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Visual Art Professional Development for STEM Teachers: Perspectives and Attitudes Toward Visual Art Integration

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Abstract

This study investigated the perspectives and attitudes of twenty K-8 non-art teachers in the southeastern United States who participated in a five-month visual art professional development (PD) workshop series for art integration, known as STEAM (Science, Technology, Engineering, Arts, and Mathematics) Beyond Borders (SBB). They explored visual art content and potential strategies for integrating art into their subject areas, including business, computer science, dance, engineering, English language arts (ELA), environmental science, mathematics, music, science, Spanish, reading, and robotics. They also participated in a series of PD workshops featuring current interdisciplinary practices and field trips to industries and businesses having strong STEAM connections. The results suggest that participants showed increasing interest in visual art content and plan to integrate it into their non-art subjects through various forms of potential collaborations. They were positive about engaging in cross-disciplinary collaborations with other teachers. The implications suggest that STEAM project-based learning (PBL) PD, by integrating visual art, may facilitate the development of meaningful STEAM connections for both K-8 teachers and learners. These study results may be also benefit visual art PD providers, such as community art centers and university art programs, in planning visual art PD for non-art teachers.

*Keywords***:** Professional development; STEAM; art integration; teachers' perspectives and attitudes; visual art workshop

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Visual Art Professional Development for STEM Teachers: Perspectives and Attitudes Toward Visual Art Integration

Researchers have indicated that visual art could make many potential contributions as part of STEAM education, including helping learners bridge the gap between various disciplines by enhancing STEM (Science, Technology, Engineering, and Mathematics; Herro & Quigley, 2017; Hsieh et al., 2019; Jamil et al., 2018; Liao et al., 2016), and helping learners' inquiry about emergent problems (Knochel, 2018). The addition of visual art to STEM could "[enhance] the divergent outcomes emerging from the art + design studio by immersing students in a diversity of knowledge bases contributing to the domains of Science, Technology, Engineering, Arts, and Math[ematics]" (Rolling, 2016, p. 4); help learners to "better understand how all things relate to each other" (Herro & Quigley, 2017, p. 417), and apply already-learned skills and knowledge to solve contemporary problems (Liao, 2016). Herro et al. (2018) further emphasized the importance of including the A (art) in STEAM for minority students in schools, that is, the STEAM approach is also "seen as more equitable for communities that are typically excluded as the inclusion of art, creativity and design skills is considered appealing to diverse populations of learners such as girls and students of color" (p. 486).

However, with increasing numbers of K-12 schools adapting the STEAM approach (McGarry, 2018), there are still challenges to address, including the lack of time for teachers to develop and implement lessons (Herro & Quigley, 2017; Park et al., 2016), and lack of administrative and financial support, as the top two main challenges. Other challenges include teachers' beliefs about the effectiveness of STEAM (Guskey, 2002; Jamil et al., 2018) and changes in meaningful student learning outcomes (Hsieh et al., 2019). More specifically, Herro and Quigley (2017) explained that "STEAM lessons require teachers to see the connections

between their own content area and others, and to understand how to create relevant problems that address multiple disciplines" (p. 419). Teachers may have sufficient content knowledge of their main subject areas; however, they need more STEAM project-based learning/professional development about how to connect with and incorporate other STEAM subjects into their own specific content areas.

Georgia was one of the first states to offer STEAM certification to K-12 schools and emphasized the importance of arts in STEAM PBL: "Arts are instrumental in teaching creative problem solving, innovation, and empathy. The arts provide hands-on avenues for students to engage with curriculum and prepare students for future careers in the growing creative economy" (The Georgia Department of Education, n.d., STEM/STEAM is for All Students section). Many art researchers have advocated that visual art is a critical component of the STEAM PBL approach and should not be mistakenly treated as an add-on subject (Liao et al., 2016; Rosen-O'Leary & Thompson, 2019); rather, it should be treated as an equal partner with STEM (Hsieh et al., 2019; Hunter-Doniger, 2018; Liao, 2016; Rolling, 2016) because, with the inclusion of visual art in STEAM, "diverse learners are able to acquire, retain, and apply knowledge in a meaningful manner" (McGarry, 2018, p. 33). Hence, the main focus of the present study was to understand non-art teachers' perspectives and attitudes toward incorporating the visual arts into their future curriculum planning through a five-month STEAM PBL PD.

Research Purpose and Overview

One of the main initiatives that the Department of Education in Georgia focuses on is to prepare learners for 21st century workplace careers through high quality learning opportunities in sciences, technology, engineering, arts, and mathematics. STEAM education is an integrated curriculum that is driven by exploratory project-based learning and student-centered

development of ideas and solutions (The Georgia Department of Education, n.d., About Us section). Since 2011 the first implementation of STEM/STEAM in Georgia, the number of STEM/STEAM certified schools in Georgia has grown 1033% (The Georgia Department of Georgia, n.d., Growth of Georgia STEM and STEAM School Since Program Inception section). In order to help K-12 teachers in developing curriculum and making connections between classroom teaching and learning, as well as business and industry applications, the Department of Education in Georgia holds a free annual summer teacher STEM/STEAM academy. More importantly, the Department of Education in Georgia sponsors grant funding to encourage collaborations between K-12 schools, universities, and communities in order to facilitate inter-disciplinary partnerships.

Providing teachers STEAM PBL PD opportunities to make meaningful connections between academic disciplines is essential for both teachers and learners (Conrady & Bogner, 2020; Guskey, 2002). Guskey (2002) affirmed that "professional development programs are systematic efforts to bring about change in the classroom practices of teachers, in their attitudes and beliefs, and in the learning outcomes of students" (p. 381). Therefore, the purpose of this study was to explore how a five-month STEAM PBL PD called "STEAM Beyond Borders" (SBB) assisted non-art teachers in making connections between visual art and their academic disciplines, as well as their perspectives and attitudes toward art integration after the completion of the PD visual art workshops.

SBB was sponsored by the Georgia Governor's Office of Student Achievement (GOSA) Innovation Fund. Two universities and one local "maker space" developed and facilitated ongoing PD sessions and workshops for 20 non-art teacher participants from four public schools on various STEAM PBL topics between June and November 2019 (I called those organizations

or institutions "PD providers" in this study). There were four components for the SBB PD project: a summer symposium/field trip in June, Fall STEAM workshops, two group online meetings (check-ins), and survey evaluations. In addition, all 20 teacher participants used a smartphone app for informal virtual dialogues and communications with fellow teachers and the university faculty conducting the study.

From June 3rd to the 5th, 2019, all 20 teacher participants visited a science facility at one university, visual art studios/facilities at another university, a community maker space (all three were the SBB providers), a local architecture/design firm, and an art museum for the summer symposium/field trips. The teacher participants were also required to sign up for two 1.5-hour visual art PD workshops held by the visual art PD provider on June 4th. They earned 24 contact hours for participating in this summer PD symposium/field trips.

All three STEAM PD providers offered a total of 36 contact hours of workshops and sessions for the teacher participants to select from between August and November 2019. All workshops and sessions were offered both in person and through online live streaming after school or on Saturdays. Each teacher participant was required to participate in workshops of their choice to earn a minimum of 16 contract hours before the end of November. The teacher participants were also required to fill out post-workshop evaluations, including written questionnaires, and to participate in verbal discussions right after the workshop.

To obtain the credibility of this study and to avoid research bias, I was not involved in teaching or interacting with any visual art workshop participants. I followed these 20 teachers in all visual art workshops as a non-participating observer and did not interact with any participants. I sent out online written surveys to all 20 workshop participants right after the PD workshops to collect both qualitative and quantitative data.

During my investigation of the SBB PD project, I observed the teacher participants during the symposiums/field trips and surveyed them after all visual art workshops. There were six visual art workshop options for the teacher participants to join during the summer symposium/field trips and another six workshops in the Fall semester (Table 1).

Rationale and Theoretical Framework

Professional development for teachers is important because it helps them learn up-to-date content and how to implement new pedagogy into their teaching practices, and more importantly, to improve and enhance their students' learning outcomes. One of the main goals for PD is to help change teachers' beliefs and attitudes in regard to effective student learning outcomes (Guskey, 2002), as well as to prompt the evolution of their beliefs into actions (Jamil et al., 2018). Changing teachers' beliefs and attitudes can have a positive impact on their students' learning outcomes. Herro and Quigley's (2017) study of 21 middle school mathematics and science teachers' perceptions and practices before and after a PD in which STEAM integration was explored through PBL found that these teachers expressed several needs in order to facilitate STEAM education, including "time to develop STEAM-related curricula, supportive administrators, productive in-service training and consulting with educational experts" (p. 421).

Arts integration has proven beneficial to learners for the STEM subjects (Herro et al., 2019; Hsieh et al., 2019; Hunter-Doniger, 2018; Liao, 2016), as well as teacher learning and professional development (Herro et al., 2019; Jamil et al., 2018). Research on arts integration for STEAM education shows how the arts help students to construct and demonstrate understanding in terms of their cognitive achievement (Rosen-O'Leary & Thompson, 2019). Silverstein & Layne (2010) also pointed out the connection between creative process and arts integrations, "students engage in a creative process which connects an art form and another subject area and

meets evolving objectives in both" (p. 1). Providing visual art training for learners can "improve cognition through its ability to strengthen the brain's attention system and increase cognitive capacities for attention, memory, and learning in general" (Rosen-O'Leary & Thompson 2019, p. 32). One effective means to achieve STEAM art integration is through teacher collaboration (Hsieh et al., 2019). Hunter-Doniger (2018) has explained the benefits of such collaborations, especially with art teachers: "Collaboration is key because it allows for everyone involved to share ideas and experiences relevant to art infusion, resulting in enhanced lessons and shared knowledge" (p. 25). In this study, all 20 selected teacher participants demonstrated strong beliefs and positive attitudes toward STEAM education with full support from their administration. All four schools represented in the study have subsequently adopted the STEAM education approach, and the teachers have been given 75 designated minutes per week for planning and developing STEAM PBL curricula. However, all of the study participants were not familiar with the content and pedagogies of arts integration for STEAM PBL. Hence, learning about arts integration was one of the main objectives of the SBB PD.

This study thus focused solely on these 20 non-art teacher participants' perspectives and attitudes toward visual art integration into other disciplines through a visual art PD.

Research Methods and Data Collection

Twenty K-8 teachers (N = 20) from four schools who were teaching non-art subjects including business, computer science, dance, engineering, English language arts (ELA), environmental science, mathematics, music, science, Spanish, reading, and robotics participated in the study. Among these, eight were from a STEAM-certified elementary academy located in an urban area, four from an urban middle school, four from a suburban elementary school, and four from a suburban middle school. All four schools had been implementing STEAM-focused

curricula with administrative support before the SBB project. These teacher participants were selected by their administration and were fully committed to this five-month STEAM PBL PD.

In order to better understand their perspectives and attitudes toward arts integrations, as well as their potential collaboration for implementing STEAM PBL lessons, I used a mixed methods research approach, examining quantitative data, which included participants' ranking of items by ranking items by Likert-type scale questions from post-workshop surveys. Qualitative data such as my field notes, audio tape recordings, open-ended written questionnaires (both in-person and online), photographs, group chats/texts/messages (all participants used a smartphone app for group communications), observations, and interviews after the visual arts PD. Parson et al. (2019) pointed that "survey methods are appropriate when research aims to capture participants' perspectives [and perceptions] about a topic or phenomenon" in their survey study exploring U.S. teachers' experiences and perceptions of a PD (p. 35). My goal was to understand the perspectives and attitudes of these non-art teachers in terms of art integration. From the survey data, I also learned what types of challenges they faced in implementing the STEAM approach in their non-art areas. I obtained the university's Institutional Review Board (IRB) approval for conducting this research study.

Data Analysis and Discussion

In order to get a higher survey return rate, I conducted the anonymous survey immediately following the visual art workshops. Fortunately, the survey return rate was 100%. In the following section, I discuss the research findings from my content analysis of both the quantitative and qualitative data I collected during the research period. Stokrocki (1997) pointed out that "content analysis is a process of forming convincing suppositions, called propositions, from data and their content" (p. 40). Thus, I provided my explanations from my content analysis

of my collected data. In terms of quantitative data, Table 1 shows the results of the post-workshop satisfaction surveys completed by the 20 teacher participants. The quantitative data were mainly used to capture the participants' levels of satisfaction with workshops and served as guides for my interviews of participants whose ratings were "Unsatisfied" or "Very Unsatisfied." The quantitative data were relatively small, but it was not my intention to apply the statistical findings to a large population. In addition, the statistical result was not used for "drawing conclusions across a variety of statistics and measures" (Thurber, 2004, p. 489). My goal was not to test a hypothesis but rather to understand 20 participants' perspectives and attitudes toward arts integration.

After analyzing the qualitative data I collected from my observations, interviews, and communications with the participants, I provide my findings in the section on the teachers' attitudes toward collaborative lessons.

Table 1

Percentages of Visual Art Workshop Participants' Satisfaction Rating

	Name of the Visual Art Workshop (Summer symposium/field trip)	Percentage of Very Satisfied	Percentage of Satisfied	Percentage of Neither Satisfied nor Unsatisfied	Percentage of Unsatisfied or Very Unsatisfied
1	Illustration as a Learning Tool (n=12)	66.67%	26.67%	6.67%	0.00%
2	Principles of 2D Design (n=8)	75.00%	25.00%	0.00%	0.00%
3	Design Thinking (n=10)	80.00%	0.00%	10.00%	10.00%
4	Experimental Printmaking I (n=12)	77.78%	22.22%	0.00%	0.00%
5	Experimental Printmaking II (n=12)	77.78%	22.22%	0.00%	0.00%
6	Digital Illustration and Animations (n=5)	20.00%	30.00%	40.00%	10.00%

	Name of the Visual Art Workshop (Fall 2019)	Percentage of Very Satisfied	Percentage of Satisfied	Percentage of Neither Satisfied nor Unsatisfied	Percentage of Unsatisfied or Very Unsatisfied
1	Research Journals/Sketchbooks (n=8)	25.00%	50%	0%	25%
2	Principles of 2D Design (n=4)	66.7%	33.3%	0%	0%
3	Skills of Observation and Object-Based Learning (n=6)	0.00%	100%	0%	0%
4	File Creation for 3D Printing (n=5)	0.00%	75.00%	25.00%	0%
5	Mandala (Various Media) (n=7)	0.00%	100%	0%	0%
6	Shibori with Bleach Discharge (n=12)	66.7%	33.3%	0%	0%

Results of the Post-Workshop Written Surveys

As shown in Table 1, during both the summer symposium/field trip and fall semester PDs, the majority of the teacher participants felt satisfied after participating in most visual art workshops, with at least 75% being either Satisfied or Very Satisfied except for the Digital Illustration and Animations workshops, which yielded only 50% as Satisfied or Very Satisfied. Through my observations during the Digital Illustration and Animations workshop, I found that the participants had a few challenges, including time constraints, unfamiliarity with the illustration application, and difficulty determining the applicability of the workshop content to other subjects. Most teachers in the Digital Illustration and Animations workshop indicated that they needed more time to become familiar with the computer application, and time to complete the project. Participants also spent an addition 30 minutes in the computer lab after the PD session. When asked how much time should be designated for the illustration workshop, more

than 50% indicated three hours compared to 90 minutes (Field note, June 4, 2019). In addition to longer PD session time as lab hours, more one-on-one time with instructor was recommended by the teachers. Comparing the Animation workshop to the Printmaking workshop, I found that additional time is important for non-visual art teachers to conduct hands-on learning. The Printmaking instructor divided her content into two 1.5-hour sections, one in the morning and one in the afternoon so that the participants had enough time to complete a small project. By comparison, the Digital Illustration and Animations workshop was a single 1.5-hour session.

All participants in the Printmaking workshops reported being either Very Satisfied or Satisfied (100%). The visual art PD provider designated 180 minutes for the printmaking workshops, the same 12 participants participated in Printmaking I as well as Printmaking II. The instructor of both workshops explained that 90 minutes for learning about basic printmaking skills/techniques and hands-on activities would not be enough time for teachers to complete the printmaking processes. This also was reflected in the post-workshop survey of the participants. The survey results suggest that the non-visual art teachers enjoyed the visual art content when they had enough time to learn the skills and digest the content knowledge. A similar survey result was seen in the Principles of 2D Design workshop, in which the instructor spent the majority of the time demonstrating how to look at and read the 2D design work through analyzing repeated symbols (see Figure 1). The broken-down, step-by-step instructions provided by the workshop instructors helped non-art teachers to gradually learn the principles of design and allowed them to ease into the art content. In the Design Thinking workshop, 20% of the participants expressed being Neither Satisfied nor Unsatisfied, but 10% were Very Unsatisfied. During the workshop, one teacher shared with me that she did not find the topic interesting because it was not applicable to her classroom teaching. She also told me that she would rather

do a hands-on workshop such as Printmaking. which may suggest that she could not connect the design thinking methodology to her subject [ELA]. In order to help non-art teachers clearly discover the content connections to their subject area, it might therefore be beneficial if workshop instructors conducted a short group discussion after the workshop to discuss both application and implementation strategies.

Figure 1

2D Design Workshop Demonstration

Note. 2D Design workshop instructor demonstrating methods of composing two-color patterns to PD participants, both in-person and by live streaming

Another workshop, Shibori with Bleach Discharge, received a 100% satisfaction rating from the teacher participants. I observed that the workshop instructor demonstrated a step-by-step breakdown of how to fold, tie, and bleach a black fabric shopping bag. One teacher said, "This is a fun project and I definitely can use this in my environmental science classes." A computer science teacher commented, "I would reach out to the art teachers and home room teachers for collaboration and supporting materials." Therefore, more hands-on with step-by-step breakdown instructions aligned with showing clear connections between non-art and art subjects could be an effective strategy for both workshop instructors and STEAM PD providers.

Supporting Materials on Visual Art Content for Non-Art Teachers

The visual art content PD provider developed a workshop catalog that conformed to both state visual arts standards and the National Core Arts Standards. All the participants received this catalog in advance as a guide for having registered for the workshops. The catalog of workshops with both national and state visual art standards alignment helped non-art teachers to navigate potential connections into standards to their own subjects.

In addition to guiding non-art teachers during the workshop on how to integrate visual art into their subject areas, explaining the elements of art (EOA) and the principle of design (POD) was also essential. The visual art PD provider also made sure that all workshop instructors addressed both EOA and POD during the PD sessions. Another important element of the workshop was in helping teacher participants see potential connections between the workshop content and different disciplines. The workshop catalog also listed potential connections between visual art and other disciplines.

However, pointing out potential connections between visual art and other disciplines was particularly challenging for workshop instructors because 90% of the instructors were professional studio artists with very limited pedagogical training. One possible solution is to have education faculty during the workshop planning work with studio faculty to address this pedagogical implementation.

Commercial and Industrial Connections Related to STEAM

During the summer symposium and PD field trip, all the teacher participants visited an art museum and a private design firm, as well as toured the visual art PD provider's studio facilities. Designers at the firm introduced the teacher participants to how designers work collaboratively on brainstorming ideas and solving problems. Later, I observed that teacher participants applied what they saw or learned from the symposium/field trip to planning their future PBL units. One participant said, "I will have a higher integration of a variety of arts" (personal communication, July 2019). After attending the animation workshop, one teacher explained that,

> I could foresee a clay and paint project made out of a large praxin[o]scope. This should show some alter-ego concepts or show hidden meanings in literature. Once the mirrored praxin[o]scope is completed, it could be used to show any kind of cycle (moon, butterfly, seed-flower, cell multiplication, etc.

After she attended the logo design workshop, one teacher wrote, "I plan to have students do a logo to represent the different units we've learned. I plan to have my accelerated students create an animation of the biomes."

Providing teachers with a summer symposium/field trip (or field experiences) and giving them opportunities to see the connections between trans-disciplinary enterprises in action could

be an effective way for them to incorporate the arts into their STEAM PBL curriculum (Jamil et al., 2018).

Potential Strategies for Visual Art Integration

There are several potential forms of collaboration for teachers to integrate visual art into their STEAM PBL, especially through discussion, brainstorming and planning. In addition to informal communications, giving or receiving advice or help, sharing resources, and proposing joint work, the teacher participants that I observed shared their intentions and plans for art integration through the following methods.

Talking to and Working with a Visual Art Teacher. Because all the teacher participants were from non-art background, one participant explained "seeking ideas from art teachers for PBL collaboration" and "collaborating with others within school such as an art teacher and someone from the cohort" were valuable.

Designing Hands-on Activity for the PBL Lesson. *Offering* hands-on activity, such as drawing a plan, sketching a draft of plan, developing a design process, or constructing a prototype is one of the effective learning methods for K-12 learners. Teacher participants saw these benefits of implementing more hands-on activities for their PBL lessons. "Illustration tools: [I] plan to use several techniques including sketching ideas quickly, visual note taking, and adding animations for my review session with my students" and "animation software and the coding can be used easily in my [class]room" (post-workshop survey, July 2019).

Inviting Teachers of Various Subjects to Collaborative Planning for STEAM PBL. Comments such as "A lot of new ideas and connections with new people [(other teacher participants from the cohort]" and "talked to [school 3] teachers and will incorporate some of their STEAM PBL ideas" showed potential for collaboration.

Utilizing Design Thinking Processes. One teacher participant noted, "I will begin using design thinking in planning PBL. I plan to use several tools from the [design firm and the art museum] in my class this upcoming year" (personal communication, July 2019).

Being Flexible and Open to Various Forms of Assessment. Jamil et al. (2018) cited the importance of teachers being open and flexible to using various forms of assessment for evaluating students' learning outcomes. In Perignat and Katz-Buonincontro's (2019) review of 44 published articles related to art integration and STEAM education, they pointed that various assessment instruments should be considered for evaluating students' learning outcomes, including assessing students' learning processes, creativity, making process (exploration, creative thinking, designing, technique, creative-expression, critique, evaluation, and redesign), and cognitive outcomes (such as visual thinking and critical thinking). The sharing of assessment instruction among teachers from different disciplines could also be beneficial. One teacher participant in the study stated that "the assessment instruments from [school 3] provided me an additional way to evaluate my current STEAM PBL unit."

The Teachers' Approaches to Collaborative Lessons

There are various approaches for teachers to collaborate with other teachers, such as sharing, discussion, or casual chat. Parson et al. (2019) pointed that that "collaborating and sharing are often valued by participants [teachers] and allow them to establish a greater support network" (p. 34). The teacher participants in this study used a smartphone closed group application as an informal communication tool for exchanging ideas about content knowledge and potential inter-disciplinary collaborations. Because collaboration is a fundamental element of STEAM PBL, with all the participants' consent, I examined their text conversations about their

ideas for post-workshop collaborations. I then analyzed their communications both from my in-person observations and through their smartphone application.

From June to November, I tracked and analyzed all 20 participants' conversations and dialogues that related to their potential future STEAM PBL collaborations that had developed during their participation in the summer field trip/symposium, visual art workshops in the Fall, and from exchanges on their smartphone app. Four categories emerged from the data: informal communication, giving or asking for advice or help, sharing resources, and engaging in joint work or collaborative work (see Figure 2). I monitored these interactions between all teacher participants, finding that they briefly communicated ideas or stories about teaching in an informal way, such as sharing their past interdisciplinary teaching experiences. Some participants specifically asked other participants for advice about teaching transdisciplinary lessons. A few even shared materials, particular teaching pedagogies, and ideas for developing interdisciplinary units or lesson plans with others. Because the STEAM PBL PD focused on the collaborations between different teachers (Herro & Quigley, 2017), I observed that 53% of their informal communications via the app were related to how to collaborate with each other for joint work or collaborative work, that is, working together to design or deliver instruction or working together to develop a solution to a problem related to teaching. The STEAM PBL method emphasizes a higher level of collaboration between teachers from its five disciplines (Hunter-Doniger, 2018; Liao, 2016). I observed that the teacher participants pursued a higher level of collaboration and joint work. More importantly, 30% (6 teacher participants) started planning joint collaborations for teaching STEAM PBL for the next semester.

Figure 2 shows four types of interactions between each teacher participant within their own school. I used the symbols of a star, pencil, check mark, and a circular arrow to represent

the teachers' four schools, while each circle represents a single participant. The color-coded lines correspond to four types of categorized communications. The colored lines between each participant represent which participant communicated with another participant on what type of communications. Teacher participants communicated with each other at least two times and up to six times except for one who did not interact with the others. This figure also indicates which participants engaged in conversations more often than the others and was also helpful for school administration in selecting potential teacher leaders for implementing STEAM PBL in their schools.

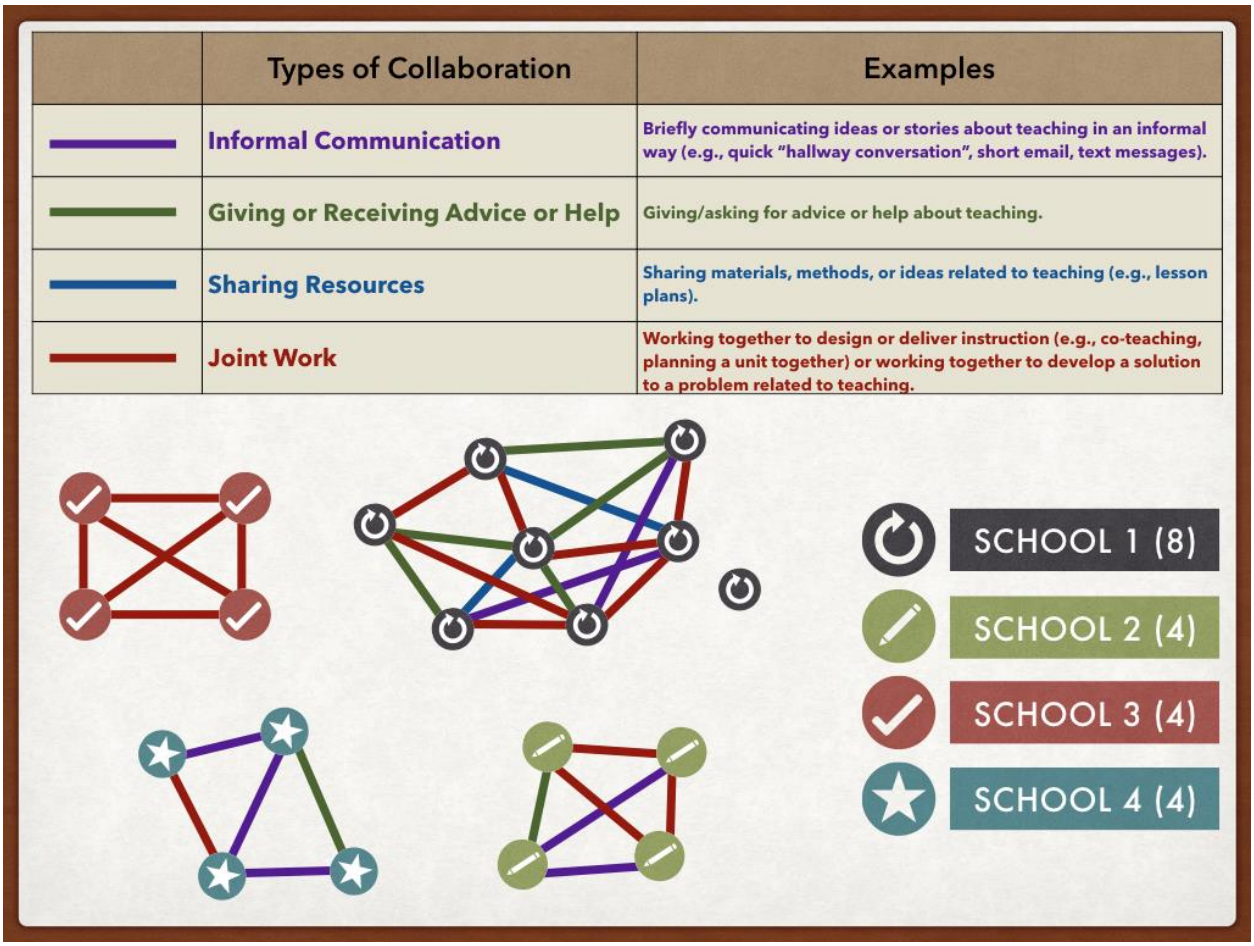


Figure 2. Types of collaboration and dialogue between teacher participants from four different schools during STEAM PBL PD activities.

I categorized four types of communication for collaboration between participants by analyzing my field notes, informal communication, giving or receiving advice or help, sharing resources, and joint work. Through examining these four types of communication for collaboration more closely, I found that there were also different levels of meaningful communication for potential collaborative teaching (see Figure 3). The color-coded curved red lines with the darker pink zone indicated a higher level of meaningful communication in terms of collaboratively working toward STEAM PBL teaching.

First, exchanging information (19% of the total communication shown with the purple curved line within the light pink zone) was the lowest level of meaningful collaboration because it is information-based and therefore less interactive, while 22% of the communication was a bit more interactive, such as asking for help or giving advice (the green curved lines). Six percent of the communication involved the participants sharing online resources, lesson plans, teaching pedagogies, or instructional materials (the blue curved line). The highest level of meaningful communication (the red curved line) was joint work (53%). I observed teacher participants actively working together generating thematic projects, planning collaborative STEAM PBL lessons, or designing transdisciplinary team-teaching units.

This graph also shows that the teacher participants' communications were more diverse, spanning four different levels of meaningful communication at School 1 (the dark grey label). Not surprisingly, School 1 is STEAM-certified, with all of its teachers engaged in collaborative teaching and planning PBL lessons. School 3 was in the process of getting STEAM certification during this study, which is reflected by the four teacher participants' higher level of communication. Both School 1 and School 3 emphasized having a culture of mutual learning

(Kelton & Saraniero, 2018) between teachers, while Schools 2 and 4 were just starting to adapt the idea of STEAM PBL.

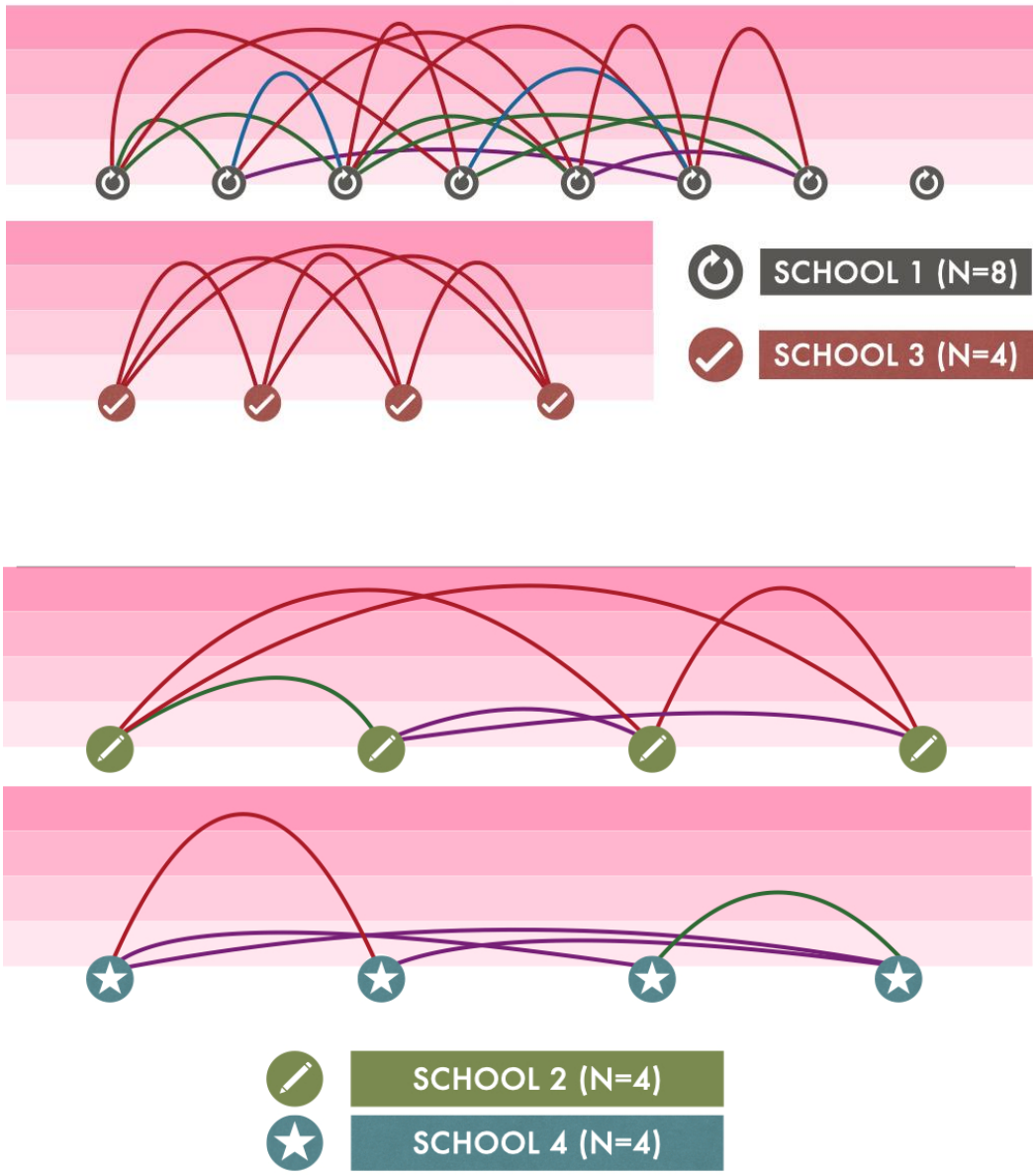
In Georgia, for those K-12 schools that are seeking STEAM certification, there are nine steps[1] to complete to become a STEAM certified school (Georgia Department of Education, n.d.). Both school 2 and 4 were at step two, which values administrators' support, the learning and adapting STEAM pedagogy among teachers, and the implementation of STEAM into teaching. Teachers from schools 2 and 4 would be expected to implement STEAM PBL teaching for the following two years as step 3 before the school conducts self-assessment for step 4. In this project, teachers from school 1 were modeling STEAM PBL collaborations for teachers from school 2, 3, and 4.

[1] 1. Learn about STEM/STEAM. 2. Visit certified school. 3. Implement for two years. 4. Complete self-assessment. 5. Schedule a pre-visit. 6. Adjustments and continued growth. 7. Complete the application. 8. Site visit. 9. Certification. https://www.stemgeorgia.org/certification/

Figure 3

Levels of Meaningful Collaboration: Teacher Participants' Informal Discussions and Dialogues

32	Types of Collaboration	Examples
6 (19%)	Informal Communication	Briefly communicating ideas or stories about teaching in an informal way (e.g., quick "hallway conversation", short email, text messages).
7 (22%)	Giving or Receiving Advice/Help	Giving/asking for advice or help about teaching.
2 (6%)	Sharing Resources	Sharing materials, methods, or ideas related to teaching (e.g., lesson plans).
17 (53%)	Joint Work	Working together to design or deliver instruction (e.g., co-teaching, planning a unit together) or working together to develop a solution to a problem related to teaching.



Limitations and Further Research

There were several research limitations with this study. First, the pool of participants was relatively small (n = 20) which limits the generalizability of its findings to other settings. Second, all selected participants were motivated to implement STEAM PBL in their teaching practices and were eager to learn new pedagogical approaches for art integration, which is not always the case with general classroom teachers who participate in a STEAM-related PD. Third, this study investigated only five months of STEAM PD training. "Teacher learning should be sustained over time given how long it takes to learn, internalize, and apply new instructional methods" (Parson et al., 2019, p. 34). Longer PD training might have a deeper and more meaningful impact on teachers' perceptions and approaches toward STEAM PBL collaborations.

Future research could conduct a follow-up investigation as to how the teachers from the different disciplines in this study subsequently collaborated on STEAM PBL, such as observing their collaborative teaching and assessment of their students' learning outcomes. However, I hope this study provides a first step and a model for identifying visual art integration methods for STEAM PBL using a semester-long or a year-long PD through school and university collaboration. Continually ongoing evaluations and observations of participants' actual teaching practices and approaches to arts integration would further benefit the effectiveness of collaborations between PD providers (universities or community businesses), schools, and teachers.

Conclusions

Developed within the past decade, STEAM PBL is a relatively new transdisciplinary approach that emphasizes close collaborations between teachers from several disciplines working with students to solve a problem through PBL. Consequently, there are still challenges to be

solved in order for teachers to be well-equipped for such joint work. In this study's survey, teachers also expressed some of these challenges. These included having enough time for developing transdisciplinary units, receiving administrative support, having designated planning periods for collaboration, and receiving funding for their PD. As noted by Conradty and Bogner (2020), "Teachers always suffer from a high workload with tight budget" (p. 5). This study also suggests that offering multiple 90-minute visual art workshops throughout a five-month period not only reduces the workload for teachers but also keeps them motivated to learn about various visual art content for art integration.

The results of this study show potential approaches for integrating visual art into other subjects, being open with positive attitudes in willing to work with other teachers to develop STEAM PBL, and making connections between their subjects and visual art. For visual art PD providers, offering more hands-on art experiences, providing step-by-step instructions of art techniques, and making interdisciplinary connections should be the main components of visual art workshops. By doing so, non-art teachers may feel less stressed about drawing skills or techniques. Secondly, helping non-art teachers to see how artists use visual creations to express ideas could also inspire and motivate their engagements in making connections between disciplines. Helping them to see these connections may potentially translate into how they may grow to help their students see the interdisciplinary connections.

Moving forward, STEAM PD should be further investigated to confirm that its participants can integrate their ideas into their actual teaching, including class scheduling and assessment. STEAM PBL helps students to build connections across disciplines and will continue to be essential to their meaningful learning.

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