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Growing Capacity in Gifted and Talented Education Through Science, Technology, Engineering, Arts, and Mathematics (STEAM)

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Abstract

A graduate-level gifted and talented education (GTE) course for in-service teachers was revised aiming to prepare teachers to integrate science, technology, engineering, arts, and mathematics (STEAM) education into existing curricula to create challenging learning experiences for students identified as gifted and talented. Two university-based teacher educators in science education and GTE, respectively, engaged in action research in order to develop and refine a semester-long STEAM project in the GTE course to accomplish this goal. In all, two elementary, one Music, and one World History teacher participated. Case study analysis explored the teachers' approaches to developing STEAM-based lessons to expand their GTE toolkit, as well as teacher-reported effects on their students. The lessons implemented are discussed in light of guidance from reviewed literature, including student-centeredness, inquiry-driven, problem-based, peer interaction, and local contextual relevance.

Keywords

gifted and talented education, arts-integration, science, technology, engineering, arts, and mathematics (STEAM) education

Cover Page Footnote

We wish to thank the GTE teachers for their participation and support of this work which will contribute to the improvement of our teaching and that of our peers. We also wish to thank the reviewers in contributing to strengthening this paper.

Growing Capacity in Gifted and Talented Education through Science, Technology, Engineering, Arts, and Mathematics (STEAM)

This study explored one way to support classroom teachers in integrating science, technology, engineering, the arts, and mathematics (STEAM) into their instruction in the context of gifted and talented education (GTE). Teacher preparation standards in GTE (National Association for Gifted Children [NAGC], 2013, para. 3) stated that teachers should be able to "design appropriate learning and performance modifications for individuals with gifts and talents that enhance creativity, acceleration, depth and complexity in academic subject matter and specialized domains." This complexity and depth may be accomplished through integrated curricular design, which is emphasized in ongoing science, technology, engineering, and mathematics (STEM) and STEAM efforts. Even more, science education framed as STEM and situated in real-world contexts is presented as more authentic and socially relevant to students (Johnson, Peters-Burton, & Moore, 2015; MacFarlane, 2016), thus supporting interest and motivation. Arts-integration further enhances STEM education by increasing opportunities for creative, hands-on experiences (Philpot, 2013), communication through varied media (Zalaznick, 2015), and deepening conceptual understanding (Gurnon, Voss-Andreae, & Stanley, 2013). The arts integrated into STEM as STEAM additionally works to overcome historical limitations in distinguishing the arts from science and downplaying the role of creativity in science (Quigley, Herro, & Jamil, 2017).

With the focus of this study being on STEAM integration in the context of GTE teacher education, the goal was to explore how integrated STEM/STEAM can support classroom teachers in providing students in GTE tracks with accelerated and complex curricula. These curricular enhancements can include increasing students' exposure to elementary science and engineering education, where the emphasis tends to be on literacy and mathematics. This exposure at the elementary level is additionally important as interest in science is sparked well before middle school (Maltese, Vincent & Tai 2009) and STEAM experiences may provide students, early on in their K-12 education, with the motivation to develop their skills and pursue advanced study and professional careers in STEM fields (Mann et al., 2011). At the same time, while interest in science and math is comparable for male and female students up to late elementary/early middle school, gender gaps in science and math education emerge and widen through high school and into post-secondary education (Gomoll, Hmelo-Silver, Šabanović, & Francisco, 2016; National Science Board, 2018a, 2018b). Various factors play roles in these gaps, including lack of gender-/culturally-responsive curriculum and instruction, teacher and parental biases, and differences in out-of-school science experiences (Mark, Constantin, Tinnell, & Alexander, 2020). Thus, beyond elementary grades, it is important to continue emphasizing STEM education and to do so in ways that are diverse and non-traditional, for instance, by integrating the arts into STEM as STEAM.

Overall, for GTE educators across the K-12 spectrum, STEAM integration into their ongoing instruction can potentially support their students in developing and maintaining interest in science and math education, along with technology, engineering, and the arts. Seeking to support this infusion of STEAM education into GTE at the classroom level, two university-based teacher educators explored ways to support GTE teachers in designing STEAM-based lesson plans. This process involved the introduction of a lesson planning framework to support the teachers in continuing this work beyond the exploratory study.

Review of Relevant Literature

From a review of literature focused on STEAM education in GTE classrooms, common themes in instructional design were identified, including student-centeredness, inquiry-driven, problem-based, peer interaction, local contextual relevance, and community connectedness. More specifically, successful models of STEAM pedagogy integrated into GTE has focused on inquiry-based, problem-centered enrichment opportunities through which students participated in hands-on experiences and active discussion with other students, teachers, as well as with their parents (Chu et.al, 2019; Mann et al., 2011; Marshall et al., 2011; Morris et al., 2019; Robinson et al., 2014). Peer and family interaction is particularly important as students in GTE need interactive experiences to increase interest and engagement (Robinson et al., 2014).

Chu, Martin and Park (2019) explored the use of hands-on activities, as well as the importance of peer interaction through group discussion amongst students to develop scientific literacy for all students. Their approach further shifted the focus of learning from teachers to the students. As students are allowed greater autonomy with this shift, they are more able to explore concepts in a manner that suits their interests. Meaning is constructed by the learner. Students are provided opportunities to develop their own ideas and engage in exploration and discovery in areas of personal interest.

Regarding local contextual relevance, Morris et al. (2019) suggested providing these opportunities through the use of local rural knowledge. This approach focuses on utilizing the local community, culture, and heritage of students to develop a better understanding of the world as a whole. This type of scaffolding allows students to utilize their pre-existing knowledge to expand the understanding of a given concept. Robbins, VanTassel-Baska and Little (2011) extended local contextual relevance to include community connectedness and suggested that curricula provide opportunities for students to apply scientific reasoning, encourage reflection and collaboration, engage students in quantitative problem solving, and expose students to real work of scientists. In conducting field work with experienced scientists, students participating in GTE are supported in situating their learning within larger, more socially relevant contexts. In providing students these opportunities, they are not only able to connect concepts to real-world situations, but also able to experience activities that are conducted by actual scientists (Morris et al., 2019).

Engineering design and problem-based learning provide coherent umbrellas under which various skills and foci can fit. For instance, engineering design projects integrate a number of disciplines, including science, technology, mathematics, language, the arts, and history, along with emphasizes problem-solving and learning culminating in projects (Cunningham & Hester, 2007). Problem-based learning has also been shown to result in greater student interest, engagement, and overall achievement (Robinson et al., 2014).

Through this study, the researchers sought to explore the ways in which a group of classroom teachers developed STEAM-based lessons to create challenging learning opportunities for their G/T students in the context of a course-embedded STEAM curriculum development project. Teachers of varied grade levels and different areas of expertise increased the complexity of this interdisciplinary instructional design. The major themes identified through the review of literature informed the analysis of the lesson plans created.

Instructional Design Framework

Each of the common themes identified from the review of literature, including student-centeredness, inquiry-driven, problem-based, peer interaction, local contextual relevance, and community connectedness, were modeled and emphasized in the STEAM project. To prepare the participating teachers to design STEAM-based lesson plans, an instructional design framework was presented. There were two phases of supporting the teachers in using the framework to plan instruction – (i) course-embedded teaching demonstrations; and (ii) a lesson plan template.

All of the teachers participating in the project were enrolled in a graduate-level teacher education course as part of a program leading to a certification in gifted and talented education. Approximately four weeks into the semester, the students were assigned a reading entitled *The wonder of discovery: Science and the arts* (Goldberg, 2017b, p. 128 - 161). The assigned reading detailed a framework for integrating the arts across the curriculum and centered in science, in particular. The book chapter also provided several examples of lesson plans of the arts integrated in science lessons and detailed instructional targets, student learning experiences, and student work. In the class meeting following the reading, the first author reviewed research on STEM/STEAM education in the context of GTE and the proposed benefits to students in GTE tracks. She also presented on and discussed the conceptual framework proposed by Goldberg (2017a) in the reading, then extended the framework to include guidance for lesson planning in STEM. Finally, she led immersive teaching demonstrations of STEAM integrated at different grade levels and in different subject areas.

In presenting the instructional design framework, Goldberg (2017a) argued that the arts can be integrated into the curriculum, across subject areas, by students learning in the following ways:

- *Learning with the arts* in which works of art serve as instructional resources. For example, students use lyrics, food, music, paintings, interactive experiences/simulations, sculptures, and more in order to perform learning and assessment tasks; and
- *Learning through the arts* in which students engage in artistic processes to create works of art as part of learning and assessment. For example, students engage in songwriting,

storytelling, sculpting, performing plays and instruments, painting, cooking, and more in order to learn and demonstrate proficiency.

In integrating the arts into STEM for STEAM education, STEM educational expectations were defined as students thinking and performing tasks to demonstrate knowledge and proficient use of foundational scientific concepts and ideas. The major expectations of student thinking and performance (doing) in STEM were established through the use of the *Next Generation Science Standards* (NGSS Lead States, 2013). These policy guidelines were chosen based on NGSS' more intentional interdisciplinary integration of technology, engineering, and mathematics into science education to reflect the nature of science more authentically and how science is learned and used in the real world. NGSS defines student thinking and performance expectations in terms of cross-cutting concepts/conceptual lenses (CCCs) and science and engineering practices (SEPs), respectively. Specifically, students are expected to be proficient in using CCCs to make sense of natural phenomena and data, as well as expected to be able to perform SEPs to understand and construct scientific knowledge. CCCs and SEPs are summarized in Table 1.

Table 1

CCCs and SEPs as defined by the NGSS

CCCs	SEPs
Patterns	Asking Questions and Defining Problems
Cause and Effect	Developing and Using Models
Scale, Proportion, and Quantity	Planning and Carrying Out Investigations
Systems and System Models	Analyzing and Interpreting Data

Energy and Matter	Using Mathematics and Computational Thinking
Structure and Function	Constructing Explanations and Designing Solutions
Stability and change	Engaging in Argument from Evidence
	Obtaining, Evaluating, and Communicating Information

Student thinking and performance in STEM is focused on foundational scientific concepts and ideas, which are termed disciplinary core ideas (DCIs) in the NGSS and serve as a third dimension of student STEM educational expectations, in addition to CCCs and SEPs, in the instructional framework. To bring the various components of arts-integration and STEM together in order to plan lessons, a template was prepared to guide the teachers. An excerpt of this template is provided in the Appendix and includes sections that solicit information on the academic and cultural backgrounds of the students for whom they are planning instruction, alignment of the lesson to state academic standards, teacher reflection on past instruction and plans for future instruction, and more. In using the template, while all possible CCCs and SEPs are listed, the teachers were not expected to integrate all of these into their lesson, but rather choose at least one of either. In the template, the teachers were also asked to identify what science-related content or idea they would focus on in the lesson, as well as how they would design opportunities for their students to learn with and/or through the arts. At minimum, the teachers were expected to integrate at least one aspect of the arts into at least one aspect of STEM.

The teachers had the opportunity to engage in several teaching demonstrations of STEAM integrated across grade and subject areas, then the template used to identify the key aspects of students learning with and/or through the arts, as well as engaging with CCCs, SEPs, and/or DCIs. One of the teaching demonstrations focused on STEAM in a high school history class. The first author presented two side by side photographs (as works of art). Each of the photographs was of the same intersection of streets in the local downtown area of the university, but one was in the 1950s, while the other was a picture of present day. The teachers were then asked to carefully look at each photograph and identify any differences and to pose explanations for these differences. Student responses were noted on the whiteboard as they were shared, then each discussed. Examples of student responses, as well as those added by the teacher educator are summarized in Table 2.

Table 2

Student and teacher educator responses during learning with *photography*

Differences observed	Explanations posed
Change in the kinds of machines/technology present – cars, drainage, streetlights and wiring	Innovations and advances in engineering and technological design
Increase in the amount of urban tree cover/number of trees	Growth in understanding of the positive environmental/ecological impact of trees and local government/community efforts to increase number of urban trees
Decrease in the number of people walking along the streets	Many businesses removed and buildings razed during era of urban renewal. So, despite

	population growth over time, services lacking in the downtown area to attract people; and/or changes in highway/road design to make downtown area less amenable to walking and businesses located elsewhere more accessible via car transportation and parking options.
Increase in the number of street markings, although incomplete	Greater attention paid to pedestrian and driver safety and development of street transportation logistics/management practices

Following discussion, the various specific academic connections were made explicit. This teaching demonstration situated STEAM in a high school history class with the following essential question guiding student engagement and learning: In what ways has this area of Louisville, KY changed over time and why? From a history perspective, potential topics of focus included 1950s – 60s desegregation efforts and civil rights movements, White flight and suburbanization, and urban renewal. While centrally engaged in any of these history topics, students would also have the opportunity to learn about the impact of humans and technology on the natural and built environment and the benefits trees and green spaces provide to their ecosystem as ecosystem services (DCIs); to analyze the photographs as data, ask questions, and construct explanations (SEPs); and to think about the two photographs through the CCC lens of stability and change. The photographs were the central instructional resources used, therefore, the lesson supported student learning *with* the arts. To conclude this teaching demonstration, the teacher educator then asked the teachers to search online for a photograph or painting that would serve as a focus for integrating a topic in science or engineering into their content area. Additional demonstrations included mathematics and science *through* and *with* poetry, environmental science *through* music, and biology *through* storytelling.

The instructional design framework as presented and demonstrated aligned with several of the key themes identified from the review of literature focused on STEAM education in GTE classrooms. STEM education (NGSS Lead States, 2013) emphasizes student-driven inquiry into observations of natural phenomena and/or authentic problems situated in socially relevant, real-world contexts. In so doing, student-centeredness, inquiry-driven, problem-based, and local contextual relevance are each emphasized. As illustrated in the STEAM-integrated history lesson, student curiosity was probed to encourage their inquiry into an ill-structured problem, further centered on an area nearby of familiarity to all of them. Additionally, STEM is recognized as a collaborative knowledge-building process which increases the need and opportunity for peer interaction in learning. Community connectedness, particularly in the form of partnerships with family and community members, was not emphasized or modeled. These kinds of partnerships would work best with long-term projects, as opposed to the shorter one- to three-day lesson plans on which the teachers were then focused. They were certainly free to extend beyond the expectations in the project to design longer-term instruction that established and maintained community partnerships.

Research Design

Action research (Stringer, 2008) allowed for systematic collaboration in support of research-based inquiry and reflection between the two teacher educators in GTE and science education, respectively. In line with Lambirth and Cabral's (2017) guidance for action researchers to engage in ongoing and cyclical processes of reflecting, planning, and acting, the collaboration began by the second author, as the GTE teacher educator, seeking to enhance the curriculum development skills and outcomes for teachers in the course. She sought a way to increase complexity, creativity, interdisciplinarity, and more into the GTE course and, learning of the STEAM education background of the first author, she initiated an in-person brainstorming and planning discussion in Fall 2018 which continued regularly via email until the week before the start of classes in Spring 2019. Following additional unforeseen circumstances, a third instructor was assigned to teach the GTE course; however, planning for the STEAM project had been completed and, so, the two named authors were still able to act and implemented the project in Spring 2019. This research study served as the opportunity to systematically inquire into the impact of the project to learn further and revise for future teaching and research.

Participants

The research was conducted in Spring 2019 during which four in-service teachers were enrolled. These teachers included two female elementary school teachers, one male Music teacher, and one male World History teacher. Their teaching experiences ranged from two to five years.

Each of the teachers utilized the instructional planning framework and drew upon the lesson demonstrations to draft, revise (with teacher educator feedback from the first author), and implement one STEAM lesson in a current class with students officially identified as GTE (or identified as potentially GTE in elementary grades). The teachers used the lesson planning template to plan and submit their lessons. Each teacher submitted written data-based progress reports and shared their experiences in implementing their lessons during in-class presentations. The presentations focused on the impact of the STEAM project on their students' learning, motivation, and engagement; project experiences; and ideas to move forward and further improve.

Data Sources and Analysis

Case study methods (Rossman & Rallis, 2003) were used for data collection and analysis. The data were varied and included all artifacts created in the implementation of the project in the context of the class, including the teacher educators' notes and plans for developing the STEAM lesson planning project; the teachers' draft and final lesson plans, as well as their written progress reports; teacher educators' observations of lesson implementation and progress report presentations; and the teacher educators' reflections and discussions. All data were compiled as a single case study and analyzed thematically (Saldaña, 2015). Guided by the review of literature, the lesson plans were analyzed in terms of the key themes identified - student-centeredness, inquiry, problem-based learning, peer interaction, and local contextual relevance. As stated earlier, community connectedness was not emphasized in the teaching demonstrations nor expected in the teachers' lesson plans. Triangulation was achieved via multiple data sources, participants, and researchers.

Findings

In the sections that follow, examples of the ways in which student-centeredness, inquiry, problem-based learning, peer interaction, and local contextual relevance are highlighted. Three of the four teachers created STEM learning opportunities *through* and *with* the arts, while one elementary teacher focused only on STEM learning *through* the arts (Table 3).

Table 3

Overview of Lesson Plans

	Mr. Dawn	Mr. Cash	Ms. Lamb	Ms. Chandy

Area	World History	Music	Elementary	Elementary
Activities	Students listened to World War II era music and reacted to Pablo Picasso's wartime painting, Guernica, followed by creating their own original propaganda posters.	Students played instruments in an orchestra, listened to their music, and performed mathematical calculations to predict scales and pitch.	Students analyzed poetry to understand the humanitarian impact of the destruction caused by Hurricane Katrina, followed by engineering design to model homes that can withstand a hurricane.	*Students will analyze photos from the city of Louisville when it was flooded and engage in engineering design to model flatboats to float down a "river" carrying cargo.

* Lesson plan not implemented

Problem-based Learning and Local Contextual Relevance

In both of the elementary grade's classroom, students were afforded opportunities to learn *through* the arts by conceptualizing and executing original designs of model homes and transportation. In these lessons, these student learning experiences were housed under the term engineering design.

Ms. Lamb designed a lesson in which students learned about the impact of Hurricane Katrina on the people and the built urban environment of Louisiana, then students engaged in engineering design to model homes that can withstand the effects of a hurricane. Students observed Ms. Lamb modeling the hurricane impacting a demo house through the use of a blow-dryer on both low and high levels. The students had to observe the effects of the wind and describe their observations carefully. Then, focusing on their observed effects, they selected materials and worked with classmates to design and build model houses that can withstand the strong wind of a model hurricane. Ms. Lamb replicated real-world constraints based on budgets, time, and availability of materials by setting costs to the materials they chose and a maximum budget, as well as limiting the number of each type of material they could choose per team and the amount of time they had to select materials and build the houses. Following design and building, each team tested their house against the low and high winds of the blow-dryer/hurricane and made qualitative judgments about which house stayed most intact. Ms. Chandy, similarly, but separately, challenged her students to use Legos to design houses in ways that would minimize damage from weather-related hazards.

Another commonality identified in Ms. Lamb's and Ms. Chandy's approach to arts-integration was that they both utilized works of art to communicate the extent of the human impact of real weather events, prior to working to solve the related engineering design problems. These approaches served to establish the importance underlying the engineering design problems and building process, as well as to connect the problems to real communities and locales. Ms. Lamb's students read poetry written about Hurricane Katrina and Ms. Chandy's students analyzed photographs of historic flood damage in Louisville, KY.

Beyond reading the poetry, which involved learning *with* the arts, Ms. Lamb concluded her lesson by having her students learn *through* the arts by writing empathetic poems imagining that they had experienced Hurricane Katrina. In doing so, the human experiences were made more personal to the students and the possibility of experiencing such destruction in their own locale made clear. For Ms. Chandy, designing this step for her students to learn *with* the arts by analyzing the photographs of the historic local flood and related damage was done to guide their thinking towards the key conceptual idea that severe hurricane weather causes risks in multiple ways, including not only strong winds, but also flooding due to heavy rain. More importantly, this scientific concept was presented in terms of a historically significant local case of a devastating flood. Students concluded the lesson by learning that modern designs in existence today involved flood gates intended to mitigate flood damage. In an extension of the lesson, Ms. Chandy planned for her students to complete another engineering design challenge where they would use various materials, beyond Legos, to design and build model flatboats to transport cargo along a model Ohio River, which is of local relevance to Louisville students. Overall, through their lesson designs, both teachers engaged their students in the creative arts through engineering design and urban planning grounded in cases of personal and/or local relevance.

Inquiry-driven

In Mr. Cash's music class, students inquired about how physics and mathematics can help them develop, then perform scales in music. To explore this, Mr. Cash's students learned *through* writing and performing music by using mathematics to calculate scales for harmonic series, explained through understanding of physics concepts, then played their instruments and listened for evidence of the series. Mr. Cash planned for students to watch a video of a famous musician playing piano music and explaining the physics of waves, the harmonic series, and its effect on music composition. Mr. Cash's lesson design had multiple purposes that were seamlessly integrated. He was able to introduce and teach about the musician's significance and history in music education; students were able to listen to the musician play music; the musician explained the physics concept and demonstrated the phenomenon by playing live music; and finally the students calculated and played their harmonic series in an orchestra.

Student engagement in inquiry was also supported through teachers' intentional questioning. In both of the elementary-level engineering design classes, following model creation, testing, and designing solutions, the teachers engaged in whole-class questioning to probe student thinking and to guide them towards argumentation to target the underlying STEM learning goals. Ms. Lamb's questioning targeted the relationship between building design and structure (e.g., area of the base of the building and the center of gravity) and the buildings' capacity to resist destruction. She also targeted student argumentation to evaluate competing house designs by having the students use a systematic process to determine how well their designs met the criteria of withstanding exposure to the model hurricane for a set amount of time. Ms. Chandy's questioning, on the other hand, targeted various weather-related hazards, i.e. wind and flood damage, and ways humans can take steps to reduce the impact of these hazards. Students responded to probing questions from the teacher, intended to highlight key concepts from the lesson, such as houses with wider bases were more structurally sound and that budget restrictions due to differences in wealth and income levels resulted in some houses being un/able to incorporate necessary structures/design features to reinforce houses from the weather-related hazards.

Student-centeredness

Mr. Dawn's World History class showcased student-centeredness by creating opportunities for his students to listen and react to music, reflecting deeply on the emotions and words they each personally experienced as a result of the music played, followed by questioning and sharing. His lesson's overall goal was to teach students about how media can be used to manipulate viewers'/readers'/listeners' emotions and how data can be manipulated to argue different perspectives. This was taught in the World History context of political propaganda.

His students first learned *with* music by Mr. Dawn playing two unidentified instrumental tracks for his class, while they listened silently. Mr. Dawn asked his students to think about and prepare to share the images, words, and emotions conjured by the music to which they listened. The class then considered the commonalities and themes amongst the answers shared out. Mr.

Dawn then identified the music as soundtracks to two World War II-era TV productions. Many students had described emotions of triumph, exhaustion, climax, and war and imagery of battlegrounds, castles, and soldiers, which aligned with Mr. Dawn's hope to illustrate to students the power of music in influencing people in specific ways. This lesson exemplified student-centeredness as the students' own perspectives and sense-making were foundational to the lesson, which was that works of art have been used to intentionally communicate messages, including political messages and propaganda.

Continuing with student-centered learning *with* the arts, Mr. Dawn next displayed an image of Pablo Picasso's wartime painting, *Guernica*, and similarly, led a class discussion of student noticings and reactions after silent inspection. Mr. Dawn then situated the painting in historical significance and highlighted connections between students' noticings/reactions (e.g., "people in anguish and agony"). Students were particularly excited by how their noticings/reactions aligned so well, especially unaided, to the real set of historical events. This cemented Mr. Dawn's learning goals about the power of the arts in influencing one's perspective and experiences for students. The lesson concluded with an assignment for students to learn *through* the arts by creating their own original powerfully influential artwork. They designed politically charged propaganda art of their own choosing that they, importantly, critiqued in terms of issues of power and bias.

Peer Interaction

All of the lessons designed by the teachers involved opportunities for peer interaction. Ms. Lamb's and Ms. Chandy's classes included peer collaboration during engineering design, whereby students worked in small groups to select materials, then designed and executed their models. Mr. Cash's class culminated in an orchestra performance, whereby students performed their calculated harmonic series. In Mr. Dawn's class, after silently listening to each song, students shared their reactions to the music for one minute in pairs and small groups.

Students responded positively to the opportunities to interact with peers during group work and some students, particularly the G/T students, may have been afforded opportunities for leadership. Regarding this latter point, in her progress report, Ms. Lamb stated: "Everyone was challenged. Everyone was engaged. Even those [students] who do not like group work were engaged. Students self-corrected misconceptions. The [unofficial] 'G/T[E]' students tended to lead their groups."

Discussion and Implications

In this study, problem-based STEAM instruction was accomplished by focusing on engineering design challenges, which were, furthermore, situated in important historical cases of real-world events. One event was local, in Louisville, while the other was focused on Hurricane Katrina and New Orleans. New Orleans is located in the same southeastern region of the United States as Louisville, but, further, the massive human and physical impact of Hurricane Katrina has made this case familiar to many at national and international levels. It is important for all students to understand the social relevance and applicability of the information and skills that they will learn in school settings. In seeking to provide G/T students challenge, these larger connections to society and out-of-school events and settings are critical. Even more, while teachers may present problems to be solved in terms of personally or locally relevant cases, the students themselves can be encouraged to source or construct these connections. This may provide opportunities for self-directed learning, initiative, exploration, discovery, and more.

Some of the teachers designed lessons involving peer interaction via small group collaboration which involved mixed-ability student grouping, whereby students at varying giftedness levels work together (Ross & Smyth, 1995), as compared to gifted-ability grouping, in which GTE students work together in their own group(s). Collaborative learning for GTE students involving mixed-ability student grouping has been critiqued by some as GTE students' access to differentiated learning opportunities is limited, including enriched and more challenging materials and tasks, faster instructional/learning pace, and interaction with other/primarily GTE peers (Huss, 2006). The debate continues in weighing mixed- versus gifted-ability grouping and regarding the positive, neutral, and negative effects of each (Preckel et al., 2019); however, "[m]ixed-ability grouping can provide an unparalleled opportunity for the development of transformational leadership skills among some gifted learners" (Ross & Smyth, 1995, p. 64). Quoting Roberts (1985), Ross and Smyth (1995, p. 67) stated: "Transformational leadership is "a leadership that facilitates the redefinition of a people's mission and vision, a renewal of their commitment, and the restructuring of their systems for goal accomplishment" (p. 1024). Reflecting on her lesson, Ms. Lamb stated that her GTE students responded by adopting leadership positions. In light of the historic literature on the pros, cons, and promises of GTE student grouping and leadership development, the authors would be interested to further explore how STEAM-based collaborative learning affects leadership development among GTE students, especially given STEAM's relatively recent entry into education reform efforts.

Student inquiry was supported via the teachers' extended questioning and through whole-class discussion and debrief. This was intended to encourage the students to think critically and to stimulate their interest by posing intriguing open-ended questions, such as what emotions and words are conjured in response to instrumental music or how can physics and mathematics help us write music? In designing curriculum to challenge G/T students, higher-order questioning and complex thinking are important as Dixon et al. (2004) stated:

> . . . curriculum intervention is needed. Students must maintain a cognitive match between their abilities and their curriculum, and teachers must help create that match by designing worthwhile instructional materials and implementing them with worthwhile instructional strategies in the classroom (p. 58).

The enriched curriculum is a major GTE programmatic approach, yet ". . . there is little research on the efficacy of enrichment options" (Worrell, Subotnik, Olszewski-Kubilius, & Dixson, 2019, p. 567). This encourages the authors to explore GTE students' own perspectives on the STEAM curriculum as enriched and more challenging compared to their traditional curriculum and to explore the patterns of the students' critical thinking and cognitive processes in STEAM learning.

Rodriguez (2015) discussed the potential impact of teachers' resistance to pedagogical and ideological change on reform and innovation in instruction. This is an important consideration in the present project in which in-service GTE teachers across grades and subject areas were newly challenged to teach using cohesively integrated STEM and the arts in challenging and creative ways. The teachers were variably involved in STEM and arts education. The elementary teachers were responsible for teaching across the curriculum but had no experience or institutional expectations in integrated STEAM education. The music teacher was involved in arts education, but not STEM. The world history teacher was not involved in STEM, the arts, or STEAM education. Despite this, all of the teachers were optimistic and productively engaged, demonstrating open-mindedness and willingness to be challenged and innovative in their teaching practice and as ongoing professional learners. From the first introduction of the project in a course meeting early in the semester, they all asked questions, shared initial lesson plan ideas unprompted, and solicited teacher educator feedback on these ideas.

Encouraged by the positive reception and willingness to innovate by the teacher participants, as well as the potential student learning outcomes in the teachers' classrooms, the teacher educators aim to extend the STEAM project. The lesson planning outcome that served as the final assignment in this first project implementation may now serve as an initial assignment for formative assessment and feedback to the teachers. Then, for a revised final assignment, the expectations for teachers will be increased in several ways. The number of days of instruction can be increased from one to three or possibly five days. Additionally, the number of aspects of STEM and the arts to be integrated can also be increased from at least one each to a level that permits greater complexity in instructional planning and student thinking. One restriction that limits the extension of the STEAM project is that there is still much more content and skills development to cover in the course beyond the project. As a result, an out-of-school teacher professional development and student learning format might be a possibility to create a more flexible space with greater time allowance to further explore STEM curriculum development for G/T students.

Limitations

The study is limited by the small number of participants, as well as the short-term length of the study/teaching intervention. Sustained classroom-level changes may be limited without follow up with the teachers; however, this study has supported an initial definition of STEAM-based lesson planning guided by research and policy documents. Initial findings have also stimulated several new lines of inquiry to explore in future large-scale and longitudinal interventions.

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Appendix: Excerpt of Instructional Planning Template

Instructions:
What student learning activities will support them in engaging in the above learning objectives and enduring understandings?

Will students be learning with STEAM and/or learning through STEAM?

If learning with STEAM, what works of art will be used as instructional resources?
and/or
If learning through STEAM, in what artistic processes will students be engaged?

In what ways will science, technology, engineering, and/or mathematics be integrated into the learning activities? Explain all that apply from the following (at minimum, addressing one of the following is desired):

<table>
<tr><th colspan="2">KNOWING STEM</th><th colspan="2">DOING STEM</th><th colspan="2">THINKING STEM</th></tr>
<tr><td rowspan="8">Science-related content or idea</td><td rowspan="8"></td><td>Asking Questions and Defining Problems.</td><td></td><td>Patterns</td><td></td></tr>
<tr><td>Developing and Using Models.</td><td></td><td rowspan="2">Cause and Effect</td><td rowspan="2"></td></tr>
<tr><td>Planning and Carrying Out Investigations.</td><td></td></tr>
<tr><td>Analyzing and Interpreting Data.</td><td></td><td>Scale, Proportion, and Quantity</td><td></td></tr>
<tr><td>Using Mathematics and Computational Thinking.</td><td></td><td>Systems and System Models</td><td></td></tr>
<tr><td>Constructing Explanations and Designing Solutions.</td><td></td><td>Energy and Matter</td><td></td></tr>
<tr><td>Engaging in Argument from Evidence.</td><td></td><td>Structure and Function</td><td></td></tr>
<tr><td>Obtaining, Evaluating, and Communicating Information.</td><td></td><td>Stability and Change</td><td></td></tr>
</table>