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Don't Run Out Of STEAM! Barriers to A Transdisciplinary Learning Approach

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Don't Run Out of STEAM! Examining Instructional Barriers to a Transdisciplinary Learning Approach

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Abstract

Reform-based instruction can maximize learning and provide equitable access for students in both mathematics and science. A proposal for change by national organizations shed light on the need for programs in integrated science, technology, engineering, and mathematics (STEM) or with the inclusion of the arts (STEAM). A balanced approach to integrated STEAM education uses real issues from around the world to challenge students to be innovative, creative, and think critically about ways they can provide solutions. The purpose of this article is to highlight the potential of a transdisciplinary STEAM instructional approach, while examining the barriers that teachers face in implementation, and provide possible suggestions that allow for successful implementation of transdisciplinary STEAM instruction. With the growing interest in STEM education, it is important to better understand teacher challenges and obstacles to provide support for educators who are developing and implementing integrated STEM instruction. Integrated STEAM allows for creativity across disciplines and promotes students to become conceptual thinkers who are ready to approach future careers and education with more imagination and innovation.

Keywords: STEAM, STEM, education, barriers, transdisciplinary

It is no secret that education approaches have changed dramatically over the years. We can all reach into a memory of our learning experiences as children, and no two of them are alike. Imagine a classroom where desks are always in straight rows, most work is assigned from a textbook, and lessons are taught through direct instruction with students following notes on the board. Many of us have similar memories of this type of learning at some point in our education, while others may have an experience that was much different. Many parents and educators feel their children should be taught using the same methods they were taught, through memorization, formulas, procedures, and repetition.

The National Council of Teachers of Mathematics (NCTM, 2009) disagrees with these traditional methods, stating that mathematics should be taught to promote reasoning and problem solving, where lessons are focused on discourse through engaging students in high quality tasks. The National Research Council (NRC) provided a Framework in 2012 that gave further support to the call for change in education practices, stating that learning experiences should engage students with fundamental questions focused on the world around them through scientific investigations and engineering design. Such reform-based teaching is intended to provide equitable access to both science and mathematics content and practices in a way that can maximize the learning potential of each and every student (Bush & Cook, 2019). This proposal for change by national organizations such as National Council of Teachers of Mathematics (NCTM), National Council of Supervisors of Mathematics (NCSM), National Science and Technology Council (NSTC) and National Research Council (NRC) shed light on the need for programs in integrated science, technology, engineering, and mathematics (STEM) or with the inclusion of the arts (STEAM).

In particular, this change is needed at the middle school level, when young adolescents are searching to find their place in the world. This work aligns to the Association for Middle Level Education's (formerly National Middle School Association) *This We Believe*, which identifies one of the 16 characteristics of successful schools as engaging students in curricula that is challenging, exploratory, integrative, and relevant (NMSA, 2010).

A balanced approach to integrated STEAM education prepares students to use innovation, creativity, critical thinking, collaboration, and effective communication to solve some of the world's most pressing issues (Quigley & Herro, 2016). Bush and Cook (2019) explain how integrated STEAM education helps to prepare students for future careers by engaging students in transformative learning experiences in the classroom. STEAM-based instruction increases academic achievement in schools and builds knowledge in critical areas that will be important to tomorrow's workforce (Quigley & Herro, 2016). Dewey's (1938) progressive education movement provided insight into the roots of integrated STEM and supports that an integrated approach is necessary to deal with today's problems in society. Global and national attention to STEAM poses a challenge to education, calling for innovative ways that teachers can implement quality tasks and help students to be successful (Quigley & Herro, 2016).

A Call for Change

STEM education has become a priority in the United States as students persistently score low in science and mathematics on international and national assessments (Du et al., 2019). The United States Congress enacted the *STEM Education Act of 2015* after Programme for International Student Assessment (PISA) produced a report in 2015 showing that the situation in the United States had not improved in nearly a decade, which provided concerns that STEM workforces would be impacted in the future (Du et al., 2019). The *STEM Education Act* was enacted by the US Department of Education (2016) which renewed commitments with the National Science Foundation (NSF) calling for a more integrated approach while moving away from the traditional approaches of learning science and mathematics in isolation to better prepare students with the skills that are necessary to solve societal problems of today (Du et al., 2019). A new vision for STEM education was introduced in 2018 by the United States Department of Education Office of Innovation and Improvement which calls for STEM to be meaningful and inspiring, where students are engaged in transdisciplinary activities that require them to identify and solve problems using knowledge across disciplines with initiative and creativity (NSTC, 2018).

The purpose of this article is to highlight the potential of a transdisciplinary STEAM instructional approach, while examining the barriers that teachers face in implementation. By identifying these barriers, we can offer possible suggestions that allow for successful implementation of transdisciplinary STEAM instruction.

A Transdisciplinary Approach

A transdisciplinary approach is, in essence, "beyond the disciplines," where students and teachers are using collaborative expertise to pose and solve problems in a way that foregrounds the problem outside a single discipline (Quigley & Herro, 2016). Bush and Cook (2019) define transdisciplinary as "going beyond the disciplines to create new knowledge or ideas" and suggest connecting with the community to identify real issues in the community so student learning can be situated in meaningful contexts. Edelen et al. (2019) describe a transdisciplinary inquiry as a way to present problems where the students become so engaged in the problem that they use previous knowledge to acquire new knowledge from multiple disciplines where the focus is on the student, allowing them to decide on their learning and the knowledge needed to find solutions to authentic problems.

Bush and Cook (2019) offer quality STEAM inquiries in their publication, *Step Into Steam.* An ideal STEAM inquiry sample task, a second-grade inquiry titled "Preventing Dehydration in a Blizzard: Melting Ice" (p. 129) from this publication lays out both content and standards and explains what students are doing during the inquiry. The problem statement for the students provides a context with a family snowed in for a blizzard. Students are asked to find a way to melt the ice so they can get their family to necessary supplies for survival. For this inquiry, students are using multiple materials to design a heater to melt ice for science, using a timer to track the time it takes to melt for technology, choosing appropriate materials and modifying their design for engineering, creating a bar graph for materials tested for mathematics, and finally simulating movements of ice and water molecules for arts. This STEAM inquiry example helps to outline the importance of an approach to learning that is transformative, allowing students to solve problems that go beyond the classroom and find solutions to issues that could be meaningful (Bush & Cook, 2019).

When examining a transdisciplinary approach, Quigley and Herro (2016) explained that life is rarely confined to artificial boundaries of a specific academic discipline, and in order to meet the demands of the societal, environmental, industrial, scientific and engineering problems of the real world, it is important to examine a problem through frameworks that allow for this type of thinking. This type of approach tends to be the most difficult to achieve, as it requires a common perspective as members of different disciplines work together to share a conceptual framework and have the same shared goals (Choi & Pak, 2006). A transdisciplinary approach integrates the natural, social, and health sciences in a way that it focuses on a humanities context and transcends individual traditional boundaries (Choi & Pak, 2006). Herro and Quigley (2016) explain that transdisciplinary teaching helps students to explore content areas using a multiple inquiry process in which students connect to the disciplines naturally through the problem-solving process.

Transdisciplinary teams share both goals and skills, using a shared conceptual framework to approach a common problem (Choi & Pak, 2006). This type of instructional approach can strengthen student learning and increase their desire to pursue a career in science or mathematics, but it is difficult to know how to effectively support transdisciplinary teaching with pedagogical techniques that meet curriculum requirements (Herro & Quigley, 2016). A transdisciplinary approach is the movement from one discipline to another fluidly (Figure 1) where students are using the skills necessary to solve problems while making connections to the world around them.

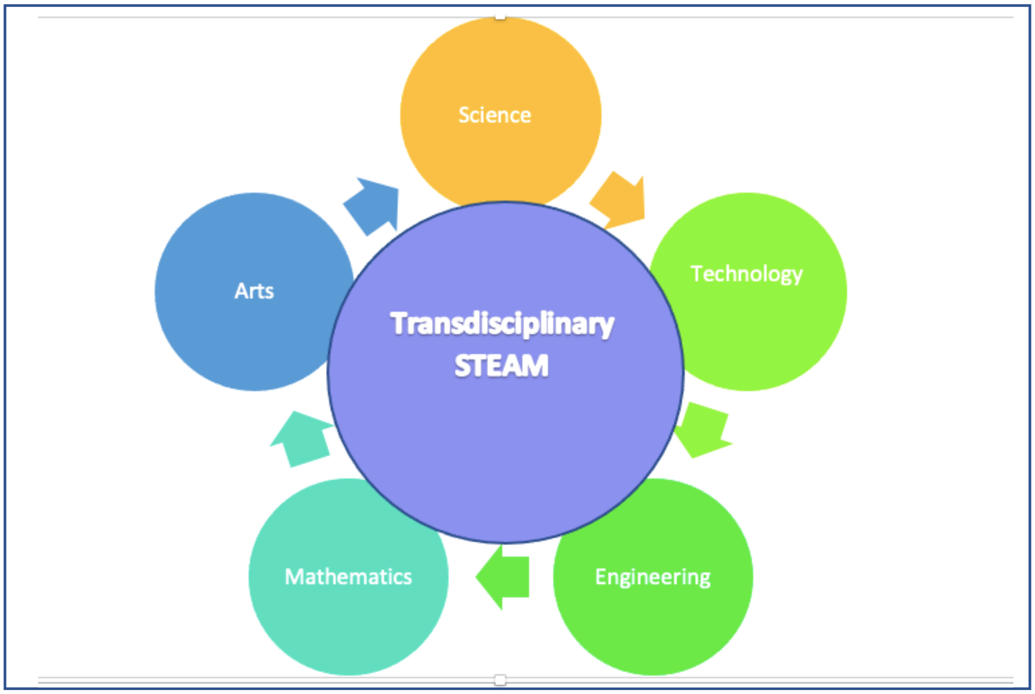

Figure 1. A diagram to illustrate the idea of transdisciplinary, showing that it moves fluidly from one discipline to another.

STEM to STEAM

Teachers need a clear definition of integrated STEAM education to allow them to truly understand what is expected and improve their practice (Quigley & Herro, 2016). The addition of the arts in the original STEM approach allows for new approaches to problem solving that provides a natural platform for a transdisciplinary inquiry and provides us with the new anacronym of STEAM (Quigley & Herro, 2016). The addition of the A acknowledges the importance of adding emotional connections and an appreciation for beauty, creativity, and aesthetics into the development of solutions in problem solving (Bailey, 2015. Art, science, music, and mathematics are fluid and breaking the boundaries between disciplines allows educators to engage learners in creative ways to solve problems (Henriksen et al., 2015).

With a focus on STEAM teaching practices in science and mathematics in middle school classrooms, Quigley and Herro (2016) found that STEAM teaching involves a major shift in teaching for many, and it takes time to refine and implement effectively. It is common for educators to express concern that content could lack rigor if not taught in a concentrated manner (Park et al., 2007; Bush & Cook, 2019). However, integrated STEAM learning helps students understand how concepts or skills are connected across disciplines and encourages them to use those skills in meaningful ways (Bush & Cook, 2019). A desire for a balanced approach lends itself to a STEAM focus, where art can incorporate new approaches to problem solving and delivers a natural entry to a transdisciplinary inquiry (Quigley & Herro, 2016). Some barriers that may prevent teachers from implementing transdisciplinary STEAM teaching include time constraints, lack of understanding of problem-based versus project-based learning, testing pressures, lack of understanding of other content areas, and collaboration among students (Quigley & Herro, 2016).

It is important to consider the reason STEAM instruction is still elusive to so many and figure out why it remains a struggle to broadly implement successfully. Eliminating barriers would allow teachers to create a learning environment that promotes investigations that allow for students to engineer solutions to problems and construct explanations based on evidence of real-world phenomena (Shernoff et al., 2017). The goal of transdisciplinary STEAM instruction is to prepare students to solve the pressing issues facing the world through critical thinking, effective communication, and collaboration (Quigley & Herro, 2016). Due to the rising trend of integrated STEAM education in K-12 schools and newly created schools specifically dedicated to STEAM instruction, it is imperative to research and support ways to support teachers in implementation. Quigley and Herro (2016) note that research is necessary to discover any barriers that could be holding back implementation and find ways to help educators to make sense of this innovative teaching practice.

Many educators have implemented inquiries in their classrooms which they have considered to be STEAM focused, but they have done so without complete understanding of what these inquiries are and what they are intended to achieve. Problems are commonly introduced by providing a problem to be solved, but the process lacks the depth and opportunity for connections or conceptual development across disciplines. Providing a real issue with a meaningful context could potentially allow the students to transcend the boundaries of a single discipline and form their own learning and understanding as they seek a solution to the problem. Problems similar to "Preventing Dehydration in a Blizzard: Melting Ice" (p. 129) by Bush and Cook (2019) have the potential to encourage engineering design, science and mathematics simultaneously without consideration of acknowledging subjects as individuals. The way an inquiry is implemented plays an instrumental role in the learning that students obtain from the inquiry. STEAM inquiries should engage students in an authentic open-ended problem with multiple solution paths where all students can contribute and work together toward a common goal (Bush & Cook, 2019). This transition in selection and implementation is what is needed in order to prepare students for the real-world problems they will face.

Barriers Educators Face in Implementing Transdisciplinary STEAM

Despite the many calls to increase integrated STEAM approaches in the classroom, there exists many barriers that have prevented educator efforts from being successful. Originally referred to as SMET by the National Science Foundation, STEM brought about educational initiatives to challenge students with critical thinking tasks designed to ready them for the future workforce (White, 2014). Barriers to STEM and STEAM instruction include a lack of teacher understanding, lack of time for collaboration and planning, and barriers of school organization (Shernoff et al., 2017; Herro & Quigley, 2016). With the growing interest, it is important to better understand challenges and obstacles to provide support for educators who are developing and implementing integrated STEM instruction (Shernoff et al., 2017).

Lack of Teacher Understanding

A lack of understanding may be a barrier that can be contributed to the somewhat recent age of technology, where teacher preparation has failed to keep up with the rapid introduction of new technologies. Teachers must be prepared to teach with technology and twenty-first century skills to have the foundation to practice, collaborate and implement STEAM units successfully (Quigley & Herro, 2016). Shernoff et al. (2017) contend that most teachers went to college before integrated

STEM became a focus, which leads to many teachers who have little to no practice in STEM approaches. The national K-12 STEM movement provided a push to develop educators in STEM areas which has been met with very little attention to teacher preparation or professional development where little research exists on methods to effectively prepare teachers for implementing STEM (Rinke et al., 2016). The call for a transdisciplinary focus also poses the barrier of lack of understanding in content and standards of subjects outside of the focused discipline of the middle school teacher (Shernoff et al., 2017). It is difficult to imagine a way to prepare teachers with the pedagogical content knowledge required to teach all STEM subjects simultaneously and effectively, when science, mathematics or technology require large amounts of content knowledge to teach each subject individually (Sanders, 2009). Introducing STEM educators to foundations, pedagogies, curriculum, research and contemporary issues allows them the opportunity to integrate complementary content and better understand integrative approaches in their classrooms (Sanders, 2009).

Lack of Time for Collaboration

This lack of understanding leads to the next barrier—a lack of time for collaboration among colleagues. Creating effective learning environments full of student engagement and effective instruction requires collaborative teacher planning that must be supported consistently by school leaders (NCTM, 2014). Time for collaboration during the school day is inadequate, and most schools do not have a daily schedule that provides time for professional collaboration that is necessary to strengthen pedagogical skills (NCTM, 2014). Both the lack of time for collaborative planning and the lack of time for STEM instruction are discussed as barriers that hinder the abilities of teachers to generate ideas and support each other's work (Shernoff et al., 2017). A team that is considered transdisciplinary is composed of members who have developed trust and mutual confidence that allows them to transcend disciplinary boundaries to move toward a holistic approach (Choi & Pak, 2006). Allotted time for collaboration would allow for teamwork to support transdisciplinary STEM education (Shernoff et al., 2017). Collaboration allows an opportunity to connect with experts in other fields to provide necessary support for implementation of multiple content areas (Herro & Quigley, 2016). Collaboration is believed to assist teachers in understanding STEAM content and connect to experts in the field which allows for transdisciplinary teaching (Herro & Quigley, 2016). Time for collaboration must be considered as a crucial component to the implementation of effective STEAM inquiries.

Barrier of School Organization

Though many teachers desire the time for collaboration with their colleagues, others suggest STEM should be its own class completely (Shernoff et al., 2107). With the arrangement of middle school bell schedules, time to implement STEM activities in the classroom is restricted (Shernoff et al., 2017). Bush and Cook (2019) explain that integrating STEAM subject areas allows for subject area standards to be addressed simultaneously, helping to address the issues of time constraints in schedules. Herro and Quigley (2016) noted the lack of flexibility over the pacing of the courses, explaining limits to transdisciplinary approaches due to the prescribed nature of the scope and sequence of the courses they wish to integrate. STEAM can be interwoven into time that is already dedicated to mathematics and science, toward the end of instructional units, or during specific blocks of time each week or month as possible solutions to scheduling issues (Bush & Cook, 2019).

Discussion, Implications, and Suggestions

With the identification of the barriers that teachers face in the classroom, it is important to examine ways to overcome those barriers and move forward. Today's young adolescents are exposed to technology in ways that were unforeseen decades ago and dated approaches to pedagogy will not be sufficient for students who are entering schools now or in the future (Wynn & Harris, 2012). Transdisciplinary approaches will take practice, and each inquiry should prove a learning opportunity for teachers to grow and improve. Professional development sessions or workshops could offer opportunities for teachers to work together to experience STEAM activities and help support them as they design and implement them in the classroom. The increase in focus on STEAM instruction as a powerful learning area for future workforce should be noted in the development of curriculum and design of school organizational structures. Building community partnerships that allow students the opportunity to experience STEAM careers or speaking with professionals that hold STEAM careers can help build interest and provide teachers with content for lessons. Support from coaches, administrators, and districts is key in promoting a positive learning environment that allows for teachers to embrace change. Further research is needed to help educators overcome the barriers in the implementation of integrated STEAM principles to allow them to provide impactful contextual learning opportunities for all students. Integrated STEAM opportunities allow for creativity across disciplines and promotes students to become conceptual thinkers that will approach future careers and education with more imagination and innovation (Wynn & Harris, 2012). Transdisciplinary STEAM should become a forefront of educational focus and discussions to allow for teachers and students to embrace this innovative learning experience.

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