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Centering Students in Transdisciplinary STEAM Using Positioning Theory

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ABSTRACT

Integrated STEAM instruction continues to be a major focus of K-12 education. In effort to better understand STEAM education, we reviewed existing frameworks for implementing integrated STEAM in classrooms. We found that existing frameworks largely focused on the lens of the teacher, thus leaving the student perspective of STEAM learning experiences out of conversations centered on both research and practice. The purpose of this theoretical paper is to center STEAM education on students' rights, obligations, and duties within integrated STEAM instruction as a way to refine understanding of students' positions in STEAM learning experiences. We use theoretical considerations and evidence to explore new ways for transdisciplinary STEAM to be conceptualized from a student perspective. We conclude with considerations and implications for future STEAM education research.

Keywords: elementary STEAM, positioning theory, student repositioning, transdisciplinary

Introduction

K-12 schools have increasingly focused on science, technology, engineering, art, and mathematics (STEAM) education (Liao, 2019) due to the perceived benefits of an integrated learning experience. While some research has been conducted related to understanding students' experiences in STEAM instruction (e.g., Bush et al., 2020) much of the literature in STEAM education remains focused on teachers' understanding or implementation of integrated STEAM instruction (e.g., Herro & Quigley, 2016; Jacques et al., 2019; Quigley et al., 2019). The purpose of this theoretical paper is to center STEAM education on students' rights, obligations, and duties within integrated STEAM instruction as a way to refine understanding of students' positioning in STEAM learning experiences. We use positioning theory (van Langenhove & Harré, 1999) to explore how students are positioned during STEAM inquiries and focus specifically on how some inquiries invite or limit students' potential positions and shape their opportunities for transformative learning. Through the exploration of student positioning in STEAM, we highlight how specific disciplinary integrations lend themselves more naturally to repositioning students towards transformative learning experiences.

While STEAM and science, technology, engineering, and mathematics (STEM) education have been a focus of policy makers and administrators (Liao, 2019) for decades, they have different roots that have ultimately positioned students in different ways. Because STEM has its roots in workforce development, students receiving STEM education are positioned with the tools needed to prepare them for eventual jobs or to meet the needs of a global market economy (National Research Council, 2011). STEAM literature adds another element to this aforementioned lens by integrating art education into STEM as a way to engage more learners (Ahn & Kwon, 2013; Bequette & Bequette, 2012; Wynn & Harris, 2012). The addition of "A," shifting from STEM to STEAM, recognizes the role that aesthetics, beauty, and emotion play in arriving at solutions to problems (Bailey, 2016). STEAM specifically focuses on students solving authentic problems by positioning them to make their worlds better (Bush & Cook, 2019). Integrated STEAM instruction draws on creativity, aesthetics, and personal expression, while positioning students to design solutions for others (Cook & Bush, 2018). An important component of integrated STEM and STEAM is the role of empathy in solving problems for others (Bush et al., 2022; Bush et al., 2020; Edelen et al., 2020; McGee & Bentley, 2017; Sun, 2017). The inclusion of empathy offers a catalyst through which students can both begin to realize why disciplinary knowledge is needed to make sense of the situation under investigation, as well as generate new and novel solutions (Bush et al., 2022; Cook & Bush, 2018).

While several frameworks exist for integrated STEAM education, the role of students within STEAM learning experiences is left largely out of the conversation. Curricular ideas for how to better understand, conceptualize, and develop the highest quality STEAM learning experiences include ideas about best practices in STEAM inquiry design and implementation, but do not address how the students are positioned within the learning, nor what can make STEAM a transformative experience for students.

In this paper, we build from several existing frameworks in the field (e.g., Bush & Cook, 2019; Hwang & Taylor, 2016; Quigley et al., 2017; Yakman, 2011) to focus on different integrated approaches to STEAM instruction (i.e., multidisciplinary, interdisciplinary, and transdisciplinary), while drawing clear connections to student authority within such integrations. We first discuss existing STEAM conceptual frameworks and then highlight the inclusion of empathy as a key component to STEAM. We then propose a new conceptual framework for integrated STEAM instruction from a student perspective.

Existing STEAM Conceptual Frameworks

During the past decade, frameworks have been developed to inform and guide components of integrated STEM education theory and practice (e.g., Bybee, 2010; Falloon et al., 2020; Honey et al., 2014; Kelley & Knowles, 2016; Lee & Nason, 2012; Reider et al., 2016; Tan et al., 2019; Yata et al., 2020), which are summarized in more detail by Jackson and colleagues (2021). In science education, the National Research Council (NRC, 2012) calls for teachers to guide students in understanding and grappling with ethical and moral implications as well as the human context of science. Frameworks such as the Science, Technology, and Society (STS), Science, Technology, Society and Environment (STSE), and Socio Scientific Issues (SSI) have provided structures and considerations for teachers to engage students with the impacts science has on society. Chowdhury (2016) explains that the "STS/STSE and SSI integrated approach may help to focus more holistically on the humanisation and socialisation aspects of science practices; and can increase the awareness of social implications" (p. 35). Our work complements these and other frameworks that have emphasized the importance of the humanistic elements of learning. And, while these frameworks have helped push the field of integrated instruction forward in important ways, this paper specifically focuses on integrated STEAM.

Therefore, we now take a closer examination of existing integrated STEAM frameworks.

One integrated STEAM framework, *STEAM: A Framework for Teaching Across the Disciplines* (Yakman, 2011), focuses on the general integration of the STEAM disciplines using a pyramid to showcase that as you move up towards the top of the pyramid from content and discipline specific silos to a more integrative STEAM approach, this leads to "more engaging and deeply embedding ways within the already well-established realm of education" (Yakman, 2011, p. 3). A second framework, *Interdisciplinary Approach to STEAM Education for Students with Disabilities*, by Hwang & Taylor (2016), focuses on STEAM for students with disabilities and includes the integration of the disciplines in STEAM, real world contexts/authentic problems, and generalizability.

Quigley and colleagues (2017) developed a STEAM framework, *STEAM Teaching Model*, but this frame focuses specifically on a teaching model for STEAM and includes two domains (instructional content and learning context) and six dimensions (problem-based delivery, discipline integration, problem-solving skills, instructional approaches, assessment practices, and equitable participation). The STEAM Teaching Model is derived from extensive work with middle school teachers and centers on (a) real-world applications that have no definitive solution; (b) the need for multiple disciplines to address the problem; and (c) the need for students to use collaborative skills in finding a solution. A fourth framework, Equitable STEAM Education by Bush and Cook (2019) focuses on equity in STEAM and identifies three essential elements for equitable STEAM education: 1) providing access to each and every student, 2) implementing reform practices in mathematics and science teaching in STEAM instruction, and 3) exploring meaningful and authentic problems through STEAM. We have provided Table 1 to aid in summarizing across each of the frameworks.

Table 1

Frameworks in STEAM

Framework	Authors and Year	Focus
STEAM: A Framework for Teaching Across the Disciplines	Yakman, 2011	General integration of STEAM subjects from a siloed approach to an integrative approach to teaching
Interdisciplinary Approach to STEAM Education for Students with Disabilities	Hwang & Taylor, 2016	Teaching STEAM for students with disabilities. Focuses on integration of subjects and using real world contexts
STEAM Teaching Model	Quigley et al., 2017	Focuses on a teaching model of STEAM. Includes two domains (instructional content and learning context) and six dimensions (problem-based delivery, discipline integration, problem-solving skills, instructional approaches, assessment practices, and equitable participation)
Equitable STEAM Education	Bush & Cook, 2019	Focuses on attending to equity in STEAM through access, reform practices, and using meaningful and authentic problems.

These four frameworks presented provide important guidance to the field regarding different aspects of STEAM education and during the past decade, based on publication dates, there is a clear trajectory towards new learning and more sophisticated ideas related to STEAM education. In this paper, we complement and expand on these ideas about STEAM teaching and learning by a) adding a key component of empathy to the discussion; and b) recentering the focus of STEAM education on a student's perspective of their STEAM learning.

The work of Bush and Cook (2019) informs our next steps as they argue that the foundation of STEAM education is a commitment to transcending disciplinary boundaries through equity, empathy, and experience. Specifically, they approach *equity* as access to STEAM instruction for each and every student (rather than STEM or STEAM instruction being available only after school or in an advanced program, for example). Whether through a laboratory setting, where STEAM instruction is the primary focus, or a traditional classroom setting, every student deserves access to the meaningful learning STEAM approaches provide such as rich discourse, collaboration, risk-taking, authentic problem solving, and connections to their community and self. Equity does not mean every student enters the STEAM conversation the same way, but that every student has the opportunity to access the conversation with their voices and lived experiences valued. The *experience* of STEAM, rich in expression, collaboration, exploration, authenticity, and innovation pushes educators to do whatever is necessary to fully engage students in the content. Finally, *empathy* grounds the STEAM experience in the "why." Empathy positions students to be change agents for the betterment of not only their realities but to also think deeply about how they might meet the needs of others in an effort to improve lives. From the educators' perspective, empathy refocuses the attention from a product only inquiry to encouraging their students to be charged with observing and engaging in more mindful, meaningful, and insightful ways in the service of others.

The Importance of Empathy in the STEAM Experience

Smith and Paré (2016) argue that incorporating empathy through the arts in STEM instruction addresses the need for an affective connection for students to grasp difficult concepts and ascribe importance to them. The inclusion of empathy through the arts makes STEAM different from STEM, and intentionally grounding STEAM in equity, experience, and empathy (Bush & Cook, 2019) differs from other movements in elementary science and mathematics education. Maxine Greene (1988) makes the following argument, connecting "art forms" and empathy to transformation.

> For those authentically concerned about the 'birth of meaning,' about breaking through the surfaces, about teaching others to 'read' their own worlds, art forms must be conceived of as ever-present possibility. They ought not to be treated as decorative, as frivolous. They ought to be, if transformative teaching is our concern, a central part of curriculum, wherever it is devised. (p. 131)

What Greene suggests as an "ever present" sense of empathy through the arts is uniquely positioned to truly transform instruction in concert with whatever content students encounter. Approaches rooted in empathy cannot be relegated to the sidelines or included only as a means of checking off a list. Greene (1995) notes "if the significance of the arts for growth, inventiveness and problem solving is recognized at last, a desperate stasis may be overcome" (p. 382).

Land (2013) points to potentially transformative uses of the arts in this way, specifically musical compositions, kinetic art, product design, prototype development, and performance art as ways to connect people. Additionally, Land (2013) explores how the inclusion of empathy through the arts as part of STEAM might affect student outcomes. Sharapan (2012) points to the famous pop culture icon Fred Rogers and his show Mister Rogers' Neighborhood as a model approach for how empathy through engagement with the arts might be fully included and valued in broader elementary science and mathematics research and pedagogical conversations, naming students as "magical thinkers" in their educator-facilitated explorations of the world around them through music, dance, descriptive language, building, making, and connecting with others. For students highlighted in this research, embracing empathy through the arts allows for creative liberation and broadening of content knowledge. For educators, embracing the arts allows students to "collaborate with different subject teachers [to] relieve teachers' burdens and save more time to acquire new pedagogies" (Ahn & Kwon, 2013, p. 1859). When educators collaborate, not only do they benefit logistically (as workloads are often shared), but also educationally as professional knowledge is shared and professional capacities are enhanced.

Elementary science and mathematics reform documents (e.g., Larson, 2017; National Council of Teachers of Mathematics, 2014; 2020; NRC, 2012; President's Council of Advisors on Science and Technology, 2010) and the incorporation of empathy through the arts encourage elementary educators to find new ways of thinking and to invite students to embrace possibilities. The inclusion of empathy represents an opportunity to look beyond the past towards better futures, futures which include equal distribution of resources, futures without discrimination based on gender identity, race, sexual orientation, being inclusive of each and every person. The Arts, a pathway for empathetic engagement, are more than merely the incorporation of simple visualizations but focused on a broader more forward-thinking, idealistic vision for what was possible. Greene (1995) suggests educators free and unleash the arts to empathize with others. According to her, doing so provides enrichment for both students and educators and brings purpose to what can be too heavy a focus on a rigid and non-emotional scientific and technological progress that can overshadow personal and social growth. In short, adding the A to STEAM and focusing on empathy brings about the opportunity to refocus on more transformative instruction.

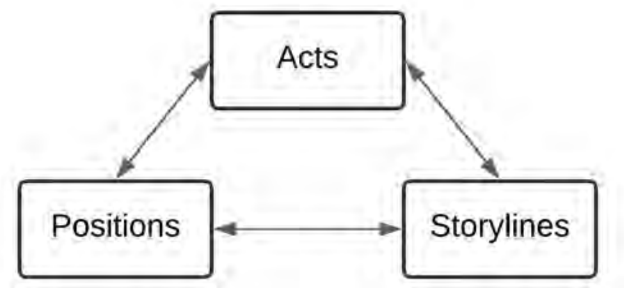
Theoretical Framing

To articulate the role of empathy and the potential it has in positioning students to transcend disciplinary boundaries, we draw from the work of van Langenhove and Harré's (1999) positioning theory. We use positioning theory as an explanatory theory (Green et al., 2020) to highlight and describe the observable and unobservable details of interactions that comprise social life. In particular, positioning theory encapsulates the positions that define storylines enacted by actors in social contexts. In this paper, we will use each of the vertices in the *Positioning Triangle* from Harré and Moghaddam (2003) to explore the social life and contexts of an elementary school classroom. Within the triangle (see Figure 1; inspired by Harré & Moghaddam, 2003), *positions* are the potential rights and duties performed within certain social situations. Importantly, a position limits what is possible for an actor to say or do in a social situation. The second vertex of the triangle, *acts*, refers to the social actions that are performed by actors in the social situation, and thus are contextually significant. The third vertex within this triangle encompasses *storylines*, which are the ways in which social situations play out due to positions, social acts, and narrative conventions. Because storylines do not unfold in random ways, but instead follow a practiced and established pattern of interactions, locating the positions of actors (e.g., students, teachers, principals, paraprofessionals) in social situations is a means to illuminate the rights, duties, and responsibilities of each person in a particular context.

For the purposes of this paper, positioning theory helps situate the exploration of classroom structures in order to gain insights into the negotiations of authority, status, and power within STEAM instruction. In this paper, we purposefully explore beyond the simple binaries of student identities in STEAM contexts (e.g., power/powerless) to engage in the complex storylines enacted by the actors (e.g, teachers and students) involved in STEAM inquiries.

Figure 1

Example Positioning Triangle

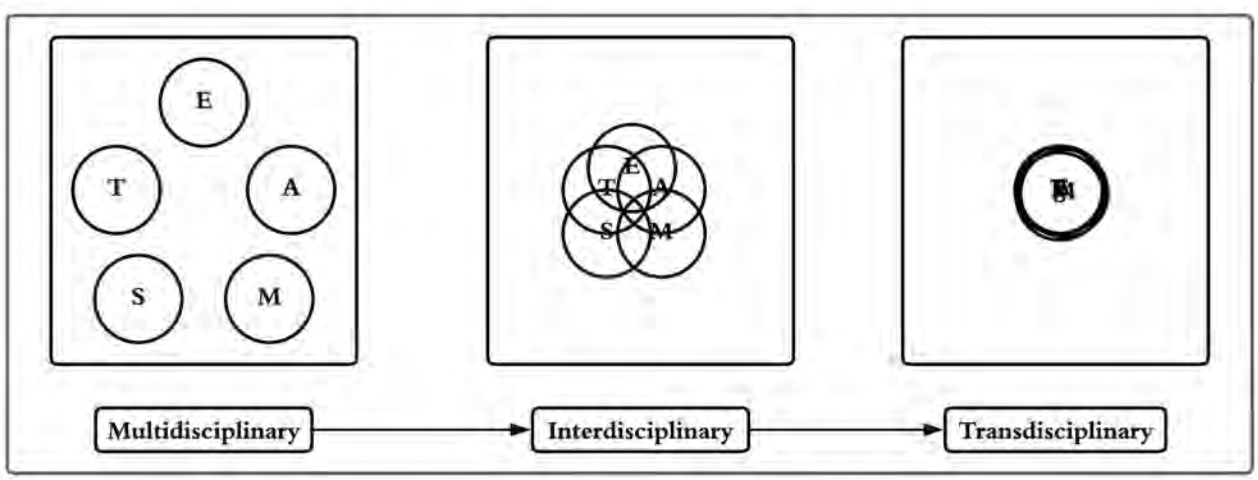


Transcending Subject Boundaries

Within STEAM, there is much discussion regarding the ways in which and the extent to which the STEAM disciplines are integrated. Three different types of STEAM integration can be best visualized on a continuum (see Figure 2, adapted from Jensenius, 2012).

Figure 2

STEAM Disciplinary Integrations Continuum



Note. Adapted from Disciplinarities: Intra, cross, multi, inter, trans by A. Jensenius, 2012, March 12, https://www.arj.no/2012/03/12/disciplinarities-2/ and Don't forget the profession when choosing a name (p. 69) by E. F. Ziegler, 1980, *Academy Papers.*

On the left side of the continuum are multidisciplinary integrations. Here, the disciplines are integrated to focus on a problem or an issue without integrating knowledge of each discipline (Choi & Pak, 2006; Kaufman et al., 2003; Herro & Quigley, 2016). In essence, students might study a singular phenomenon, but in departmentalized classroom settings or with clear disciplinary approaches (e.g., science component, then mathematics component, etc.). In the center of the continuum are interdisciplinary integrations. Interdisciplinary learning is the integration and interaction between disciplines of thought or practice (Stentoft, 2017). Interdisciplinary refers to the incorporation of two or more disciplines that are integrated to allow students' utilization of knowledge from multiple disciplines in observation of an object of study or problem under investigation (Choi & Pak, 2006; Klein, 2006). Interdisciplinary is different from multidisciplinary in that subjects are integrated in a way that builds upon the disciplinary connections; therefore, disciplines complement each other as a means to explore phenomena through a connected disciplinary lens. On the right side of the continuum is transdisciplinary integrations. Within transdisciplinary integrations, students move beyond the constraints of one discipline, such as mathematics or science, to formulate new and novel solutions (Nicolescu, 2005; 2010). In a transdisciplinary investigation, students become so enthralled in the problem that they use previous knowledge and acquire new knowledge from multiple subject areas to generate a solution (Cook & Bush, 2018). Transdisciplinary integration becomes nebulous when it is put into practice, as educators seek to discover the catalyzing force through which students might transcend subject boundaries. In the following section, we offer a framework to conceptualize the importance of student positionings in transcending subject boundaries.

Repositioning Students in STEAM Inquiries

While there are several ways to integrate the disciplines in STEAM inquiries, we contend that integrated STEAM should be focused on student experiences, and the ways in which students are positioned within this learning. Maintaining a focus on students allows for a repositioning of traditional roles in integrated STEAM learning. Through this repositioning, we critically examine the positions of actors (e.g., students and teacher) in STEAM settings. For the purpose of this paper, we will examine those actors who have the authority to define the rights and duties of the positions associated with learning in integrated STEAM.

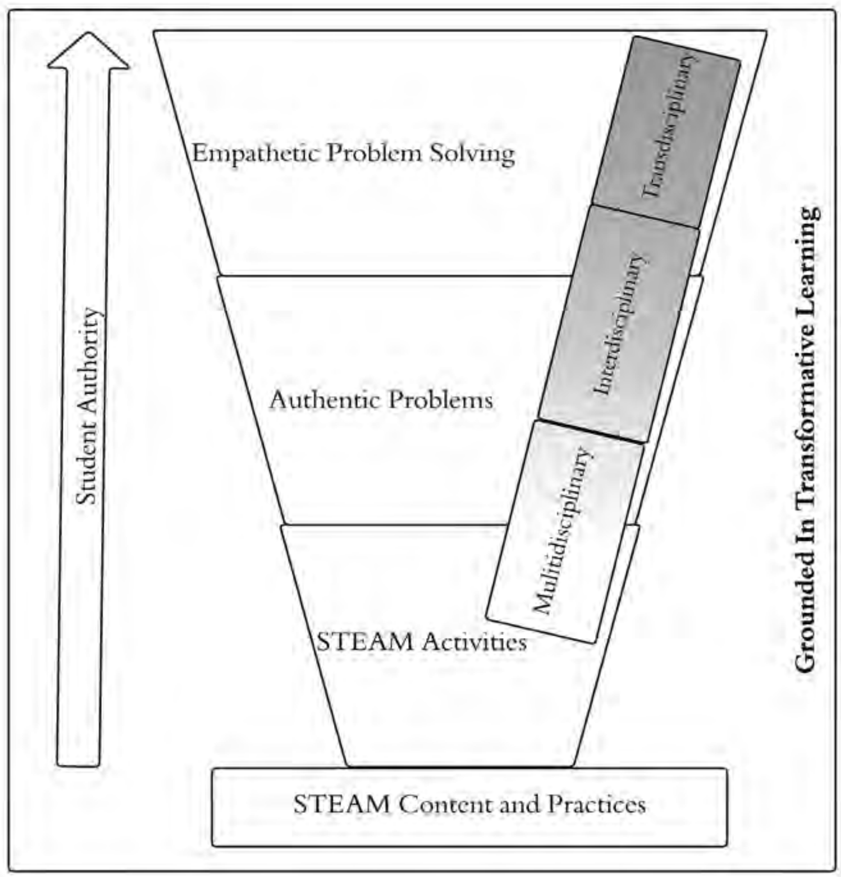
Bush and colleagues (2020) determined that there were three hierarchical levels of STEAM learning experiences, as found by student perceptual data: a) STEAM activities, b) authentic problems, and c) empathetic problem solving. The first level of the hierarchy, *STEAM activities*, are defined as STEAM challenges that students identified as being fun or challenging, but that had no deeper connection to the mathematics or science content and practices. The second level, *authentic problems*, are defined as problems that position students to connect an authentic or real-world integrated STEAM problem to science and mathematics content and practices. The third and highest level of the hierarchy, *empathetic problem solving*, is defined as inquiries that position students to connect with other peoples' (or animals', or the environments') needs. In these experiences, students use integrated STEAM to better inform their understanding of the social situation under investigation, with a deep connection to science and mathematics content and practices. While the hierarchy highlights key practices and a way to evaluate the quality of STEAM inquiries, we wish to better articulate the positions of students in the context of integrative STEAM learning.

Student Repositioning: Transdisciplinary STEAM Framework

It matters how students are positioned in STEAM inquiries. To articulate this phenomenon, we present a framework to illustrate the positions of students within integrated STEAM inquiries. Within this framework, transformative learning (Mezirow, 2009) is presented as the orienting theory for STEAM and is highlighted in Figure 3 as the backdrop for each component. We use transformative learning because it centers students in an effort to shift students' perceptions of their worlds and shape their understandings and beliefs (Cranton & King, 2003; Mezirow, 2009). Ultimately, STEAM learning inquiries should result in students making better sense of their worlds. Importantly, there is a key distinction that undergirds our framework; transformative learning greatly depends on students' frames of references, or the ways they view their worlds. These frames of reference are shaped both by their experiences, as well as the sociocultural worlds in which they have experiences (Mezirow, 2000; 2009). Thus, for transformative learning to occur, STEAM learning inquiries must create opportunities for students to make sense of their worlds in an effort to continually shape and reshape their frames of reference.

Figure 3

Student Repositioning: Transdisciplinary STEAM Framework



However, not all STEAM inquiries have the same impact on students, as indicated in the three levels presented in our framework (i.e., STEAM activities, authentic problems, and empathetic problem solving). Within the hierarchy, we have included the approaches to disciplinary integrations (multidisciplinary, interdisciplinary, and transdisciplinary) to note how we conceptualize the progression of student experiences within STEAM content. Importantly, our framework is built on the foundation of STEAM content and practices. STEAM content comprises the core subject's disciplinary knowledge (i.e., science, technology, engineering, arts, and mathematics), while STEAM practices are made up of the practices associated with the disciplinary knowledge used during STEAM inquiries (i.e., Mathematical Practices [National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010], Science and Engineering Practices [NGSS Lead States, 2013]). In our framework, the disciplinary integrations cross the hierarchy levels to indicate which STEAM learning inquiries (activities, authentic problems, and empathetic problem solving) naturally lend themselves to each integrative approach.

As transformative learning is based on extending frames of references for students engaged in the learning opportunity, the ways in which students are positioned must also be considered. Within transformative learning, students have a strong tendency to reject ideas or claims that are not easily viewed through their frames of reference (Mezirow, 2009). To honor students' rich frames, STEAM learning must offer opportunities for students to shape and build upon their lived experiences. Because frames of reference are cultivated through students' culture and language in use (Mezirow, 2009), each student will have different opportunities offered to them based upon the STEAM learning inquiry and they will approach those learning opportunities through different lenses. Importantly, student repositioning in STEAM learning must provide opportunities for students to redefine their rights and duties in the learning event, so that students can explore how STEAM might be used in their worlds.

Within our framework, we use student authority to point to the opportunities students are offered to extend upon, reshape, or use to redefine the STEAM learning event. Here, authority is defined through a positioning theory lens to identify which actor (teacher or student) has the power to redefine their positions within STEAM learning. In the following sections, we build on this concept to clearly outline the importance of student authority; more specifically, we focus upon the rights and duties that are associated with different levels of STEAM integration.

Positions in STEAM inquiries

While other frameworks focus on the instructional moves that teachers make to transcend subject boundaries within STEAM (e.g., Bush & Cook, 2019, Hwang & Taylor, 2016; Quigley et al., 2017; Yakman, 2011), the *Transdisciplinary STEAM Framework* privileges the student at the center of the. We propose that educators cannot ultimately determine what is transformative for students. Within our framework, there are three possible levels of inquiry across multidisciplinary, interdisciplinary, and transdisciplinary integrations. We use positioning theory to discuss the positions, rights, and duties available to students to act within based upon storylines in each of the levels. During STEAM inquiries, there are many ways in which students can be positioned to act; however, we will focus upon three: teacher(s), problems under investigation, and STEAM content.

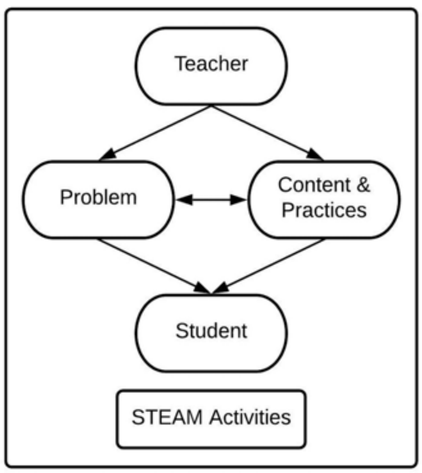
In the subsections that follow (STEAM activities, authentic problems, and empathetic problem solving) we offer conceptual representations of the organization of positionings within each of these STEAM inquiry levels. To help the reader visualize each level, we use the traditional integrated STEAM inquiry of building and designing a garden (commonly known as the garden inquiry) to further explore the rights and duties of students within each of the levels.

STEAM Activities

Within this level, an important question must be asked, *Who has the authority to define the rights and duties associated within STEAM inquiries?* Typically, the storylines available to students are clear due to how they are positioned within STEAM activities. Here, students are positioned as receivers of knowledge because they do not have the authority to design the learning event. While these learning situations make up those activities that students might indicate as fun, they lack a larger connection to a problem under investigation or for a greater purpose. As such, students do not have the authority to outline their learning event; thus, integrations are seen as top down and teacher directed. Within this level, students might experience multidisciplinary integrations in which STEAM subjects are integrated, but with clear disciplinary boundaries. In Figure 4, the three ways in which students are positioned are outlined. The teacher is at the top of the positioning map, demonstrating how the inquiry or activity is designed by the teacher. Teachers maintain this position because they develop what students might learn about (e.g., the content and the problem). In this regard, the content and problem directly positions the student and the ways in which they may act, as well as the storylines available to them. In returning to transformative learning, the content and problem directly position the ways in which students use their frames of reference to solve and make sense of the STEAM learning experience. Thus, students lack authority to explore learning outside the storylines that are presented to them. As indicated below, the problem and content created by the teacher directly position the storyline so that students are able to enact in the context of the STEAM situation. Therefore, the teacher indirectly positions students through the design of the STEAM content, integrations, and problem under investigation, as they control what is being investigated and how the content is to be integrated.

Figure 4

Positionings in STEAM Activities



In using positioning theory, potential storylines that students have the opportunity to enact are limited due to clearly defined roles and duties: student as receiver and teacher as generator of knowledge. Students within these integrations and activities are not granted the right to authorize themselves past the current learning event due to the ways in which students are positioned.

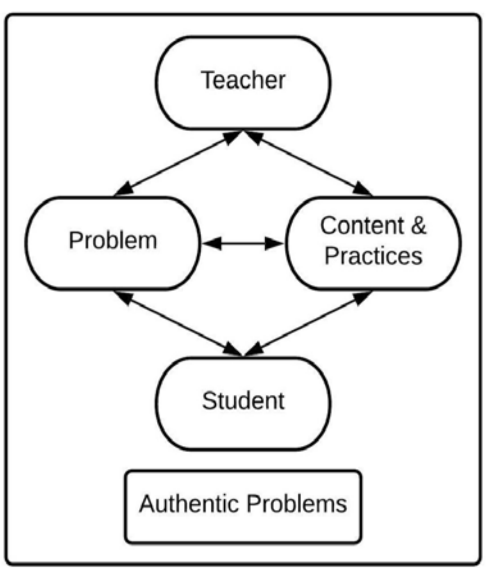
Using the garden inquiry, we can further make visible how students could be positioned within this level. As STEAM activities are generated by the teacher and lacking a larger connection to students' frames of reference, the garden inquiry may typically be outlined as follows. The garden inquiry would be centered around students visiting a school or community garden to learn about each or some of the STEAM disciplines. Importantly, the teacher would decide how each of the subjects were to be explored by the student, and thus the storylines available to students as they explore the garden inquiry would be limited. For example, students might use mathematics to find the total area of the garden. They might use scientific thinking and exploration to document living and non-living things. Students could use technology to chart differences electronically in plant species. They could also be asked to draw a specific plant as an art component. Students might also use engineering to explore certain structures that aid plants' growth in the garden. Each of these components would be teacher-directed, multidisciplinary in nature, and remain siloed due to the lack of disciplinary integrations. In this specific garden inquiry, students would only be positioned as receivers of knowledge; the storylines in this type of inquiry would direct students to play out the obligations associated with the teacher directed content. New mathematics and science content and practice learning would be limited and certainly not transformative in nature within this level (Bush et al., 2020). Although some learning could take place, essentially, the inquiry would not allow for students to reposition themselves to redefine their rights and duties.

Authentic Problems

Within this level, the storylines available to students become more nuanced because there are more possibilities for repositioning of student rights and duties, as compared to STEAM activities. However, student acts, as determined by student positions, are more informed by the problems students are investigating. Figure 5 outlines the indirect and direct positionings of students and displays how students are still positioned to act as receivers of knowledge. In this level, the teacher is still positioned to maintain authority to generate and delineate STEAM content to students. In the position mapping, the teacher is at the top of the map (similar to STEAM activities) because they generate the content and the problem to be explored. Because the teacher generates the inquiry, the storylines for students to act within are predetermined, and thus their positions lack the authority to renegotiate to better use their frames of reference. However, within this level, students can inform the content and the problem under investigation, as seen in Figure 5. This figure outlines the ways in which the teacher directly positions the problem and the content for STEAM inquiries; ultimately, the teacher clearly defines how and in what ways disciplines should be integrated. Figure 5 is different from Figure 4 in that the arrows are bidirectional to account for how students might position the content and problem based upon the integration. There are two types of integrations within this level: multidisciplinary and interdisciplinary. Within multidisciplinary integrations, students do not have the same potential to explore the connections between disciplines. However, as inquiries become more interdisciplinary, students have the potential to authentically explore how disciplines might be connected; they therefore have more authority to explore the content and the problem under investigation. Importantly, within this level, meaningful mathematics and science content and practice learning can occur for students (Bush et al., 2020).

Figure 5

Positioning in Authentic Problems



One of the defining features of authentic problems is that the problem under investigation still has clear disciplinary boundaries. This distinction means that students might be positioned to see the connections across disciplines, but these connections are defined by the problem under investigation and the person who designed the problem. Thus, this type of integration ultimately outlines the rights and duties of students in the STEAM learning inquiry.

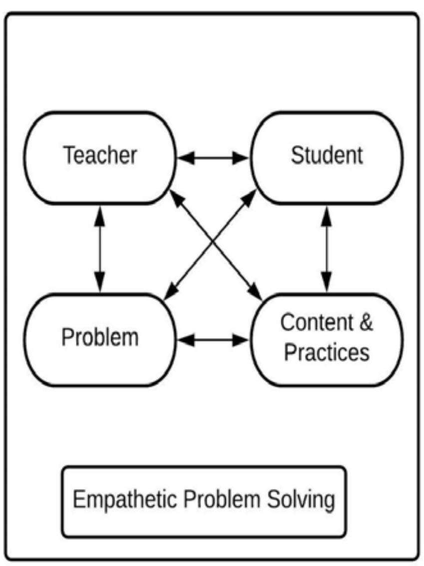
To further explore this integration, we return to the garden inquiry as an interdisciplinary example. As indicated previously, a defining feature of this level focuses upon an authentic problem for students to explore; thus, the authentic problem in this example could center around building a garden for the students' school. In the garden inquiry at this level, students could be working to design and build a garden. However, the teacher would design the disciplinary parts that the students would explore. For example, students might use mathematics to design the garden to scale on paper first to ensure their plans would fit within the constraints of the inquiry. They might research different plants and the growing cycles to determine what should be planted in the garden. They might explore different engineering designs of raised beds to use in their plans or decorate and color their plans to denote key characteristics of their included plants. Students might also use design software to develop their 3-D plans. While students might clearly see the connections between the subjects, they are still positioned as the receivers of knowledge in this level. While they gain the authority to describe connections between disciplinary content and the problem under investigation, they do not have the authority to reposition themselves to act out different storylines other than those that have been pre-determined by the plans of the teacher as generator of the inquiry.

Empathetic Problem Solving

Within this level, the possible storylines and positionings become muddled as new possibilities are introduced due to the empathetic component of the problem. Including an empathetic component into STEAM inquiries changes the rights and duties of students, thus changing their positions. Figure 6 outlines this phenomenon.

Figure 6

Positionings in Empathetic Problem Solving



In Figure 6, students are moved from receivers of knowledge to constructors of knowledge because they are positioned alongside the teacher. Students are no longer solving the problem only for content understanding. They also are not solving the problem to align themselves more closely to the thought processes of the teacher. Instead, they are actively working to solve the problem for someone else or to make their worlds better. Learning within this level has the most potential for being transformative for students (Bush et al., 2020).

The inclusion of an empathetic component allows for students to reposition themselves to better use frames of reference because teachers alleviate their own authority. This alleviation creates an opportunity for students to renegotiate their obligations for learning. In this situation, the storylines available to students differ from the others because of the grounding in the empathetic component; thus, students may take on a new role of evaluator, solver, problem generator, or STEAM expert. In this context, students have the authority to redefine their rights and duties in STEAM situations. Here, we extend on the garden inquiry by including an empathetic component.

In this example, students could design a local community garden. To do so, they would begin their inquiry by trying to understand the needs of the community through building empathy for members in the community. Students might interview, research, and contact community members to better understand the specific needs of those that live in the area in which the garden would be built. Instead of prescribed disciplinary content from the teacher, the students are now potentially authorized to decide on the content and practices they need to apply to be able to best meet the needs of the community. For example, students might learn that the community lacks access to a grocery store. In this context, students would try to better understand the situation and the community's needs, thus students have the potential to explore the inquiry alongside their teacher because they must work together to best meet the needs of the community.

Here, students could be repositioned as an engineer, when they work to design a produce stand for the community to receive fresh produce from the garden. Students could be architects, as they meet with the community to try and learn the constraints of where the garden could be built. Once students begin to explore why there is not a grocery store in the community, students could become social justice advocates and use mathematics to model recent trends in grocery store locations around the community. Students might also be positioned as nutritionists when they explore what produce to plant in the garden based upon the communities needs and wants. Here, the arts integration can position the students as artist if they were to collaborative paint a mural depicting the community.

We also extend this to include the humanistic or empathetic part of solving problems, in that students are not solving a problem for content understanding or because they have been positioned as receivers of knowledge, but instead one of empathy and a desire to improve the world around them. Notice that the storylines for students to act out are much more open for students to decide upon the position they might occupy during the inquiry. In particular, students have the authority to transcend the disciplinary constraints of any single subject to explore a problem in an effort to better understand the community in need, but also use their frames of reference to intentionally build new knowledge. In the end, this transcension actually leads to deeper science and mathematics content and practice understanding, and connections.

In short, how students are positioned in STEAM inquiries matters. For students to transcend subject boundaries, they must be given the authority to reposition themselves to better understand the problem under investigation. Each level in our framework demonstrates a clear connection to the student positions and the storylines in which they have the obligations, or non-obligations, to act out in the inquiry. By including an empathetic component, teachers can potentially allow for new storylines to be enacted in STEAM inquiries. Empathy repositions students within the positioning mappings to gain the authority to explore and redefine the rights and duties of the inquiry. It is through this repositioning that transdisciplinary learning can occur for students. In our framework, empathy is the catalyst to generate opportunities for authorizing students.

Opportunities for Future Research

In the following sections, we explore new directions for STEAM education to highlight the importance of a student repositioning approach to both learning but also research and collaboration.

Exploring the Role of Research in Positioning

Cannella and Lincoln (2011) propose a more ethical research stance as one that focuses on research with people and a thorough examination and analysis of "competing power interests" (p. 97), with Foucault (1994) affirming and zeroing in on work requiring "self-criticism that historically examines the constitution of self" (p. 91). When we approach research in STEAM through a qualitative lens and as "the reconceptualized, broad-based critical social science that addresses institutionalized, policy-based, intersecting forms of power" (Cannella & Lincoln, 2011, p. 93), we can build alliances and work towards a more just elementary school and, perhaps, society at-large. So, to pursue research as solidarity and to honor participants, beneficence, and justice, it is key to select approaches, agendas, and research paths that reveal power structures and "attend first and foremost to the needs of participants and to the goals of social change" (Kincheloe et al., 2017, p. 247). Examining positionings allows researchers to move forward with the guiding notion that empowered (including the researcher) and disempowered people exist in the same space. In a school, especially, there are visible and invisible structures that perpetuate injustices and reinforce the status quo.

Research that firmly positions students at the center of the work invites students to participate in a humanizing way in which they see themselves as useful individuals with freedom of thought and ability. The exploration of that participation helps us link social phenomena to wider sociohistorical events and expose prevailing systems of domination, hidden assumptions, ideologies, and discourses with the goal of redefining experiences. Exploring the positions of students is an opportunity for exploration in the STEAM research conversation (and research in general). Often discounted because of arbitrarily-placed age or developmental constraints, research verifies that elementary school-aged students are able to "think critically about the world around them…deepen strategic thinking, abstract thinking, empathy and taking the roles of others, temporal and causal ordering and metacognition" (Mitra & Serriere, 2012, p. 745). It is essential to center student experience in research related to potentially impactful student learning initiatives. Exploring where and how students exist in STEAM contexts, contexts through which we often ask students to engage in their learning in a deeply personal way, provides additional insight into our selected curricula and our individual and collective pedagogies. It also provides space for students to make connections with how their school life intersects and informs the rest of their lives, and vice versa.

Exploring the Role of Discourse in Positioning

To truly understand the impact of student and teacher positioning in the learning and teaching space of integrated STEAM learning, it is important to consider specific nuances which might inform that understanding. Of particular interest is how students and teachers use language in connection to their positions in integrated spaces. Specifically, in this paper, we used positioning theory to show the potential storylines that were available to students. However, these are more stagnant relationships. To gain a deeper understanding of how certain integrations position students, we need to research the in-the-moment positionings within STEAM spaces. In order to better understand the student experience in STEAM, researchers must begin to explore the role of language and language usage in STEAM, as these can be interpreted as the social acts associated within student positionings.

To explore the role of language usage, future research might focus on discourse, defined as the way humans use language at particular moments and the differences in how language is used from one time and place to another (Holland & Leander, 2004). As a key example, Barwell (2016) focuses on relational meaning in his research on mathematics education, which has implications for other disciplines and the integrated spaces. From Barwell's perspective, mathematics discourse exists in relation to other types of discourse and multiple voices, perspectives or intentions are present in every mathematics utterance. Barwell notes: "When students talk about mathematics, they must use words that precede them, and these words carry overtones or undertones of the previous history of these words" (p. 336). Barwell also notes that Bakhtin's theory of language includes a "continual tension between a centripetal force towards uniformity…and a centrifugal force towards heteroglossia" (p. 336). If Bakhtin's theory of language is applied to teaching and learning in mathematics, suggests Barwell, it demonstrates how students must constantly navigate traditional and progressive models of both content and teacher instructional methods. Barwell asserts that from a Vygotskian perspective (a prevailing cognitive framework of STEM/STEAM teaching), students are being socialized into understanding through careful teacher-guided lessons, where the teacher replaces the student-constructed responses with socially, agreed-upon standard language. Alternatively, and more powerfully, Barwell asserts, is a Bahktian perspective where students work on expanding their "discursive repertoires, giving them a wider range of ways to make meaning in different mathematical situations" (p. 343). In the former, the path is set – there is a formalized mathematical language students must eventually internalize. In the latter, the path is less clear – students must build mathematical language. Barwell suggests that his research shows that if we do not learn, speak, interact, or communicate in a vacuum, why then, would we do mathematics in a vacuum?

There are powerful implications for STEAM research and practice in Barwell's work. If applied to and during the development of a theoretical/philosophical STEAM framework, as in this work, a Bahktian perspective could be transformative. Barwell's work seems to further justify the facilitation of student generated knowledge, positioning students as the drivers of knowledge, with the teacher as guide instead of sage, as the ideal integrated classroom experience.

Student-to-Student Positionings

Within this paper, we discussed students as a whole entity in relation to the role of the classroom teacher. Research should also begin to explore the student-to-student positionings and repositionings in STEAM inquiries to better understand how some inquiries might be transdisciplinary for some, while remaining interdisciplinary for others. In order to develop a more robust understanding of the transcension of discipline boundaries in STEAM, research must place greater emphasis on individual experiences and how such learning events are constructed from a student perspective.

Concluding Thoughts

In this paper, we have articulated the importance of repositioning students to be at the center of the transition of subject boundaries in STEAM. Building from previous frameworks in STEAM education research, we theorize new framework from the perspective of students. Using positioning theory, we demonstrated how not all STEAM experiences are the same for students involved in the learning event. From that perspective, we contend that we should not be asking what allows for the transcension of subject boundaries, but instead how can we position our students to transcend the boundaries of the STEAM disciplines and reposition their experiences and connections to be at the center of the STEAM inquiries. Throughout this paper, we have elucidated how STEAM education allows for multiple storylines in which students have differing obligations as a learner; thus, attention must be given for how different storylines and positions can be afforded to students to better their understanding of not only content, but increase their sense of belonging in STEAM. However, in order for students to have transformative learning experiences in STEAM, we must position them to be able to enact storylines that are based on their frames of reference. Our framework, *Transdisciplinary STEAM Framework,* outlines the role of empathy in repositioning our students to transcend subject boundaries. The intent of STEAM education is to foster and cultivate students of whom have a desire to make the world a better place, we must also acknowledge that our students come to us with many diverse experiences. Empathy has the potential to better position students to be the problem solvers of tomorrow; however, we need to ensure we position them to authentically use empathy to drive their learning experiences towards a transformative outcome.

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