Chapter 4

Promoting 21st Century Skills in Problem-Based Learning Environments

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Abstract

This paper investigates the relationship between problem-based learning (PBL) environments and the promotion of 21st century skills. Programs like STEM education and technology and engineering education (TEE) that promote PBL are also explored. Various print and electronic sources were examined and the literature selected from review comes from experts in fields of education, 21st century skills, PBL, STEM education, and technology and engineering education (TEE). The review of literature suggests that 21st century skills are best developed through hands-on and problem-based activities. Since STEM and TEE incorporate many hands-on activities focused on solving problems, both programs are recognized fields that teach 21st century skills in addition to science, technology, engineering, and math content knowledge. However, STEM and TEE classrooms and labs need to be carefully designed in order to accommodate collaborative and hands on activities. Some specialized PBL environments like Makerspaces, Tinkering Studios, and STEM Labs already exist, but the need for additional dedicated PBL environments continues to increase as the focus on teaching 21st century skills through PBL becomes more widespread and prevalent in the educational system.

Keywords: 21st century skills, problem-based learning, STEM education, technology and engineering education

Introduction

Education plays an important role in preparing students for the society in which they live. In the past, students were equipped with the skills necessary to fill the roles that involved routine manual or cognitive labor. However, today's economy and industries are very different. Computers and machines are able to do the jobs that once employed a large part of the population and, as a result, greater numbers of people are employed in jobs that require higher-level thinking and communication skills – tasks that computers and machines cannot perform autonomously (Dede, 2010).

If students are expected to survive and thrive in a technology driven world and "navigate the complex life and work environments in the globally competitive information age," they must be given opportunities to "[develop] adequate life and career skills" (Morrison, Roth McDuffie, & French, 2015, p. 245). In other words, schools need to prepare students to meet the challenges of working in an ever-changing, technology driven society by helping them to develop the higher-level thinking and communication skills that they will need when they enter the workforce. These higher-level thinking skills will also allow students to adapt when they meet challenges and changes due to the development of technology. As John Dewey once said:

> It is impossible to foretell definitely just what civilization will be twenty years from now. Hence it is impossible to prepare the child for any precise set of conditions. To prepare them for the future life means to give them command of [themselves]; it means so to train them that they will have the full and ready use of all their capacities; that their eye and ear and hand may be tools ready to command, that their judgement may be capable of grasping the conditions under which it has to work, and the executive forces be trained to act economically and efficiently. (Gomez & Albrecht, 2014, p. 15)

Due to the rapid improvement of technology, the world is changing more quickly than ever before, so the future Dewey describes is even more uncertain. As a result, it is important to equip students with not only academic content knowledge, but also with general skills that will enable students to face any situation with confidence. It is no longer enough for students to be proficient in math, reading, and writing; students need to have more tools at their disposal. These tools generally come in the form of various higher-level thinking and communication skills, often referred to as 21st century skills.

21st Century Skills

21st century skills consist wide range of skills and abilities that are necessary for success in a technological world (Dede, 2010). 21st century skills promote lifelong learning, which allows students to adapt and be more responsive as the world around them changes and as they, themselves grow and change (OECD, 2005). Since today's workplace and society is constantly changing, the ability to adapt to the fast-paced life of the global community becomes increasingly significant to success in the global workplace. Therefore, it is important that students to have adequately developed 21st century skills so that they are able to be flexible and change with the world around them.

Although different conceptual frameworks for teaching 21st century skills vary slightly, common themes and skills listed in these frameworks include critical thinking, problem solving, collaboration, communication, and creativity (Dede, 2010). Once developed and mastered, this collection of skills will go with the students for the rest of their lives. Students with these abilities are better able to adapt to new situations, solve their own problems, share their ideas, and reflect on how their actions affect others. As adults, they will be able to react positively to inevitable changes in the world around them and solve problems that arise because of these changes (Lemke, 2002).

In the 20th century, during the peak of the Industrial Age, high importance was placed on students' and workers' abilities to follow explicit directions from teachers and supervisors. However, due to changes in industry, the economy, and technology, there is a need for today's workers to not only follow directions, but also to adapt to the changing world (Lemke, 2002). Students must be prepared to enter a workforce that is drastically different from that of the 20th century. As Dede noted:

> Declining portions of the labor force are engaged in jobs that consist primarily of routine cognitive work and routine manual labor – the types of tasks that are easiest to program a computer to do. Growing proportions of the nation's labor force are engaged in jobs that emphasize expert thinking or complex communication – tasks that computers cannot do. (2010, p. 51)

As a result, today's students need to be proficient in not only reading, writing, and mathematics, but also in areas like critical thinking, problem solving, creativity, communication, and collaboration so that they are prepared for a workforce that requires higher-level thinking and communication skills (Dede, 2010). In other words, students need to have various 21st century skills in addition to basic content knowledge of subject matter in order for success in the modern world.

"Major shifts in the ways people communicate and access information" has also had an impact on the skills students need to develop (Prettyman, Ward, Jauk, & Awad, 2012, p. 7). With the ease of access to information through the Internet, it is no longer a matter of remembering information, but knowing how to use the information available to us. Students need to be able to use the fundamental subjects taught in school and know how to apply these subjects in new and creative ways to solve problems and communicate their ideas to others.

Why Our Students Still Lack 21st Century Skills

Although it is generally agreed that certain 21st century skills are necessary to be successful, business leaders have reported that students have "deficits" in these skills, and the lack of these skills in our society will "significantly impact the future economic growth in the United States and abroad" (Mosier, Bradley-Levine, & Perkins, 2016, p. 13). What is more, American students are also falling behind in traditional areas of math, reading and science as well. A study conducted by the Organization for Economic Cooperation and Development (OECD) shows just how far behind American students are compared to their international peers. The results of this study, which are based on the Programme for International Student Assessment (PISA) – a test that measures reading, math, and science abilities of students in developing and developed countries – show that the United States ranks 38th out of 71 countries in Math and ranks 24th out of 71 countries in both science and reading. With rankings falling in the middle of the pack, the United States clearly is not preparing its students to compete with top global academic performers like Singapore, Hong Kong, Ireland, South Korea, Japan, Canada, Germany and the United Kingdom (Desilver, 2017). Therefore, in order to keep up with the global economy, America's schools need to do a better job of developing their students' 21st century skill sets in ways that enhance and enrich standard math, science, and reading curriculum.

Since the era of the Space Race in the 1950's, there has been a growing need for innovation and creative thinking in order to keep America on the top of the world's educational ladder. Money from the government has been "poured" into educational initiatives and reforms in order to increase the development of 21st century skills, which can help to create a more innovative society (Bartholomew, 2015, p. 14). Although the goal was to improve education and preserve America's position as a global leader, schools and teachers today are still struggling to instill 21st century skills in students.

The main challenge when teaching 21st century skills is finding the time to teach these skills in an already full curriculum. Teachers and students are often confined to learning and testing environments that are limited by curriculum and assessments imposed by the school or state (Strimel, 2014a). Many teachers already have difficulty teaching the entire required curriculum for their content area in order to enable their students to pass standardized tests. Adding additional curriculum – even necessary curriculum that includes the teaching of crucial 21st century skills – would create more difficulties for teachers who are trying meet standardized testing requirements.

However, according to Dole, Bloom, and Kowalske (2016), 21st century skills cannot be properly measured through current standardized testing methods. In other words, skills like critical thinking, problem solving, creativity, communication, and collaboration – the skills students need most for success in the workplace – are not even covered by the tests they spend so much time preparing to take. Therefore, when teachers teach to the test, or when they employ teacher-centered methods in order to teach a curriculum that will allow students to be successful on statewide assessments, students may be missing opportunities to develop their creativity, critical thinking, problem solving, communication, and collaboration skills. While students may seem successful based on their tests, they may be lacking the abilities to succeed in the working world. As a result, today's students may be able to pass standardized reading, writing, and math assessments, but these test do not show if a student is adequately equipped with all the skills necessary for success in the rapidly changing world.

Even though standardized testing does not adequately measure students' skills, testing has greatly influenced the learning environment. Accommodating standardized testing has led to teaching practices that limit the development of 21st century skills. Because of high stakes testing, "teaching to the tests has led to the adoption of teacher-centered pedagogical strategies to meet the time and content demands of the tests" (Dole, Bloom, & Kowalske, 2016, p. 45). Teacher centered instruction (e.g. lectures and teacher demonstrations) is prevalent in many classrooms because it allows teachers to have more control of the pacing of the curriculum (Dole et al., 2016). However, these teacher-centered strategies do not often allow for the development of 21st century skills like creativity, critical thinking, or problem solving, which are essential for success in the modern world. One of the best ways to promote the development of 21st century skills, properly prepare our students for the future, and combat ineffective teacher-centered instruction is through problem-based learning (PBL). Advocates of 21st century skills stress the importance of student-centered methods like PBL or project-based learning. PBL and other student-centered teaching methods are widely acknowledged as being effective, even if they pose classroom management challenges to teachers (Rotherham & Willingham, 2009).

The PBL Environment

The essence of teaching 21st century skills is for students to "learn to develop their own ideas," test and share those ideas, and take input from their teachers and peers to further develop their ideas (Prettyman et al., 2012, p. 11). This type of teaching and learning is best reflected in the PBL approach. PBL is an educational method that provides students with authentic learning opportunities with a focus on teaching through real-life situations and solving real world problems. In PBL environments, teachers introduce a situation that their student care about or can relate to. The students then identify problems within the given situation, brainstorm ideas to solve those problems, test their solutions, and communicate their results. Through the problem solving process in PBL, students not only gain content knowledge, but also develop their 21st century skills.

In addition, PBL is highly student-centered and involves students developing their own knowledge and discovering important information through teacher guidance, not teacher lecture. Therefore, PBL is fundamentally different from teacher-centered approaches that involve teachers simply giving students the information they need to know. Through PBL, students are no longer passive "consumers of knowledge," but are becoming active "creators of knowledge." In other words, students in a PBL environment are not just handed information so they can pass standardized assessments; students have to learn how to use information in new and unique ways and create their own knowledge by attempting to solve a problem that is relevant to their lives. In this way, students gain experience with finding answers to their own questions and rely less on their teachers for the right answers. In life there is not always going to be someone around to answer questions or solve problems; by incorporating a student-centered learning environment students become self-dependent and are better able to face the changing world with confidence (Prettyman et al., 2012, p 13).

History of PBL

PBL is not a new concept and the idea behind it has not changed much over the years. In the past, PBL was used much the same as it is today – as a teaching method to provide students with "authentic learning experiences" and to aid in the development of essential life and career skills like creativity, critical thinking, problem solving, communication, and collaboration (Vega & Brown, 2013, p. 8). PBL was originally designed to aid medical programs when instructors discovered that students were graduating with a "wealth of information but without the problem-solving skills to use the information wisely" (Vega & Brown, 2013, p. 8). By training medical students in a PBL environment, they were better prepared to think quickly, solve problems, and stay calm under pressure while interacting with patients. After success in the medical field, PBL began to be recognized as an effective teaching method in other areas of education.

PBL was such a powerful and innovative teaching method that multiple educational reformers in the 1800's believed PBL was essential to student learning. These reformers like Fredrich Froebel and Johann Heinrich Pestalozzi thought that students should be taught "in a full range of real-life activities...using a hands on approach" (Kelley, 2012, p. 34). It was an "attractive idea" if these activities could be the base to integrate multiple academic contents and incorporate issues that affected or interested students (Kelley, 2012, p. 26). In other words, Froebel and Pestalozzi believed that learning academic content through hands-on activities would make the information more relatable and pertinent to their students. Even John Dewey – one of the "fathers of modern education" – recognized the importance of students' "natural curiosity" concerning their learning (Crippen & Archambault, 2012, p. 158). This curiosity could be more easily tapped through hands-on PBL than through lecture-based instruction.

All three of these educational reformers were aware that "students need to be able to relate their own life experiences to the topics that they are learning" in order to engage in their education. These reformers were also aware that hands-on problem solving activities like those found in PBL are a great way to make educational topics relatable. The authenticity found in PBL provides a "clear application" of what the students learn to their own lives and makes content more relevant to them (Strimel, 2014a, p. 9,10). Through the efforts of educational reformers like Froebel, Pestalozzi, and Dewey, school systems continued to adjust in order to reflect the changes in society and provide for the needs of the students.

Learning to Think

While educational reformers focused on making classroom topics more relatable to the students through PBL, using PBL as a teaching and learning method also has the ability to "[emphasize] higher order skills" like critical thinking, creativity, and problem solving instead of "lower level skills...[like] memorizing facts and repeating procedures" (Morrison, et al., 2015, p. 245). Teaching content is important to develop the minds of students, but teaching students to think is even more important. Problem solving, like that done through PBL, is important to this process because "problem solving is one of the most valuable ways in which [people] think" (Gomez & Albrecht, 2014, p. 14). Through PBL, students are expected to "internalize" important themes and concepts instead of memorizing facts (Asunda & Mativo, 2016, p. 11). The most important idea in PBL is for student to learn "how to think, not necessarily the specific details" (Morrison et al., 2015, p. 249). This idea is a reflection of the student-centeredness of PBL – teachers do not give students all the answers, but provide them with enough of the main concept that students can solve their own problems and find their own answers. With the rapidly changing world, it is more important than ever that our students can think for themselves and solve their own problems. Being dependent on others for the right answers can slow down communication, prevent innovation, and create a lack of creativity. Students who depended on their teachers to give them the right answers may struggle in the workforce when they are expected to think critically and use problem-solving skills when issues arise (Vega & Brown, 2013).

This undesirable dependency on others for answers can be either encouraged through teacher-centered instructional methods, or lessened through student-centered practices like PBL. When teachers simply "spoon feed" all the answers to their students – as is common in teacher-centered approaches like lecturing – the students become unused to "thinking on their own" (Vega & Brown, 2013, p. 18). PBL helps to remedy this detrimental situation by providing opportunities for students to use critical thinking skills and other 21st century skills. When students are engaged in problem-based activities that teach 21st century skills, the students "are not learning what to think, but how to think" (Prettyman et al., 2012, p. 11). As a result, students begin to have confidence in their own ideas, rely less on their teachers for all the answers, and become independent thinkers.

Benefits of PBL

Students who become independent thinkers by partaking in authentic learning opportunities like those found in PBL are the students who are on the way to having a developed set of 21st century skills and are better prepared for the real world (Strimel, 2014a). In order to fully gain 21st century skills, students need to learn through “relevant, real world ... contexts” by participating in authentic and PBL opportunities (Partnership, 2015, p. 9). These types of PBL opportunities have been “shown to improve the understanding of basic concepts and to encourage deep and creative learning despite academic content area (Clark & Ernst, 2007, p. 24). This improvement and development of skills is apparent in all learners who have had exposure to a PBL environment. Studies have shown that when “low ability” students are “immersed in a PBL environment” they show 446% increased used of critical thinking and collaboration skills; “high ability” students show an increase of 76% of these same skills (Mosier et al., 2016, p. 3). Clearly, PBL is suited for all learners – high and low achievers alike – to improve their 21st century skills. As a result, PBL helps to prepare all students for the rapidly changing world regardless of their cognitive abilities.

PBL not only develops 21st century skills, but also improves student motivation, which is another important aspect to success in the modern world. PBL improves student motivation in two ways: (1) introducing meaningful activities and (2) developing positive student perceptions of the PBL strategy. Students who participate in activities which are meaningful to them become more interested and motivated to complete tasks, even if the tasks are difficult and challenging (Morrison et al., 2015). When students persist at difficult tasks, they increase the quality of time spent learning and developing their academic content knowledge and 21st century skills. In addition, the use of PBL is “strongly linked” to student perceptions of content relevancy and 21st century skills (Moiser et al., 2016, p. 8-9). Overall, these perceptions are positive. Students believe that by participating in solving real world problems – like those presented in PBL – they are learning 21st century skills as well as content. Students also feel that a PBL environment provides learning opportunities that are suited for different learning styles (Moiser et al., 2016). Most importantly, after being engaged in a PBL environment, students feel like they have “learned how to learn” (Morrison et al., 2015, p. 250). Students with positive attitudes and perceptions towards PBL, who believe that their learning needs are being met and that the content is relevant to them, are more likely to be cooperative, engaged, and motivated in the PBL environment. Likewise, students who are more engaged in their education learn more and develop more skills than those who are not engaged or motivated to participate. Therefore, by increasing student motivation, PBL is also providing students with more skills needed for success in the modern world.

Another benefit of PBL is increased scores on state assessments. Studies have shown that after two years of being immersed in a project based learning environment, high school students improved more and scored higher on state and year-end assessments as compared to their peers who were not immersed in a project based learning environment (Morrison et al., 2015). This suggests that learning through PBL can also help students retain and recall more information. While remembering information is not necessarily a 21st century skill, the more knowledge students have readily available to them, the more they will benefit as they enter the working world.

The reason PBL can lead to an increase in academic success is that a PBL environment creates a “culture that is interdisciplinary” and takes resources from all the content areas into account in order to solve a problem (Prettyman et al., 2012, p. 10). In other words, PBL integrates multiple content areas so students can learn in context. Problems in the real world are not based on a single subject matter, and neither are the problems proposed in a PBL environment. By partaking in PBL, students develop 21st century skills while gaining experience working in interdisciplinary situations. With this concept in mind, a new movement in education has been specifically designed to integrate the content areas of science, technology, engineering, and math through hands on PBL.

STEM Education

STEM is the "integration of science, technology, engineering, and mathematics content" and is the epitome of interdisciplinary education (Clark & Ernst, 2007, p. 26). In recent years, there has been a STEM Education Reform movement to increase the quality of STEM education in schools. This movement arose because of "national workforce issues" caused by the changing work environment (Strimel et al., 2017, p. 19). Like PBL, STEM education provides reasoning for learning academic content by introducing hands on and PBL experiences. Through real-world or career oriented problems and activities, integrative STEM demonstrates the rationale for learning academic content and provides a context in which concepts can be applied (Gomez & Albrecht, 2014). Through the PBL found in STEM education, students are able to become "actively engaged in learning" and "realize the meaning" of what they learn and importance of why they learn it in regards to specific content areas like science, technology, engineering, and math (Capraro & Han, 2014, p. xvi). Just like PBL, STEM helps to answer the question of 'why are we learning this?'

However, STEM takes providing rationale to a new level. Students need to be "explicitly shown the rational and application" of the content they learn and STEM does just that (Gomez & Albrecht, 2014, p. 8). Not only does STEM provide students with reasons for learning content, but STEM also links content in ways that allows students to see connections between various academic disciplines - through STEM, students are better able to perceive the relationships between the various fields of study. These connections make learning experiences even more meaningful because "direct continuity between content across subject areas serves as an agent that conveys relevance to students by allowing them to observe a sequential process in place of disconnected educational components" (Clark & Ernst, 2007, p. 26). In other words, a holistic education that connects different content areas provides more relevance than teaching content areas separately. This relevance can lead to more student engagement and higher levels of student motivation within the STEM classroom.

STEM also takes PBL to a new level by placing an emphasis on technology and engineering to solve problems. "STEM has been described as much more than math and science education, but a way of thinking that views technology and engineering as tools in solving problems and promoting innovation" (Talley & Scherer, 2013, p. 340). In STEM education the relationship between science, technology, engineering, and math in conjunction with a problem solving method work together to form a "whole solution" for a given problem. Science "proposes why" and provides the theory behind the problem. Technology "explains how" by describing the necessary processes needed to solve the problem. Engineering "determines what" and provides the design concepts. Math "reveals relationships" and helps to tie all the concepts together (Mitts, 2016, p. 31). By learning to incorporate various content areas to understand and explain concepts, students are no longer compartmentalizing the skills and knowledge they learn in specific content areas. When students are able to de-compartmentalize the skills and knowledge they learn in one subject area, they are able to bring those skills and knowledge with them into other content areas. This ability to use skills in all situations is critical if students are to be able to adapt in the changing world.

While STEM education focuses on science, technology, engineering, and math, STEM lessons are not limited to only these four content areas. Other academic disciplines like art, social studies, and reading should be incorporated as well when they "support student learning and provide elements to the learning experience" that enhance and enrich the STEM lesson (Froschauer, 2016, p. 5). By encouraging students to think in cross-disciplinary ways, STEM educations better prepares student for the type of thinking that is necessary for success in the modern world.

Although many administrators and teachers have seen the benefits of STEM education and strive to implement STEM programs in their schools and classrooms, it is important that they do not to force STEM integration into lessons that do not provide natural connections between academic disciplines. STEM "involves constructing valid experiences that highlight all disciplines" (Froschauer, 2016, p. 5). Therefore, to create these valid experiences, STEM education needs to be fostered in an environment that allows for the smooth integration of content areas. When STEM is implemented through "disconnected projects," students may fail to see the connections between content areas (Asunda & Mativo, 2016, p. 8). Instead, STEM lessons should focus around a theme that allows for the integration of content areas (Asunda & Mativo, 2016). In this way, students are able to get the most out of STEM integration and develop abilities to think across disciplines.

In addition, it has been proposed that "students cannot fully comprehend STEM-related concepts without engaging in problem-based learning experiences" (Asunda & Mativo, 2016, p. 9). Therefore, the environment in which STEM will be most effective is in a PBL classroom. Since the teaching of STEM is "rooted in interdisciplinary applied application of knowledge designed around a cooperative effort to provide students with a comprehensive, meaningful, real-world learning experience," PBL and STEM education go hand in hand (Gomez & Albrecht, 2014, p. 8). PBL is a great student-centered method that can integrate STEM concepts. At the same time, STEM content is a great way to introduce meaningful hands-on, PBL activities. Working together, PBL and STEM can help students learn the content and skills they need in order to thrive in the modern world.

Technology and Engineering Education (TEE)

Another program that supports both STEM and PBL is technology and engineering education (TEE). TEE is a field that strongly supports STEM education and even incorporates STEM principles through hands-on, problem-based activities. According to Loveland & Love "STEM should focus on active learning through engineering problem-based activities" (2017, p. 15-16). Through TEE, students are exposed to these types of engineering problems and engineering habits of mind (Strimel et al., 2017). In order for STEM to be effective, teachers in various content areas must work together to implement an integrated STEM education. Since TEE naturally incorporates components of STEM and utilize engineering design problems, TEE and its teachers can be a great starting point and model for implementing school wide STEM (Clark & Ernst, 2007).

Like STEM, TEE has a "longstanding history" of using PBL (Kelley, 2012, p. 34). "Activity-based learning is the signature characteristic of technology and engineering education" (Mitts, 2016, p. 30). As a result, TEE will also be looked to as an environment in which both STEM and PBL can thrive. Since technology and engineering activities provide "doing-based" or hands-on activities to solve problems, technology and engineering are the "logical subject matter to deliver STEM education (Moye, Dugger, & Stark-Weather, 2014, p. 25). As a result, TEE is also the logical subject matter in which to teach 21st century skills.

In addition, TEE is a great foundation for STEM because TEE has a history of integrating various academic content areas into the TEE curriculum seamlessly (Kelley, 2012). Since TEE is cross-curricular by nature, TEE can implement STEM without forcing content integration; STEM education is already naturally found in many standard TEE activities. For example, building and testing bridges – a common TEE activity –teaches science and math principles in addition to technology and engineering content. Through bridge activities, students have the opportunity to learn concepts based in trigonometry and use those concepts to study and calculate forces on structures while they build and test their bridges (Gathing, 2011). The central theme of bridge constructions allows for connections between science, technology, engineering, and math to develop naturally and in ways that are unified and natural to students.

Other themes are often found as a focus of instruction in the TEE classroom. These themes like bridges, rocketry, simple machines, robotics, and drafting serve to successfully combine STEM subjects in meaningful ways. Due to the focus on central themes in which science, technology, engineering, and math are logically connected instead of introduced through several unrelated project or activities, TEE is especially suited for the integration of STEM through the use of PBL. Therefore, like PBL and STEM, TEE is also suited for preparing students for the future.

In addition to teaching STEM principles, TEE is a source for engineering education and 21st century skills. Since "current educational initiatives ... are placing increased emphasis on the importance of engineering education for providing the skills necessary for the 21st century," TEE will be looked to as the provider of 21st century skills through engineering concepts (Strimel, 2014b, p. 16). TEE will become a provider of these essential skills because TEE can be used to "provide a context for learning math and science" through technology and engineering (Kelley, 2012, p. 37). TEE lessons can tie together multiple subjects and provide context to learning because TEE activities often incorporate the application of science, technology, engineering, and math in a single lesson. By providing these necessary contexts and applications of academic content through PBL and STEM, TEE can increase student motivation, pique student interest in other academic disciplines, and develop students' 21st century skill sets through engineering activities.

Technological Literacy

One 21st century skill that is unique to TEE is the development of technological literacy. Technological literacy is the "ability to use, manage, assess, and understand technology" (Ward, 2015, p. 18). Since our world is full of technology, students need to be able to understand and use technology in their everyday lives. As a result, technological literacy is one of the most important 21st century skills that TEE can provide.

However, technological literacy goes beyond being able to operate a computer. The International Technology and Engineering Educator's Association (ITEEA) describes a technologically literate person as one who understands "what technology is, how it is created, how it shapes society," and how society shapes technology. According to Loveland and Love, "technological literacy is not a characteristic of an individual, but a characteristic of how one experiences and acts in relation to situations and technological processes" (2017, p. 14). A technologically literate person must be able to consider the "nature, behavior, power, and consequences of technology" and use his or her knowledge to make decisions about technology

(Ward, 2015, p. 18). When it comes to technology, "there are very few other things that influence our everyday existence more and about which citizens know less" (Bybee, 2010, p. 30). In other words, technology is a major part of modern society, but citizens rarely understand all of the consequences and implications the use of technology involves.

Without the essential understanding of the technology they use every day, students will never be able to comprehend how much technology affects their lives and the lives of those around them. As a result, it is important to educate students about the use and effects of technology so they can make "informed and responsible decisions" regarding the technology available to society (Strimel, 2014b, p. 16). Technological literacy is such an important set of skills that the ITEEA created an educational framework for developing these skills called *Standards for Technological Literacy* (Loveland & Love, 2017). Since technology is a prominent factor in the modern world, it is of the utmost importance that students are able to use and understand the technology available to them. Without these skills and understandings, students will quickly fall behind in the rapidly changing world.

A Closer Look at TEE and STEM

The ITEEA defines integrative STEM as "the application of technological/engineering design based pedagogical approaches to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education" (ITEEA). This definition indicates that STEM and TEE are inter-dependent on each other. With such a close relationship, it is not a surprise that TEE and STEM are very similar. Both utilize hands on, problem-based activities to facilitate learning. This student-centered strategy is unique because many teachers continue to use teacher-centered approaches to meet the demands of high stakes testing. In addition, both TEE and STEM offer avenues for content integration. Like STEM, TEE often integrates technological concepts with other content areas like science, math, engineering, reading, and writing into a single cohesive lesson. This is why TEE is often looked to as an example of STEM implementation.

However, when considering TEE and STEM, it is important to realize that they are not identical. The purpose of TEE is to increase technological literacy so students are able to make informed decisions in a technology driven world (Loveland & Love, 2017). The purpose of STEM education, however, is to create connections between various content areas. TEE is an established content area, while STEM functions as a teaching method. TEE has its own content, follows standards and curriculum, and uses teaching methods like STEM integration to increase technological literacy. STEM education, on the other hand, is a "comprehensive and interdisciplinary teaching and learning approach" (Capraro & Han, 2014, p. xv). There is not a set curriculum or standards that STEM follows because it is a pedagogical practice, not a content area. However, classroom teachers of any content area can implement STEM to meet their content's standards and create an enriched learning environment.

Although there are slight differences between STEM and TEE, both are excellent programs that cultivate 21st century skills. By participating in TEE or STEM activities, students have the opportunities to develop and grow their critical thinking, problem solving, creativity, collaboration, and communication skills. As a result, student who participate in PBL through TEE or STEM programs are better prepared for success in the future.

How TEE, STEM, and PBL Promote 21st Century Skills

Although STEM and TEE both use PBL (which has been proven to increase 21st century skills), it is not always easy to discern how TEE and STEM influence student development in these areas. Participating in engineering activities – like those often seen in STEM and TEE classrooms – allows students to develop 21st century skills in a meaningful way through PBL. STEM education often focuses on combining science, technology, engineering, and math to solve real world problems. These authentic and problem-based STEM activities provide students with opportunities to think critically and creatively, collaborate with others, and communicate their results verbally or in writing (Partnership, 2015). In addition, engineering habits of mind are often incorporated in the TEE classroom through design projects. These habits of mind have "direct links" to 21st century skills like creativity, collaboration, and communication that engineers use on a daily basis (Loveland & Dunn, 2014, p. 13). As a result, when students take part in well-developed TEE or STEM activities, they are able to work not only on their technological literacy and science, technology, engineering, and math abilities, but also on their 21st century skill sets. These skill sets are important for success in the changing world.

However, since TEE is not a core academic subject, it "has been overlooked as a tool for improving student achievement" (Kelley, 2012, p. 38). However, STEM and TEE are great resources to instill numerous 21st century skills in students. This is because STEM and TEE incorporate PBL and promote critical thinking and problem solving through hands-on, problem-based activities that allow students to use high order thinking skills (Partnership, 2015). These high order thinking skills include 21st century skills like creative and critical thinking, collaboration, communication, and problem solving.

Critical Thinking and Problem Solving

Critical thinking and problem solving are skills that involve analyzing and critiquing situations in order to make educated decisions. Both critical thinking and problem solving involve various habits of mind like persisting when tasks are difficult, managing impulsivity, thinking flexibly, applying past knowledge to new situations, taking responsible risks, and learning continuously (Costa & Kallick, 2007). These habits of mind can be developed and promoted by using the engineering design process, which is a common problem solving method used in many STEM and TEE classrooms. This process requires students to define a problem; brainstorm solutions; and build, test, and evaluate their solutions all while considering criteria and constraints of the problem. Through the engineering design process, students must analyze a problem, consider any criteria or constraints, and make decisions based on their observations and prior knowledge to come up with a suitable solution. These actions activate critical thinking and problem solving skills in addition to design thinking skills. Closely related to critical thinking and problem solving, Dym describes design thinking as a "broad spectrum of talents" that includes "various kinds of judgment, reflection, and experience[s]" (2006, p. 423). Once students become familiar with the engineering design process and develop their design thinking, critical thinking, and problem solving skills, they may begin to apply these skills to solve problems in their personal and professional lives (Rigler, 2017; Strimel, Grubbs, & Wells, 2017).

In addition, TEE uses PBL to increase technological literacy. This same approach is also crucial to developing critical thinking skills (Kelley, 2014). Therefore, while developing technological literacy, students are also learning to think critically about technology and solve problems that pertain to technology or technological processes. Through both STEM and TEE, students have multiple opportunities to gain critical thinking and problem solving skills that they can apply to any problem they encounter, not just the problems that are assigned during the school day.

Creativity

Not only does PBL require higher levels of critical thinking, but it also requires higher levels of creativity to solve the problem. Creativity, which involves creating new and unique ideas and products, is another skill that can be cultivated through exposure to PBL provided by TEE and STEM. Creativity is "developed, not taught" (Kelley, 2014, p. 19). Therefore, it is important for students to be given opportunities to work creatively so that they can develop their creative skills. Problem-based engineering design activities and lessons like those found in TEE and STEM are "ideal contexts" in which to foster creativity (Loveland & Dunn, 2014, p. 14). TEE and STEM provide creative opportunities when they "employ ill-defined design problems" (Kelley, 2014, p. 19). This is because these activities do not have a single best answer or one correct solution. When students are exposed to activities that do not have strict right or wrong answers, they are able to think of creative answers instead of searching for the single right answer.

In addition, STEAM – Science, Technology, Engineering, Art, and Math – is a new twist that places emphasis on creativity by including the arts. This focus on the arts (which are creative in nature to begin with) further encourages creative thinking by combining the creativity of art and music with the somewhat structured nature of science, technology, engineering, and math. Once students begin to think creatively, they will be able to carry that creativity to other aspects of their lives.

Collaboration and Communication

While STEM and TEE activities help to develop critical thinking, problem solving, and creativity, these activities also develop collaboration and communication skills. These skills are essential for working with others and effectively sharing ideas. Since STEM and TEE activities usually require or encourage group work, students encounter numerous situations in which they can develop collaboration and communication skills.

Although students often feel that working in groups is more challenging than working individually, it is important that students develop good team working skills that enable them to work efficiently and effectively with others (Morrison et al., 2015). A 21st century learner is one who is capable of learning independently, yet is also able to work well in groups (Prettyman et al., 2012). As a result, it is important for students to have opportunities to bring their individual skills and knowledge to a group setting and share those skills to accomplish a common group goal.

When technology teachers group students to work in teams, this gives students the opportunity to share their individual talents in addition to enabling students to develop "competencies in intrapersonal skills" (Loveland & Dunn, 2014, p. 15). These intrapersonal skills like communication and collaboration enable students to work not only with others similar to themselves, but also with others who differ in some way.

Working in groups can also promote collaboration that is effective and respectful. Through teamwork, students work together to combine their ideas into a final team solution. In doing so, they are also developing communication skills. When working in groups, students must clearly explain their thoughts to each other in order to complete the activity. In addition, problem-based activities like those common in STEM and TEE encourage students to present their findings to others during class presentations or class conferences. Since students collaborate and communicate so much through TEE and STEM activities, they are able to become comfortable working with others and presenting their ideas. These traits of comfortably collaborating and communicating will follow students throughout the rest of their personal and professional lives and benefit them in the global workplace.

Not only does participation in group work enhance communication and collaboration skills, but it also promotes better understanding of academic content. Sometimes the way a teacher phrases concepts can be confusing to students. Students who work in groups are able to ask their peers questions about the material and have it explained in another way that makes more sense. In addition, students who tutor or aid their groupmates reinforce the concepts they already know by teaching them to their peers. Through the peer tutoring and mentoring that occurs naturally in group work, students can develop a better understanding of the content and form better relationships teammates. As a result, students are better able to solve conflicts within the group and show more respect to each other, both of which are skills needed in the workplace (Loveland & Dunn, 2014).

Communication is recognized as such an important 21st century skill that educational curricula have been developed to make sure communication skills are taught in schools. As a result, communication – especially communication through text – is enhanced through literacy requirements of the Common Core State Standards (CCSS). These standards focus on improving "critical-thinking, reading, writing, speaking, and listening skills" (Loveland, 2014, p. 8). One of the focuses of the CCSS applicable to PBL is to improve comprehension of technical and informational texts (Loveland, 2014). These texts are often rich in information, but due to technical wording, students often have difficulties understanding the text. Since "reading is enhanced when there is a purpose of gaining information or verifying existing knowledge in order to complete in-class assignments," STEM and TEE activities are opportunities to enhance student reading skills like comprehension (Loveland, 2014, p. 10). Therefore, reading skills can be enhanced and developed through hands on activities found naturally in TEE and STEM education. Such activities are often accompanied by design briefs, which can include extensive, detailed, or technical directions (Loveland, 2014). By reading and breaking down the information and instructions found in design briefs, students are developing their comprehension and written communication skills.

Specialized Classrooms for PBL Environments

Since it can be agreed that 21st century skills are necessary for success in the modern world and PBL is especially suited for equipping students with a multitude of 21st century skills, it would be easy to assume that schools incorporate areas and classrooms appropriate for PBL. However, it is not always the case that teaching and learning environments are arranged in ways conducive for PBL even though TEE and STEM already employ PBL. The reason for this discrepancy between educational expectations and classroom design is a result of the history of education in America.

The educational framework many modern schools employ has been around since the late 1800's. This framework "reflected the factory model" so that schools would prepare students for the industries and economy of that period (Vega & Brown, 2013, p. 6).

> America had developed into an industrial and technological giant. Factories covered the landscape. … It was a manufacturing economy that was reflected in all parts of society. Even the process of education was modeled on the factory. Classes changed on the sound of a bell. Each student tended to his or her own studies. The teacher was the center of focus. (Childress, 2017)

As a result, classrooms were arranged with rows of desks and operated on a bell schedule to reflect a factory environment. What is more, by promoting the factory style framework, students were "not expected to learn at high levels," but play a role of "compliance and obedience". Although factories and industry have less influence on society today and other factors like creativity and ingenuity are valued instead of rote memorization, many schools still employ the factory framework of teaching and learning. However, the attitudes set by the factory model can "[hinder] the educational experience and development of students" (Vega & Brown, 2013, p. 6).

In addition, methods of instruction from the 19th and 20th centuries, such as chalkboard lectures, are now considered to be "insufficient for representing 21st century understandings and intellectual/psychosocial performances" (Prettyman et al., 2012, p. 7). Due to changes in TEE and with the new focus on STEM, many TEE facilities have become outdated and "ill-equipped to accommodate" new standards in TEE (Daugherty, Klenke, & Neden, 2008, p. 19). These outdated facilities can have negative impacts on the way teachers are able to deliver instruction and can even "influence student and public perceptions of the [TEE or STEM] program" (Daugherty et al., 2008, p. 20). If students are expected to master 21st century skills like critical thinking, problem solving, creativity, collaboration, and communication, they need classrooms that are adapted to teach those skills (Martin, 2015). Since there is such a strong connection between learning 21st century skills and PBL, modern classrooms should be equipped to provide a PBL environment. Therefore, in order for students to get the most out of their education and develop the skills they need, up to date facilities designed to accommodate PBL are of the utmost importance.

Several characteristics separate 21st century PBL classrooms from factory style classrooms of the past. Over the past decades, the K-12 environment has been changing to accommodate the new skills needed for the modern age. There has been a shift from "mastery of declarative subject knowledge" to a "focus on literacy" (Crippen & Archambault, 2012, p. 157). As a result, teachers act as facilitators in PBL environments, encouraging critical thinking in their students (Partnership, 2015). In other words, the role of teachers is not to lecture. Instead, teachers "[guide] the construction of knowledge" as students go through creative and problem solving processes (Schnittka, Brandt, & Evans, 2012, p. 10). As a result, students become less reliant on teachers as they explore new information and become more self-directed.

In addition to a shift in teacher roles, 21st century PBL classrooms also include computers and other technologies that are accessible for student research and technology skills development as well as to help teachers enrich and their lessons (Martin, 2015). Since today's society is dominated by computer technology, it is important that students have experience using computers and the Internet and they understand how to reap all the benefits these resources have to offer. If schools do not take advantage of available technologies in their classrooms they "cannot hope to meet the demands of a globalized, knowledge based society" (Crippen & Archambault, 2012, p. 158)

The final characteristic of a 21st century PBL classroom is active learning. Active learning is the process of having students that are engaged in their own learning – the students are active participants in their education and not just passive bystanders. If content is taught in a "contextual or applied manner," learning experiences become more "meaningful" to students (Gomez & Albrecht, 2014, p. 15). When educational experiences become more meaningful, students are more likely to become active participants in their own learning. Students who participate in active learning take interest in their education and become more likely to retain the knowledge and skills they gain through PBL (Morrison et al., 2015). All these classroom characteristics – teachers as facilitators instead of lecturers, access to computers, and active learning – have one goal in mind: create environments that foster 21st century skills and provide opportunities for PBL.

STEM and TEE classrooms take the 21st century PBL classroom a step further by creating environments designed exclusively to support PBL. These classrooms have the space and resources students need to think critically and creatively, collaborate with each other, and communicate their ideas and findings. Therefore, STEM and TEE classrooms should not look like the typical classrooms that consist of rows of desks. Instead, STEM and TEE classrooms are designed to "blur the boundaries between formal and informal, individual and group" (Daugherty et al., 2008, p. 24). As a result, well designed STEM and TEE classrooms should have separate areas for presentations, collaborative group work, research, fabrication, and testing (Daugherty et al., 2008). The goal is to create flexible learning spaces that will help to facilitate learning through student collaboration and innovation (Martin, 2015). Common trends found in up to date STEM and TEE classrooms include access to digital tools like computers, 3D printers, and laser engravers; mobile tables that can be moved to suit either individual or group work; and separate areas for lab and lecture (Martin, 2015; Daugherty et al., 2008). All these trends and characteristics help to create classrooms that have the space and resources necessary for hands on group work that will promote 21st century skills through PBL.

Many specialized STEM environments and TEE classrooms have already been created with these characteristics and trends in mind. One example of STEM education that utilizes a specialized space is Studio STEM. In this program the studio or classroom is used for "tinkering and experimenting" while learning engineering and science concepts in a "supportive environment" (Schnittka et al., 2012, p. 25). In an environment that provides "mental and physical spaces," students are able to develop "deeper understanding of content" and are overall more successful and motivated to complete engineering and science tasks (Schnittka et al. 2012, p. 3).

Other creative learning environments, such as STEM Labs, Makerspaces and Tinkering Studios, are also being integrated in schools. These educational areas provide the tools and space for people of all ages to build, tinker, explore ideas, fail and retry, and collaborate on projects of interest. In essence, STEM Labs, Makerspaces, and Tinkering Studios provide an environment where students can explore and experiment. These special learning and working environments are designed with hands on activities in mind, incorporating areas where students can work collaboratively on projects. However, the way these specialized classrooms are implemented can vary from school to school. Some STEM programs use their classrooms for afterschool clubs or extracurricular activities, while others integrate the use of the classroom into the curriculum as part of the school day (Martin, 2015).

No matter how dedicated classrooms like Studio STEM, STEM Labs, Tinkering Studios, or Makerspaces are used, they all have a common goal to provide students with an environment in which they can work on collaborative, hands-on, problem-based activities. These specialized learning environments provide the room, materials, and resources students need in order to work together effectively, solve problems creatively, and take ownership of their learning. By doing so, these classrooms provide students with authentic opportunities to develop 21st century skills like critical thinking, problem solving, creativity, collaboration, and communication. Therefore, as the drive for teaching 21st skills continues to increase, the need for specialized classrooms like STEM Labs, Tinkering Studios, and Makerspaces to house PBL is going to increase also. Not only are these environments essential in teaching STEM skills and technological literacy, but they are opening doors to the skills of the 21st century as well.

Conclusions

It is recognized that having a well-developed 21st century skills-set is the key to success in a technology driven, global society. However, due to teacher-centered methods, not all students have mastered these essential skills. With the help of PBL, STEM, and TEE, more students are being given opportunities to develop 21st century skills like technological literacy, critical thinking, problem solving, creativity, collaboration, and communication. By providing opportunities for authentic learning activities and content integration, PBL, STEM, and TEE are preparing students to survive and thrive in a technologically driven world. Although the benefits of PBL, STEM, and TEE are easily observed, classrooms that support these methods and programs can be hard to come by because of the prevalence of out dated facilities and teaching methods. If our students are expected to gain the skills they need through PBL, STEM, and TEE, classrooms need to be designed with hands on activities in mind. The only way students will be able to keep up with the changes in our technology driven world is if they are provided with the tools, materials, and environments (like those suited for PBL, STEM, and TEE) necessary to develop 21st century skills.

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