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Challenge-Based Learning & STEAM Curriculum

Abstract

STEAM education is being integrated into elementary schools as a way to engage more students in creativity, hands-on learning, and problem-based learning also referred to as Challenge-Based-Learning (CBL). This article focuses on elementary educators' curriculum design for STEAM and presenting students with open-ended questions phrased as a challenge as a way to raise student interest and achievement (DeJarnette, 2018; Hunter-Doniger, 2018). When students received challenges to solve, they felt more open to sharing their ideas since there was more than one potential right answer (DeJarnette, 2018; Drake, 2012). When implementing CBL, teachers act as facilitators using a constructivist approach as students work in small groups to design, test, and iterate prototypes of their solutions (DeJarnette, 2018; Driscoll, 2005). This article highlights the impact of CBL on student engagement in a STEAM Lab or Makerspace.

Keywords: Constructivist Theory, Challenge-Based Learning, STEAM Lab, Makerspace, Elementary Education, K-5th Grade, Growth Mindset, Problem-Based Learning

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Challenge Based Learning in a STEAM Curriculum

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Introduction

Challenge-Based Learning (CBL) is a curriculum tool that teachers use in a STEAM Lab to increase student engagement (Bender, 2017; Casteel, 2018; Drake, 2012). Constructivism is the theory that in practice fosters the role of the teacher as a facilitator, so students work together to find the solutions to their own scientific problems (Driscoll, 2005; Harasim, 2012; Tebes, 2018). The combination of constructivist theory and CBL as a curriculum design instrument is used in STEAM Labs as a practice to increase student engagement, scientific understanding, and growth mindset (Gopal & Pastor, 2015; Handelsman & Smith, 2016).

The importance of stressing science as one of the core academic subjects is outlined by The National Science Teaching Association as “critical” for students to make sense of the world and “make informed decisions.” The problem in elementary education is that subjects are usually taught independently from one another when the best way for students to learn and understand in depth scientific concepts is through real-world applications of CBL used with a constructivist approach by the teacher (Drake, 2012; Ertmer & Newby, 2013; Mergel 1998). These combined methods in a STEAM lab foster students’ exploration of scientific concepts and leads to a personalized understanding versus rote memorization of learning standards (Ertmer & Newby, 2013; Harasim, 2012; Tebes, 2018).

For example, in the most recent “Programme for International Student Assessment” (PISA) rankings, the United States placed 38th in math and 24th in science out of a total of 71 countries. As a result of these low rankings, it became important for the United States to find ways to strengthen education in science and math, and, subsequently, STEAM education programs became the solution in many elementary schools to engaging more students in science and math class using an interdisciplinary and project or problem-based approach.

The past 5 presidents launched initiatives to address science, math, and engineering in schools to prepare more students with the skills required for STEM degrees and increase the number of Americans graduating and going into the STEAM workforce (Mukherjee, 2018). Across the nation, schools continue to implement either STEM or STEAM programs into schools. However, many teachers, administrators, and parents are trying to understand what STEAM-focused curriculum and instruction are in terms of application, design, and implementation in a classroom setting (i.e., STEAM Labs or Makerspaces).

Current studies have found when a STEAM curriculum includes CBL students are provided with the opportunity to collaborate and share their own ideas and leads to an increase in student engagement and participation (Casteel, 2018; Courey, 2016; Bryk, 2014; Snow, 2014; Bulls, 2018; Weist, 2014). These practices combined with constructivist methodologies where the teacher takes on the role of a facilitator empowers students to develop an individualized understanding of in-depth scientific principles and learning standards (NGSS, 2019, Harasim, 2012; Gopal & Pastor, 2015).

Constructivist Theory

In a STEAM Lab or Makerspace, constructivist teachers foster students to create an individualized meaning and, many times, it also asks students do this work alongside other students simultaneously (Ertmer & Newby, 2013; Harasim, 2012). The focus in constructivism is the individual's experience within the world and how this applies to their cognition or understanding (Mergel, 1998). The importance of constructivist methodology in STEAM education is for students to take ownership over their work and attach meaning that is memorable (Ertmer & Newby, 2013; Harasim, 2012; Mergel, 1998).

As elementary schools' transition from traditional based science and math classes to STEAM education, many teachers are encouraged to use hands-on activities, Challenge-Based Learning, arts integration, and collaborative learning opportunities for all students (Casteel, 2018; Bryk, 2014; Snow, 2014; Weist, 2014). The Next Generation Science Standards and the Common Core Math Standards detail *what* students are to achieve in science and STEAM education, but do not detail *how*. The constructivist approach is the *how.*

STEAM pedagogy with a constructivist approach engages students' problem-solving skills while working in small groups (Drake, 2012; Tebes, 2018). When teachers introduce a STEAM-based curriculum and play the role of facilitator, this practice encourages individualized meaningful learning and fosters students to make connections to the world around them through personal experience (Ertmer & Newby, 2013; Harasim, 2012; Mergel, 1998; Quigley & Herro, 2019). Teachers report improvements in student engagement and achievement in STEAM Labs and Makerspaces when implementing a constructivist approach in their instructional technique (Cunningham & Berger, 2014; Gopal & Pastor, 2015; Tebes, 2018).

Challenge-Based Learning

Challenge-Based Learning is when teachers "challenge" students to solve a specific open-ended problem to solve (Tanenbaum, et al., 2016; Jamalian, 2018). Drake (2012) defined this type of Problem-based Learning (PBL) as Challenge-Based Learning (CBL), which includes introducing students to a big idea, asking an essential question (EQ) on the topic, and presenting students with a challenge to solve. Students work together to solve the challenges presented by the teacher. A CBL curriculum includes instruction designed to encourage student problem-solving skills to foster engagement and achievement (Berwick, 2019; Drake, 2012; Jamalian, 2018).

The approach to a STEAM curriculum that includes CBL integrates transdisciplinary and interdisciplinary approaches to education. Each subject in STEAM (Science, Technology, Engineering, Art & Math) is integrated into units of study instead of being taught individually or the traditional siloed approach to education. Interdisciplinary learning was first documented by John Dewey in 1929. His studies on progressive education, integrated curriculum, and learner-centered approaches to teaching and learning all encouraged collaborative, hands-on learning (as cited in Flinders and Thornton, 2017). Researchers posit that the implementation of transdisciplinary and interdisciplinary curriculum, such as CBL, improves student engagement and understanding of difficult material, which results in higher achievement (Casteel, 2018; Drake, 2012).

Studies conducted on STEAM and CBL in schools found that out-of-the-box curriculum and integrated teaching increased student engagement, achievement, and memory of learning objectives (Cunningham & Berger, 2014; Gopal & Pastor, 2015; Negreiros, 2017; Tebes, 2018). Concordia University (2017) published findings that a STEAM curriculum and CBL instruction broke away from the traditional approaches in education to foster creative learning and that is led to higher student achievement. Additionally, there was an increase in students' ability to problem solve and collaborate (Casteel, 2018; Negreiros, 2017). STEAM educators reported positive side effects from implementing

CBL; such as, higher quality education, increased student interest, and motivation (Casteel, 2018; Gopal & Pastor, 2015; Handelsman & Smith, 2016).

The research demonstrates that flexibility in a STEAM curriculum using CBL motivates more teachers and students to engage in class. Educational standards and content become increasingly more difficult as students progress through K-12 standardized education system. Students are more likely to participate in STEAM Labs and Makerspaces if they are presented with a challenge (CBL) and are given the opportunity to problem-solve in creative ways (Cunningham & Berger, 2014; Tanenbaum et al., 2016; Venditto, 2018).

Cases of Challenge-Based Learning in a STEAM Lab

Cunningham and Berger (2014) developed and tested a STEAM curriculum integrating engineering into the elementary science classroom. The curriculum included physical, life, and earth science for grades K-5. They found that at first many students, ages 5-12 years old, did not know what role engineers played in society but, with the implementation of their curriculum, students gained a better understanding by solving problems collectively to determine and experience the role of an engineer. The constructivist approach where the researchers acted as facilitators fostered student development and understanding of an “engineer” through building projects. Students were presented with a challenge and solved the problem by constructing samples of prototypes. As a result, students increased knowledge and applied techniques used by engineers to understand on a deeper level the role of an engineer (Cunningham & Berger, 2014; Ertmer & Newby, 2013; Harasim, 2012). Additionally, students increased their cooperative learning skills such as verbal communication and sharing (Cunningham & Berger, 2014).

In a different study, Johnson, Smith, Smythe, and Varon (2009) researched the efficacy of CBL in science education. They worked with 29 teachers and 321 students to focus on problem-solving skills. Their curriculum presented students with real-world challenges to solve (i.e., CBL) instead of the traditional rote memorization skills used in a science lab. Their curriculum demonstrated that students can learn from one another and teach each other simultaneously (Johnson, et al., 2009). When students were presented with a STEAM CBL curriculum, teachers shared those students worked together to determine, test, and retest possibilities to solve the real-world challenge (Johnson, et al., 2009). Many teachers reported that CBL motivated their students on a deeper level, increased collaboration among students, and created a shared learning experience (Cifaldi, 2018; DeJarnette, 2018; Quigley and Herro, 2019). Additional findings on STEAM and CBL integration included students reporting increased positive attitudes in class and the practice of using a growth mindset (Johnson, et al., 2009). Researches stated that teaching CBL instead of using traditional science and math siloed education techniques proved to be effective as a methodology for improving STEAM education in schools (Johnson, et al., 2009).

Recommendations

While standardized testing measures are linked to Common Core Standards (CCS), and therefore subjects, such as, math and English (Turano, 2018), The Next Generation Science Standards (2013/2017) are written as *performance* standards. STEAM education in an elementary setting is not subject to standardized assessments like the Common Core, but rather the NGSS asks that the students perform or show their understanding of the content. Therefore, a CBL framework applied to STEAM education fosters student demonstrations of their knowledge learned and creates a deeper level of understanding and memory (Tebes, 2018, Johnson, et al., 2009, Harasim, 2012). In performative assessments, educators gather materials, such as, demonstration pictures or videos, journal entries, portfolios, PPT presentations, and teacher-generated rubrics (Berwick, 2019; Drake, 2012; Tanenbaum, et al., 2016).

Early Intervention

Researchers across the board published findings on the importance of early intervention in STEAM to engage and motivate students to participate (Holdren, 2013; Jamalian, 2018; Tanenbaum et al., 2016; Venditto, 2018). Holdren and The Committee on STEM Education and the National Science and Technology Council (2013) found that exposing children to a STEAM curriculum in elementary school sets a foundation for learning. The importance of early intervention increases student engagement and fosters their creativity (Venditto, 2018). As students advanced through school and STEAM curriculum becomes increasingly difficult, students stay engaged in STEAM subjects with a foundation formed in their early learning years. When they are presented with challenges, they feel prepared to problem-solve in creative ways (Cunningham & Berger, 2014; Tanenbaum et al., 2016; Venditto, 2018).

Growth Mindset

Traditional science and math education gave praise to students based on the correct "right" answer and the ability to perform according to a series of prescribed steps, which has resulted in generations of students disengaging from science and math (Johnson, et. al, 2009, Weist, 2014). On the other hand, when STEAM educators present students with challenges to solve and offer praise based on effort and reasoning skills; and as a result, student engagement and achievement increased (Casteel, 2018; Courey, 2016; Jamalian, 2018; Weist, 2014). Praising a student based on effort and reasoning skills is a pedagogical technique Carol Dweck (1986) calls "growth mindset," so students understand that with hard work and dedication, they are capable of learning any and all subjects (M. Buoncristiani & P. Buoncristiani, 2012; Jamalian, 2018). Growth mindsets encourage educators to provide students with the opportunity to be risk-takers and occasionally fail, which is in actuality how STEAM operates in the real world (M. Buoncristiani and P. Buoncristiani, 2012; Tebes, 2018). Growth mindsets and a CBL curriculum teach students grit, determination, and perseverance, which is necessary to stick with subjects like STEAM where failure often occurs (M. Buoncristiani & P. Buoncristiani, 2012; Quinton, 2014).

Conclusions

To increase the number of students and graduates in the STEAM fields, the traditional teaching methodologies of siloed science and math instruction need to be reevaluated. The recommendation is to implement a Challenge-Based Learning framework to promote student engagement and achievement (Johnson, et. al, 2009; Tanenbaum et al., 2016; Weist, 2014). When presenting students with challenges, teachers act as facilitators and allow students to work in small groups to problem-solve, actively struggle, and develop their own understanding of the material (Driscoll, 2005; Ertmer & Newby, 2013; Mergel 1998). CBL and STEAM pedagogy combined foster student-centered learning.

STEAM teachers support without giving students accolades for "right" and "wrong" answers (Jamalian, 2018). The effectiveness of these combined theories and strategies (i.e., constructivist approach, CBL, and a STEAM Lab or Makerspace setting) result in higher student participation, collaboration, and achievement (Bender, 2017; Casteel, 2018; Drake, 2012). The recommendations are for schools to start engaging learners earlier in STEAM-minded education and move away from traditional educational practices.

Additional resources for interested educators, administrators, and parents:

The National Science Teachers Association and their elementary educator magazine titled, *Science and Children* https://www.nsta.org/elementaryschool/, offers free lesson plans, articles of support, and other ideas for creating innovative STEAM education

Agency by Design is a research branch based in Harvard's Graduate School of Education that studies and produces engaging maker-centered and CBL ideas for educators across the globe. More information is available at this link http://www.agencybydesign.org/. Additional lesson plans, tools for teachers, and thinking routines are available for free through their research center.

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