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The effects of a makerspace curriculum on the 4C's in education

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Abstract

Makerspaces are becoming more common in schools K-12 as well as at the university level and encourage educators to think differently about learning. This review examines how a makerspace curriculum impacts the way in which learners apply the 4 C's (creativity, critical thinking, collaboration, and communication). Thirteen peer-reviewed research studies published between 2014 and 2018 were selected for analysis. The reviewed research studies indicated that students who participate in makerspaces tend to use their creativity to problem-solve, are communicative and collaborative with other makers, and tend to use critical thinking skills when presented with an obstacle. Recommendations for implementation of and access to makerspaces K-12 and beyond are discussed including additional professional development for teachers. Future research to delve deeper into the post-education research of makerspaces improving the 4C's skills of adults in the workforce is also suggested.

The Effects of a Makerspace Curriculum on the 4C's in Education

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THE EFFECTS OF A MAKERSPACE CURRICULUM

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Abstract

Makerspaces are becoming more common in schools K-12 as well as at the university level and encourage educators to think differently about learning. This review examines how a makerspace curriculum impacts the way in which learners apply the 4 C's (creativity, critical thinking, collaboration, and communication). Thirteen peer-reviewed research studies published between 2014 and 2018 were selected for analysis. The reviewed research studies indicated that students who participate in makerspaces tend to use their creativity to problem-solve, are communicative and collaborative with other makers, and tend to use critical thinking skills when presented with an obstacle. Recommendations for implementation of and access to makerspaces K-12 and beyond are discussed including additional professional development for teachers. Future research to delve deeper into the post-education research of makerspaces improving the 4C's skills of adults in the workforce is also suggested.

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Introduction

There's an age-old saying that "one man's trash is another man's treasure." Walking into a makerspace may look like trash with containers of buttons and beads; boxes of tin foil and duct tape; and a table covered in 3D filament and wires. But in actuality, all of these materials can be building blocks to foster creativity, critical thinking, collaboration, and communication.

The purpose of this literature review is to examine how a makerspace curriculum impacts how learners apply the 4 C's (creativity, critical thinking, collaboration, and communication). This problem is important because schools without makerspaces number fewer than schools that have them (Nagel, 2018). In fact, "user-reported numbers show nearly 1,400 active spaces, 14 times as many as in 2006" (Lou, 2016, p.88). It would be helpful to have data demonstrating how these facilities impact students. The topic is also important because there is an increased emphasis on 21st-century skills such as creativity, collaboration, communication, and critical thinking (Bowler, 2014). Teachers are preparing students for jobs that do not yet exist. Certain skills, however, like those of the 4C's are essential in any future profession. The scope of this review includes students in all levels of education, including K-12 and collegiate level.

Due to the popularity of makerspaces, it is necessary to measure how makerspaces affect students' creativity, critical thinking, communication, and collaboration. This review can be applied by librarians, teachers, and other educators to demonstrate how the creativity, critical thinking, collaboration, and communication of learners with access to a makerspace at their school are impacted. It could lead principals and other educators to the reasoning for or against the implementation of a makerspace because of the increased importance of learners having 21st-century skills such as the 4C's.

Some terms that the reader should understand include:

Makerspace- "A physical place in the library where informal, collaborative learning can happen through hands-on creation" (Bowler, 2014, p.59).

4C's- Critical thinking, communication, collaboration, and creativity (NEA, 2012)

Critical thinking- "The ability to "use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation" (NEA, 2012, p.8). "Reflect critically on learning experiences and process" (IMLS, 2009, p.23).

When studying the research into makerspaces and the 4C's, the following themes emerged:

- The effect of makerspaces on developing critical thinking skills in learners.
- The effect of makerspaces fostering creative skills in problem-solving in learners.
- The effect of makerspaces impacting learner collaboration.
- The effect of makerspaces affecting communication skills in learners.

Methodology

Several methods were used to identify and locate sources for this review. First, I used Google Scholar and used the boolean search terms *makerspace,* *curriculum* and *makerspaces, collaboration, and research.* I started with Google Scholar to see what initial information I could locate and possibly find beneficial search terms. I then searched Education Fulltext (EBSCO) where the search terms used were *makerspaces, collaboration, makerspaces, and communication*. I have researched this database in the past and have found many helpful articles. It allowed me to narrow the results more than with Google Scholar. It also has a specific focus on education, narrowing results specifically to that field. One of the most beneficial resources was the Rod Library OneSearch search engine and entered the following terms using a boolean format:

- *makerspace*
- *collaboration and creativity*
- *communication and critical thinking.*

These terms were used with “and” commands in the search to find articles with these specific topics. This source was helpful because it allowed me to search multiple databases without the overwhelming results of Google. It also gave me multiple databases for each article in which I was able to access the full-text copy. Reference lists of valuable sources were examined to find more relevant articles. In fact, seven additional studies were added and contributed to the research presented in this literature review. Lastly, I worked with the librarian at my local AEA to find books relevant to makerspaces in education. This resulted in finding five texts relevant to my research.

My first rationale for selecting the sources to analyze was to limit my search to peer-reviewed journals. This ensures the article has been evaluated for credibility and quality by experts in that field. The next selection was for K-12 schools, which was my initial focus. Lastly, I selected sources based on their content including the 4C's. As long as the article or text included at least one of the 4C's (communication, critical thinking, collaboration, and creativity) I included it in my list.

When looking at my initial source list, I selected articles and texts that contained my keywords in the title and/or in the description. Once I had read the articles selected, I filtered them down to resources that included specific areas where the makerspaces impacted creativity, collaboration, communication, and critical thinking. Locating research specific to makerspaces at the elementary, middle, and high school levels was problematic. Therefore I changed my initial scope from K-12 to include academic libraries because several resources provided actual studies at the collegiate level. Finally, I filtered out results that only contained basic information about creating makerspaces because this information is not pertinent to the specific topic.

My criteria for identifying the articles to use centered around the reliability of the source. I first considered the year of publication to ensure relevance to my field of study. I didn't want information more than ten years old because of updated information regarding the 4C's and makerspaces. I originally limited the range to five years, but several older articles had important information. My second criterion was validity and credibility. Was the article written and reviewed by experts in the field? Finally, I analyzed the data in the sources found. Was the quantitative data reliable in terms of sample size? Did qualitative data address any possible biases?

Overall, I studied the research articles to determine whether proper procedures were followed in collecting data and data analysis.

Analysis and Discussion

There are now more schools with makerspaces than there are without (Nagel, 2018) and reportedly an increase in 14 times as many from 2006 to 2016. (Lou, 2016). School administrators, teachers, parents, and even community members believe that students who use makerspaces to create and implement project-based learning (PBL) are better prepared for college and for the workforce (Nagel, 2018). The focus of education has indeed “shifted towards helping students gain twenty-first-century skills that lead to success in higher education and the workplace” (Vongkulluksn, Matewos, Sinatra, & Marsh, 2018, p.1). But does student participation in makerspaces impact how learners use the 4C’s? How are students using critical thinking, creativity, and problem-solving in a makerspace? How are students collaborating and communicating with others in a makerspace? This research reviews to what degree a makerspace curriculum impacts how learners apply the 4 C’s (creativity, critical thinking, collaboration, and communication).

Several themes were found in the literature, mainly focusing on the 4C’s. The first theme examined the relationship between makerspaces and critical thinking in learners. Another explored how makerspaces are fostering creative skills in problem-solving in learners. Another common finding was about the impact of makerspaces on learner collaboration. Lastly, a common thread involved investigating how makerspaces are affecting communication skills in learners.

For the purposes of this review, the themes are organized according to the findings of the research and will explore how makerspaces tend to foster the 4C's in learners.

The 4C's and Design Thinking in Makerspaces

In a makerspace, students are able to use a multitude of items to create something new requiring creativity, critical thinking, and problem-solving. Many times this requires students to work collaboratively and have the ability to communicate with others while working together. "Students naturally pick these skills [collaboration and contribution] up in a makerspace environment. They need to work together to be successful" (Noonoo, 2017, p.1).

Graves (2014) explains, "In our world, students need creative-thinking and problem-solving skills so they can be prepared to enter the job market after college. We want our students to develop problem-solving skills and become engaged with making technology, not just using it" (p.8). Many participants use a design thinking mindset to guide their making. Design thinking or the design process, is a five-step model that includes: Ask, Imagine, Plan, Create, and Improve ("The Engineering Design Process", n.d.). The design process and makerspaces seem to naturally incorporate critical thinking skills. According to Mansback (2015), one of the highest levels of critical thinking is creating where students demonstrate skills that require them to plan, design, construct, and produce.

Bowler (2014) described observations from their study of students using makerspaces. Their premise was that these flexible environments can require students to use their creativity and innovation while completing a design challenge.

They had students create a robot using the Hummingbird controller and programming language that would be able to interpret a children's story. Many of the students felt as though the design process was done once they had created their plan. Students were surprised when their robots did not work the way they wanted after the first design. They found that their initial programming did not necessarily give them the expected results. This required students to continually redesign their robots and modify the coding program in order to achieve their goal. Students learned that the design process was integrated into the entire project.

Cooper (2016) tells the story of a middle school teacher who tasks her students to build a machine that will throw another object. The author continues to explain that because of the problem they are tasked to solve, the students are innately using "critical thinking, creativity, and working in teams" (p.24). One set of researchers took this design thinking a step further into authenticity and tasked students with building prototypes of a tiny home using makerspace materials including a 3D printer and laser cutter. The teachers noted that out of their 90 students (all of whom had formed collaborative groups), every single group had to continually rethink and redesign their models. Some groups had to redesign based on the software not printing their home in the way they had imagined, others realized their design wasn't sustainable for actual living situations. These mistakes forced students to think critically about how to modify their design, therefore incorporating creative problem-solving to make their tiny homes livable (McKay, Banks, & Wallace, 2016).

Similar to the previous study, Kitagawa, Pombo, and Davis (2018) challenged their students to use the engineering design process to solve a real-world problem regarding the amount of plastic pollution found in the oceans. Using a makerspace would allow the teachers to "provide a safe learning environment for students to develop their 21st-century skills of critical thinking, creativity, communication, and collaboration" (p.38). Using materials such as cardboard, hot glue guns, newspapers, etc., second-grade students created recycling bins for their school that would engage other students. The teachers began by explicitly using the steps in the design process: Ask (creating their essential question), Imagine (think of a design), Plan (teams collaborated together to plan out their design), Create (students built prototypes), and Improve (create better prototypes). When students were working on step 3, Plan, the teachers observed that students communicated with one another what they felt their design should be. Students were also observed collaborating with one another in order to agree on a design. In the Create step, the teachers revealed that many of their students had troubles with their first designs. Students had to come up with creative solutions to improve their designs, which took them to the Improve step to make the prototypes work more efficiently (Kitagawa et al., 2018).

Smay and Walker (2015) described how, in a cross-curricular project, several teachers from different content areas at the middle school level "sought to enhance this curriculum by building critical-thinking and problem-solving skills through the design process" (p.42). They used their makerspace to provide 3D models and stop-motion videos to enhance their stories from language arts. The art teacher worked with students individually as problems occurred to walk them through appropriate approaches to problem-solving and critical thinking (Smay & Walker, 2015).

Vongkulluksn et al. (2018) took a different look at makerspaces at the elementary level to examine student motivation and self-efficacy as related to designed-based learning (DBL), another name for design-thinking. The researchers noted that despite the rise in popularity of makerspaces, there was little previous research. Using a mixed-methods approach, their research setting included 100 students at an elementary school in grades 3-6 who were taking a semester-long makerspace class. Participants attended a private, affluent school where tuition ranges around $20,000 a year. “At the time of the research, administrators introduced the makerspace program as a way to combine the school’s focus on student-led inquiry with technology-rich instruction” (Vongkulluksn et al., 2018, p.5). Makerspace materials included but were not limited to computers, a green screen, a 3D printer, hand tools, and consumables. Using a 5-point Likert scale, the researchers used both statements and emoticons for their surveys which were given to students three times during the semester. In addition to this quantitative data, the researchers included qualitative data including multiple classroom observations at all grade levels, semi-structured field notes, and personally interviewed 70 of the 100 student participants in a think-aloud structure.

There were several common themes in the student interviews where students repeatedly discussed how they had to collaborate and communicate with their partners in order to be successful in their task. One student mentioned “me and my partner are both good at problem-solving, and whenever one of us gets stuck, we help each other out. (Vongkulluksn et al., 2018, p.10). Students commented again and again about addressing design challenges where they would have to think critically and creatively to solve problems. One stated “this is a trial, kind of. We were planning to make it, but we didn’t have enough time. Our project turned out different. When we first started, I thought we would make the real thing, but in the end, we [just] made the model (Vongkulluksn et al., 2018, p.11). The researchers concluded that makerspaces that focus on design thinking and the design process tend to increase learning at the elementary level. Students in this study who demonstrated the ability to communicate, collaborate, and think both critically and creatively, completed their design projects and mastered content standards within the course.

Future Skills

In their 2016 report on jobs of the future, Leopold, Ratcheva, and Zahidi contend that 65% of students currently in school will have careers that do not yet exist. Their research shows that in order for adults to be successful in the future job market, they must demonstrate skills that include creativity, critical thinking, collaboration, and communication. Skills which many argue can be fostered when students participate in makerspace activities. Cox (2018) asserts that critical thinking is a skill students will require after formal education. She lists teaching strategies to encourage critical thinking, including brainstorming, classification, making connections, and collaboration. One activity she suggests is giving students all the materials they need to make or build something and then requiring them to do it on their own. "This will allow students to become critical thinkers because they will have to use their prior knowledge" (Teaching Strategies to Encourage Creativity section).

Nagel (2018) in partnership with Project Tomorrow, focused on how workplace skills were being demonstrated by students who had access to makerspaces. They used the survey data of 435,510 K-12 students, 38,512 teachers, 4,592 administrators, 29,670 parents, and 3,778 community members about "the role of technology for learning in and out of school" ("Speak Up Research Project for Digital Learning," n.d., Heading section). The data from this survey was retrieved between October 2016 and January 2017. "The data is collected from a convenience sample; schools and districts self-select to participate and facilitate the online data collection process. The data were analyzed using standard cross-tabulation analysis" ("Speak Up Research Project for Digital Learning," n.d., Methodology section). Respondents overwhelmingly responded that makerspaces are beneficial in giving students the skills they need to be successful in college and the workplace, like collaboration, critical thinking, and "applying knowledge to practical problems" (Nagel, 2018, p.34). The librarians surveyed listed creativity, critical-thinking, problem-solving skills, and collaboration as four of the five top benefits of school makerspaces (Nagel, 2018). A similar report by Evans (2017) used data from 2016 Speak Up Research findings to note that among parents, district administration, and community members, the best way to develop workplace skills included using technology, STEM, and project-based learning. All of which have their role in a makerspace.

Dougherty (2012) presents evidence of how making develops students who are able to communicate with one another and share ideas and products to stakeholders. They give answers to questions about the process of creation, how and why it was created, and how the materials were selected. Instead of consumers, students experience things that are “real” and are allowed to “be active participants in constructing a new kind of education for the 21st-century, which will promote the creativity and critical thinking we say we value” (para. 13).

21st Century Skills

The Partnership for 21st Century Skills (P21) lays out what 21st-century skills students need in order to be successful and productive in a future workplace. “Within the context of key knowledge instruction, students must also learn the essential skills for success in today’s world, such as critical thinking, problem-solving, communication, and collaboration” (2019, para. 3).

Martinez and Stager (2013) advocate for makerspaces not only as places where students enjoy what they are doing but “because [tinkering and making] are powerful ways to learn” (p.3). The authors begin by presenting their research into learning theories as to the reason behind the impact of makerspaces on student learning. Using constructivism and constructionism, along with theories by Piaget and Seymour Papert, they argue that students who engage in makerspace activities, where design process thinking is embedded, have increased 21st-century skills. They cite collaboration as one of the most important 21st-century skills and note that “when the collaboration is authentic, students will gain a greater appreciation for the benefits of collaborating and the result of the experience will be richer” (p.163).

Martinez and Stager (2013) also encourage teachers not to intervene too quickly when students encounter roadblocks. Instead, they recommend allowing students to work through frustration to solve their own problems to foster critical thinking and creative problem-solving skills.

Clapp, Ross, Ryan, and Tishman (2017) completed a three-year research project to gain an understanding of the benefits of makerspaces as student-centered spaces for learning. Not only did they review current literature, but they visited several sites around the country, conducted interviews, and specifically researched the makerspaces of several educators in California. Patterns in their observations emerged with students demonstrating characteristics including problem-solving, collaboration, curiosity, and flexibility. In interviews with educators, the researchers noticed that there was a trend of reports of makerspaces helping students "see themselves as people who can effectively take action in the world" and have "a set of life skills, like self-reliance and courage" and "creative confidence" (p.9). Clapp et al. (2017) also observed key characteristics of makerspace instruction to determine how students met learning targets. One of the characteristics most commonly noted was how teachers facilitated student collaboration. "In the current educational climate, collaboration is often talked about as a 21st-century skill, something students will need to master if they are to be successful in the contemporary world" (p.63). The collaboration was documented in one makerspace in several ways, including students working together on a project, sharing resources of information and materials, students acting as teachers by instructing one another, and also giving feedback on what students were creating and how it could be improved.

In their 2017 report, Freeman, Adams Becker, Cummins, Davis, & Hall Giesinger state that with makerspaces increasing in schools, and not just in the United States, there are some who are beginning to research the educational benefits and best practices. One study they found was an elementary school in Denmark researching how makerspaces are affecting 21st-century skill development. Early findings suggest that "the environment must be configured in a manner that nurtures creativity and collaboration" (p.41). Gutsche (2013) supports these findings and continues by saying that "makerspaces are not just about the physical act of fabricating things. They are collaborative, exploratory, community spaces that foster a whole spectrum of skills, which enable people to be fully engaged 21st-century citizens" (Is Making Learning section, para. 3).

Meyer (2017) worked with educators and makerspace experts to define the most important components of a makerspace. While they listed space as a component, it was inconsequential compared to the learning that must take place. The most essential elements consisted of a mindset where students were encouraged to "build those other skills of collaboration and communication and critical thinking" (p.27). Even entire school districts are adopting this mentality with one school district in Pennsylvania adopting the mission statement that guarantees to "establish and support a maker culture through 21st-century resources" (Meyer, 2017, p. 27).

Learning Environments

In their 2009 report, the Institute of Museum and Library Services maintains that museums and libraries are critical in helping build skills, including communication, critical thinking, problem-solving, and creativity. They provide seven case studies (3 libraries and 4 museums) demonstrating evidence of how these learning environments tend to provide opportunities for people of all ages to engage in hands-on, innovative, and creative activities ranging from understanding healthy food, cultural dance, and literacy programs.

To compare learning spaces at the university level, Bieraugel and Neill (2017), surveyed 226 students. Students were selected at random without cross-sectional representation and were chosen randomly while physically present in the space. The researchers were looking to see which locations fostered creating new knowledge and the creative process. In order to properly measure these behaviors, they used a seven-point agree-disagree Likert scale. Reliability of the data was tested by “examining the interrelations among each scale’s items using item-to-scale correlations, exploratory factor analysis, and Cronbach’s alpha” (Bieraugel & Neill, 2017, p.40).

The findings showed that makerspaces “ranked the highest overall in fostering creativity and innovation” and students who are exposed to and have access to makerspaces are shown to have “the most innovative behaviors and exploration of new ideas” (Bieraugel & Neill, 2017, p.48).

While Bieraugel and Neill (2017) only examined one library, the research of Sheridan et al. (2014) did not have this limitation. Instead, they used a comparative case study of three different makerspaces in order to discern how they served as learning spaces. Using a method of purposive sampling, the researchers collected data from the three sites for one year. Data included field observations, interviews, observations, reviews of artifacts, and analyses of archives on the internet. To strengthen the accuracy of the data, the researchers used triangulation (Sheridan et al., 2014).

The findings from the study were separated based on each site. The first makerspace was open to learners of all ages, including adults. It focused on technologies such as 3-D printers, woodworking tools, sewing machines, welders, and a laser cutter (Sheridan et al., 2014). When people first enter this space, they encounter collaborative workspaces with couches and other LEGO tables where people typically socialize and work together. Collaborative projects are evident, including members who work together on “building and racing power cars” [for] “competitions against other makerspaces and engineering school teams” (Sheridan et al., 2014, p.513) and launches of several high-altitude balloons. One visitor to the makerspace mentioned that because of the collaborative and communicative nature of the space, he has learned more at this makerspace than he ever did working alone. The learning environment does not limit learners to working collaboratively, but encourages it as participants of the makerspace are required to participate in safety training. This usually occurs by more advanced users teaching novice ones. “This approach to equipment training illustrates the creativity of the learning environment” (Sheridan et al., 2014, p.514).

The second makerspace in the study was located in a church basement, with most participants between the ages of eight and nineteen. “The evolving mission statement drafted collectively by makerspace participants...states their priority [is] for engaging in ‘creative work and productive learning’” (Sheridan et al., 2014, p. 516).

Because of the design of the building, the spaces are “separate but connected” to encourage connections of the makers (Sheridan et al., 2014, p. 516). Interviews of students using the makerspace mentioned that they increased their time thinking about how to problem-solve when their projects didn’t work the first time. Other interviewees “repeatedly highlighted how they were thinking about and doing things they had never even thought about before” (Sheridan et al., 2014, p.518). Collaboration and communication among members is also an expectation of this makerspace. “Sharing knowledge is fundamental to the space...if you learn something, you are responsible for teaching it” (Sheridan et al., 2014, p. 517).

The last site chosen by researchers was located in a children’s museum and it “supports learning in making with digital and physical materials” (Sheridan et al., 2014, p.519). Divided into three areas, children were able to create a multitude of items, from woodworking, digital technology, and sewing projects. Students in this space tried new technologies, tools, and learned new skills all while using a design process that encouraged critical thinking, problem-solving, and creativity. One particular observation of these skills occurred in the sewing area. The facilitator was working with two siblings at two different levels of expertise. The younger sibling had to figure out how to sew a ball while the older sibling wanted to sew a hat. The older sibling and the facilitator worked together on what design challenges they would need to overcome.

When analyzing the three makerspaces together, researchers found that these unique learning environments continually changed based on the needs of the makers. Overall, the data suggested that in the three different makerspaces, the skills taught in each makerspace tended to contribute to a learning environment that encouraged communication, collaboration, creativity, and critical thinking. It "leads to innovative combinations, juxtapositions, and uses of disciplinary knowledge and skill" (Sheridan et al., 2014, p.526).

Burke (2014) contends that the maker movement is changing from an individuals only mindset to that of the collaboration of makers in the learning space. Collaboration and communication among makers can take the form of working together on a project or looking to others for suggestions or advice. "Alongside and within the coworking and collaboration is a willingness to teach others. Makers who share space do not necessarily share an equivalence of talent" (Burke, 2014, p. 12). Burke (2014) does not limit collaboration to face-to-face interactions but also explores the idea that collaboration and communication should be worldwide using video conferencing tools, collaborative tools, podcasts, how-to videos and more.

Most of these research studies show that makerspaces are fostering one, if not all of the 4C's, in learners at all levels of education. Learners who engage in hands-on and experimental components like those of a makerspace tend to demonstrate the ability to be collaborative, critical thinkers who develop creative and innovative solutions to authentic, real-world problems. "And while school-based makerspaces will likely include the newest technological toys, such as 3-D printers and laser cutters, the focus in design for learning is not on tools but on the process and the product" (Halverson & Sheridan, 2014, p.499).

Conclusions and Recommendations

This literature review explored how makerspaces impact how learners apply the 4 C's of creativity, critical thinking, collaboration, and communication. Based on the research found, it is my conclusion that a makerspace can have a positive effect on how students use critical thinking skills and creativity to problem-solve (Bowler, 2014; Cooper, 2016; McKay et al., 2016; Bieraugel & Neill, 2017; Smay & Walker, 2015; Sheridan et al., 2014). This type of thinking encourages students to solve problems that are real-world, authentic, and ones with more than one possible answer.

Research also suggests that a makerspace encourages student communication and collaboration, an important skill for future professions (Vongkulluksn et al., 2018; Nagel, 2018; Clapp et al., 2017; Sheridan et al., 2014). As educators, it is our job to prepare our students for their world outside and after their formal education. Teachers and other educators (such as librarians) who implement a makerspace design are empowering students to be more prepared for any profession, even those that do not yet exist, because of their increased commitment to implementing 21st-century skills (Kitagawa et al., 2018; Clapp et al., 2017; Dougherty 2012); Nagel, 2018).

It is my recommendation for future research to delve deeper into the post-secondary research of makerspaces improving the communication, collaboration, critical thinking, and creative skills of adults in the workforce. How do students who have participated in a makerspace curriculum compare in the workforce to those who have not? Do they have an increased chance of employment? It would also be recommended for this research to focus on makerspaces “demonstrating the marked diversity of learning arrangements we see occurring within each of the studied spaces" (Sheridan et al., 2014, p.528).

An additional recommendation is for future research more specific to the elementary student. Many of the studies cited in this review have taken an in-depth look at college-level students, high school students, and even middle schoolers, but few empirical research studies gave quantitative data on how learners at the elementary level are impacted by the 4C’s of communication, collaboration, creativity and critical thinking (Vongkulluksn et al., 2018).

It is also recommended that classroom teachers (K-12) should take advantage of makerspace opportunities at their schools allowing students to foster problem-solving skills (Bowler, 2014), critical thinking (Evans, 2017) and collaboration (Clapp et al., 2017). Academic libraries should implement collaborative rooms as makerspace areas for students to encourage innovation and creativity (Bieraugel & Neill, 2017).

In addition to classroom changes, there should be additional educational policies and procedures in place. It should be the policy at each school that students have access to a makerspace under the supervision of a librarian, classroom teacher, or knowledgeable adult (Sheridan et al., 2014). For many educators, a makerspace may be a daunting space. Therefore professional development should be implemented to “engage and support teachers as makers... to help [them] develop the qualities identified as critical. We need to create safe places for teachers to tinker” (Bennett, 2010, p.16). Professional development should take place in multiple makerspaces where teachers can learn from one another, or even have student experts teaching the teachers (Meyer, 2017).

Not only is it the recommendation of this literature review to implement makerspaces, but also that of former President Barack Obama. In his presidential proclamation on June 17, 2014, where he hosted the first-ever White House Maker Faire, he announced “I am calling on people across the country to join us in sparking creativity and encouraging invention in their communities” (White House, 2014, para.4).

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