feasibility of incorporating Makerspaces in a school, technology integration opportunities, and the positive effects Makerspaces have had on secondary education students. Another table was utilized to determine the commonalities between the two separate groups. The conclusive analysis and discussion highlighted the data that most adequately answered the research questions.

Findings

The interview data were analyzed and presented into three tables. The first two tables were the results of the interviews within each of the two groups. The responses of the three experts who work outside of a secondary school were compared in the first table (see Table 1). The outcomes of the three teachers and one administrator who work in secondary schools were compared in the second table (see Table 2). The third table was used to compare the findings of all seven interviewees together (see Table 3).

Table 1
Key Data from Group 1: Experts

Research Questions	Public Studio, LLC	Carnegie Mellon University's CREATE Lab	West Liberty University's Center for Arts and Education
What role do Makerspaces play in a secondary school?	▪ Give students opportunities to learn about the design process ▪ Engage students who are disengaged by traditional teaching styles	▪ Bring STEAM together and encourage making ▪ Have a purpose – to help solve a problem	▪ Enhance student's enthusiasm in learning by doing ▪ Engage students who are disengaged by traditional teaching styles
What spaces can be used in schools to become Makerspaces, and how will they be supportive?	▪ Incorporate design among all content areas ▪ Rotate between classes to give opportunities for deep meaningful projects	▪ Embed STEAM in every classroom	▪ Rearrange any creative and flexible learning space
What resources, besides financial, should be included in a Makerspace?	▪ Allow for self-directed learning opportunities ▪ Allow students to analyze the design of what they are making, and not just the product	▪ Use low-cost or inexpensive technology to support STEAM education	▪ Integrate STEAM and Makerspaces across all class times (not just one period) ▪ Embed STEAM and Makerspaces before/after school activities – provide more opportunities ▪ Do not limit to one time
What kinds of technology should be brought into a secondary education Makerspace?	▪ Circuits – littleBits, Squishy Circuits ▪ Game Design – Gamestar Mechanic, Scratch ▪ Digital Content – Gigapan, Videolicious, Animated Gifs, Augmented Reality Image Triggers	▪ Arts and Bots ▪ Simple robotics kits that combine making with recycled materials	▪ Makey Makey and Hummingbirds ▪ iPads with apps that can do video and audio ▪ Technology that does not have to be learned in a structure way, or only for specific projects
How can STEAM education be incorporated into the Makerspace?	▪ Create context for students using engaging tools, techniques, and on-trend influences (e.g., digital media and visual communication, physical pixels and tangible technology)	▪ Encourage learning from failure	▪ Provide open-ended making activities ▪ Engage students in new ways of thinking and learning

Table 2

Key Data from Group 2: Secondary Teachers and Administrator

Research Questions	7th & 8th Science Teacher	6th-8th Art Teacher	Technology Specialist	Principal
What role do Makerspaces play in a secondary school?	▪ Offer one of the most relevant places for learning ▪ Allow for cross-curricular environment ▪ Allow for collaboration which is key for 21st century learning	▪ Give ways to self-directed learning ▪ Encourage students to be inclined tc study STEAM	▪ Enable students to problem solve through thinking about a problem, sketching out a solution, and then using the items available to come up with a workable solution	▪ Enable students become leaders
What spaces can be used in schools to become Makerspaces, and how will they be supportive?	▪ Transfer a space that allows for readily available resources ▪ Concern teachers who are less familiar with Makerspaces	▪ Incorporate a flexible space that gives students a lasting positive impression	▪ Enrich a space which is able to stretch students' ideas and imaginations to solve the questions posed to them ▪ Support students who have special learning needs to be paired up with others to help them also find success	▪ Allow students space to be creative and learn through doing
What resources, besides financial, should be included in a Makerspace?	▪ Engage both high- and low-level students with materials which can be used in a hands-on fashion ▪ Give diverse opportunities for students	▪ Bring teachers in to learn more about the dynamics of a Makerspace	▪ House tools and items to allow students to create an open-ended product that fulfills a task	▪ Include moveable materials if there is no one particular space ▪ Get teachers comfortable with repurposed materials and technology
What kinds of technology should be brought into a secondary education Makerspace?	▪ Updated technology allowing students to build their own computers	▪ Technology with younger teacher support	▪ 3D printers ▪ Little Bits ▪ Robotics	▪ Technology that can easily be maintained
How can STEAM education be incorporated into the Makerspace?	▪ Enhance students' enthusiasm with STEAM activities and encourage students to exceed expectations	▪ Enable students to utilize all senses in learning ▪ Help students discover new concepts by creating	▪ Create STEAM projects purposely for problem solving cross different curricular areas	▪ Encourage Makerspaces and help teachers integrate them in STEAM curricular because Makerspaces are solid student engagement

Table 3

Key Data from Two Groups

Research Question	Experts	Teachers & Administrator
What role do Makerspaces play in a secondary school?	▪ Give students an outlet to create, and really focus on the process of making ▪ Allow for deep meaningful cross-curricular connections	▪ Get students thinking outside the box ▪ Help students solve problems and think critically in an independent way
What spaces can be used in schools to become Makerspaces, and how will they be supportive?	▪ Not be defined as one space ▪ Include flexible and mobile resources for cross-curricular instruction	▪ Open to any teacher who wants to use it with proper professional development training to help teachers understand what it is ▪ Create a place for enrichment and intervention practices for students
What resources, besides financial, should be included in a Makerspace?	▪ Include all the resources possible, but expensive items are not always the best items (not needed) ▪ Focus on the process over the product ▪ Include resources to allow for before and after school access	▪ Include repurposed materials and technology equipment ▪ Have flexible and movable carts to make materials mobile ▪ Use items in a hands-on fashion and give students freedom and open concepts
What kinds of technology should be brought into a secondary education Makerspace?	▪ Purchase specific technology tools that are designed with students making activities in mind (e.g., Makey Makey, Hummingbird, Arts and Bots, LittleBits)	▪ Purchase up-to-date technology that can easily be maintained ▪ Focus more on incorporating regular technology tools into making, but also have interests in high-tech equipment, like a 3D printer
How can STEAM education be incorporated into the Makerspace?	▪ Give ways to authentic learning, especially when activities are very open ended ▪ Appeal to a wide range of students, especially those who may not have found success in a more traditional classroom	▪ Engage students with STEAM activities very well and give educators a great opportunity to integrate various subject matters into one activity ▪ Surprise students in their making abilities and give ways to students taking control of their own learning

Discussion and Conclusions

Both groups of interviewees, the experts in STEAM and educators in secondary schools, were extremely positive in discussing their experiences with Makerspace activities in STEAM

among secondary education students. The expert from the Center for Arts and Education at West Liberty University stated that she noticed middle school and high school aged students tend to react with a great deal of enthusiasm, especially those who disengage in more traditional classroom settings. The expert from the Pittsburgh Public Studio, LLC agreed with her statement as well. The art teacher claimed that by introducing concepts of Makerspaces in STEAM and encouraging students to exercise their critical thinking skills early on in their schooling will incline them to create and troubleshoot at an even deeper level as they progress through school. In addition, the science teacher stated that the materials in a Makerspace can not only give students diverse opportunities to discover academic contents, but also allow them to work collaboratively and creatively to solve problems in real life. The technology specialist also discussed the potential for students to use their imagination to come up with a creative solution to a problem through Makerspaces.

The key that Graves (2014) emphasizes in developing successful STEAM activities at Makerspaces for secondary students is to allow them to be in charge of the topics and procedures relevant to problem solving. The expert at Carnegie Mellon University's CREATE Lab noted in particular, the value of solving problems by learning through failure. He found in his experiences working in a photography studio with high school students that trying an idea and failing gives students the opportunity to re-evaluate and try new ideas until the result they want is yielded. All the interviewees agreed that making in Makerspaces gives ways for students who may struggle with school a means to demonstrate their true knowledge in a way that more appeals to them.

The interviewees commented some potential drawbacks in the integration of STEAM and Makerspaces, though they came up with methods to address them. For example, the principal

noticed some of the secondary students who excelled in school were uncomfortable about not having any directions, while others became leaders and thoroughly shined at Makerspaces.

The science teacher observed that some teachers in the secondary schools do not know how to utilize Makerspaces to support learning. The art teacher agreed and gave the solution of conducting teacher professional development with specific guidelines demonstrating how to effectively integrate Makerspaces into STEAM learning activities.

There is also the issue of purchasing and maintaining technology equipment. The expert at Carnegie Mellon University's CREATE Lab stated Makerspaces could be powerful even though there are not many expensive technology tools in there. Even if Makerspaces just include basic crafting supplies and recycled materials, they still could eventually lead to further growth. A common thread that should run through all Makerspaces, no matter the level of technology, is a focus on the process of making as opposed to the process of consuming (Colegrove, 2013).

This study includes limitations that should be addressed in future research. The study would be more comprehensive if more professionals working with Makerspaces and STEAM in secondary schools were also interviewed. The research would be further validated if a study among secondary students had taken place to evaluate their reactions regarding STEAM making activities at Makerspaces. After looking at the results from this investigation, a one-year study after a school implemented a Makerspace would be a meaningful analysis to further validate this study. The study could first ascertain secondary students' opinions on STEAM subjects. The survey would evaluate their prior experiences with STEAM and gain a basic understanding to what caused those opinions. Baseline data could be established from students prior to the Makerspace being implemented. Then after a year of having a Makerspace in the school, the students could be surveyed again to reevaluate their beliefs about STEAM subjects.

Since there would be hard evidence to answer the research questions, the results of the study would be difficult to contest. It might also be beneficial to implement two similar studies between two separate secondary schools where one implemented a simple crafting Makerspace, and another that implemented a very high tech one. This could be done to assess if spending a large amount of money on high tech equipment at a Makerspace is significantly more valuable to secondary students in STEAM learning, or if a simply done Makerspace would yield similar results. Even though the results from this study was significant in answering the initial set of research questions, these future research suggestions could even further support the data. The best part about this topic is that it can be constantly researched in variety of ways well into the future of education.

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Appendix A: Interview Questions for Experts in STEAM

1. What is the title of your official occupation, and how many years have you been at this position?
2. How does your job relate to the concept of STEAM education?
3. What is your experience with Makerspaces, especially those located within schools?
4. How have you worked with educators, specifically middle school and high school teachers implementing Makerspace STEAM activities?
5. Do you have first-hand experience working with middle school or high school aged students in the STEAM fields? If so, please describe some specific activities.
6. How do students typically react to Makerspace making activities in your experiences? Are there any types of students that they appeal to more, or are there students who disengage?
7. Is there anything you have been working on that you would like to see incorporated more in a regular STEAM classroom? If so, please describe it.
8. In your honest opinion, do you think Makerspaces have a relevant place in the middle school or high school classroom? Please rationalize your answer.
9. What sorts of Makerspace technology tools do you have experience with implementing in the STEAM classroom? Please describe them if possible.
10. Is there anything you want to specifically add that is relevant to the topic?

Appendix B: Interview Questions for Secondary Education Teachers and Administrator

1. What is your occupation? What grades/subjects do you teach (if relevant)?
2. What do you know about Makerspaces? What do you want to know?
3. What do you know about STEAM education? Have you implemented any STEAM activities before in your classrooms?
4. Based off your experiences, how do your students generally respond to Makerspace making activities? Do you find benefits in implementing these or not?
5. Which kinds of students do you think will benefit the most from Makerspaces in schools? Are there any you think will not benefit?
6. What is your biggest concern about bringing a Makerspace into your school specifically?
7. Ideally, what resources would you like your school's Makerspace to have?
8. Are you comfortable learning how to use new technology with students? What issues could arise, and how could you resolve them?
9. In your honest opinion, do you think Makerspaces have a relevant place in the middle school or high school classroom? Please rationalize your answer.
10. Is there anything you want to specifically add that is relevant to the topic?