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ORIGINAL PAPER

Innovations in science education: infusing social emotional principles into early STEM learning

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Abstract We report on the development of an after-school and summer-based science, technology, engineering, and mathematics curriculum infused with the arts and social emotional learning content (STEAM SEL). Its design was motivated by theory and research that suggest that STEM education is well-suited for teaching empathy and other emotion-related skills. In this paper, we describe the activities associated with the development and design of the program and the curriculum. We provide expert-ratings of the STEAM and social emotional elements of the program and present instructor and participant feedback about the program's content and its delivery. Our results revealed that infusing the arts and social emotional learning content into science education created a holistic STEM-related curriculum that holds potential for enhancing young children's interest in and appreciation for science and its applications. The data also suggested that the program was well-developed and, generally well-executed. However, experts rated the STEAM elements of the program more positively than the SEL elements, especially with regard to sequencing of lessons and integration among the lessons and hands-on activities, indicating that program revisions are warranted.

Keywords Science education · Social emotional learning · STEM education · Twenty-first century skills

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In this paper, we report on the development of an after-school science, technology, engineering, and mathematics (STEM) curriculum infused with the arts and social emotional learning (SEL) content. Infusing STEM topics into art education and vice versa has become known as STEAM, with the "A" being added to represent the essential role of the arts in STEM learning (Sousa and Pilecki 2013). The design of our *STEAM Social Emotional Life Skills* (SEL) program was motivated by theory and research that suggest that STEM education is well-suited for learning about empathy and other emotion-related skills (Castano 2012). SEL has been defined as the process of acquiring core competencies of understanding and regulating emotions, developing positive goals, understanding the perspectives of others, maintaining positive social relationships, making responsible decisions, experiencing empathy for others, and managing challenging interpersonal situations (Elias et al. 1997). It is important to acknowledge that social and emotional competencies are embedded within a larger sociocultural context. Moreover, cultures create shared understandings of emotion and the behaviors that precede or accompany them (Halberstadt, Denham, and Dunsmore 2001).

The STEAM SEL program was focused especially on the understanding, expression, and regulation of emotions because the experience of learning science is connected to and evolves in relation to emotional output of both children and their teachers (Kwah, Milne, Tsai, Goldman, and Plass, 2016). These skills have proven essential to learning in the STEM areas as many topics in this area elicit highly intense responses from children (Broughton, Sinatra, and Nussbaum, 2013). However, because social emotional competence is a multidimensional construct, it was important that the curriculum target a broad range of social-cognitive competencies, some of which are sometimes referred to as twentyfirst century life skills. In so doing, we embraced Randall Collins's (2004) interaction ritual theory, which posits that emotional exchanges during collaborative experiences, such as those that occur in science classrooms, contribute to a shared emotional and learning experience, heightened emotional energy in relation to the group activity, positive social relationships, and compassion for others. We however, remained resolute in the commitment to the supposition that both cultural *and* social factors shape SEL. Therefore, we considered the perspectives of students, teachers, and university- and community-based experts in the design and re-design of the curriculum to ensure that the program would appeal to a wide range of children from various sociocultural and academic backgrounds. In accordance with Vygotsky's sociocultural theory, peer collaboration is also an important element of the program. Vygotsky conceived of learning as a socially-mediated process in which the skills and abilities of each child are interweaved to facilitate learning for everyone involved. Working with others also creates a dynamism that reflects emotional synergy needed for higher-order thinking and complex problem-solving (Levykh 2008).

Twenty-first century life skills

Achieving long-term success in the twenty-first century requires communicative competence, creativity, the ability to work collaboratively, and critical thinking skills (Greenberg et al. 2003). Global citizenship, confidence, and empathy have also been highlighted as being important for long-term personal and professional success (Ee, Zhou, and Wong 2014), and as essential for the establishment of a free and democratic society (Elias 2009). Several conceptualizations of these twenty-first century life skills have been advanced. Some researchers group them as either innovation skills, digital literacy proficiencies, or workplace competencies. Others suggest that they be categorized as cognitively-based, social-emotionally based, or as cognitively-based skills infused with social-emotional competencies (De Fruyt, Wille, and John 2015), the approach that we adopted here.

In 2007, the United States Congress passed the America COMPETES Act, which is aimed at improving STEM programs from kindergarten through graduate school (Sousa and Pilecki 2013). In 2010, the Common Core standards were introduced to establish consistency across states for expectations of grade-specific knowledge and skills across the K-12 years. Despite these initiatives, higher level problem-solving and critical thinking skills in the STEM areas did not improve (Porter, McMaken, and Yang 2011). Including the arts in STEM-based instruction is relatively rare in the United States (Dusenbury, Zadrazil, Mart, and Weissberg 2011), perhaps because of the inflexibility of the standards-driven curriculum (Fusarelli 2004).

Although some teachers perceive students as having positive emotions and attitudes about STEM (Milner, Sondergeld, Demur, Johnson, and Czerniak 2012), many children have negative attitudes and low self-efficacy for learning about these topics (Christidou 2011). Experiencing high levels of negative emotion during science lessons can interfere with the development of science literacy (Tobin and Llena 2010). However, children who are curious, actively engaged in their learning, and able to regulate their emotion-related behavior tend to perform well in school (Lepper, Corpus, and Iyengar 2005). Compared to their peers, children high in social emotional competence may be more likely to use appropriate emotion when completing tasks that require focused attention (Izard 2009). Thinking creatively and critically about science provides opportunities for conceptual thinking and emotional engagement (Saracho and Spodek 2008). Moreover, self-reflection about emotion-related behavior is essential for scientific inquiry and to learning more broadly (Kayumova and Tippins, 2016). Thus, as described below, we took a comprehensive approach to program development. Specifically, we were attentive to the needs of both students and their teachers in an attempt to capitalize upon their multiple intelligences. As described below, we were also mindful of research that shows that the learning space, a global approach, and hands-on learning are essential to science education.

Experiential and place-based

Experiential learning theory asserts that individuals grasp information through experience as well as thought (Kolb 1984). The theory posits that individuals must progress through five phases in order for learning to occur: experience or engagement with the activity, ability to react to and observe in a social context, opportunity to analyze and reflect upon what happened, identifying what was learned, and application of what was learned (Woffinden and Packham 2001). Thus, experiential learning encourages understanding of content, improves social skills and attributes (Knecht-Sabres 2013), and focuses on the learner's need for an emotional connection with the physical world (LeDoux 1997).

An associated element of the experiential nature of the program is that it is place-based, which means that it is focused on expanding learning beyond the confines of the school environment (Powers 2004). Placed-based education involves using the local community as the basis for teaching content in science and other academic subjects (Sobel 2005). This form of teaching and learning has become popular as a strategy for encouraging environmental social action and civic engagement as it embraces a commitment to community values as well as academic learning (Clark 2008). Place-based education also provides opportunities for children to contribute to their own learning, as the specific lessons do not necessarily look the same when implemented across locations.

Neurodiversity/strength-based learning

The term “neurodiversity” was first used in the 1990s to suggest that all students have strengths and talents and that individual differences in brain diversity should be viewed using the same criteria and language describing biodiversity, cultural diversity, and other forms of diversity are discussed (Armstrong 2012). A strength-based perspective emphasizes assets rather than challenges (Burt, Resnick, and Novick 1998) and asserts that individuals are resilient and have a self-righting tendency (Werner and Smith 1992). Thus, the program recognizes that all children are capable of achieving, despite their different perceptual strengths and challenges (Douglas, Burton, and Reese-Durham 2008).

Global citizenship and social responsibility

Another important element of the program was global citizenship. Global interdependence requires today’s students to become globally competent and socially responsible (Breitkreuz and Songer 2015). Global citizenship focuses on the extent to which individuals respect the global landscape, demonstrate an awareness of social responsibility in the search for community-based solutions (Schattle 2008), and understand people, cultures, events, and systems from a global perspective (Ibrahim 2005). Many experts believe that a social justice and global approach to learning and teaching in the STEM areas may contribute to the understanding of social issues and the development of a democratic society (Amadei and Sandekian 2010). However, STEM disciplines tend to be focused primarily on developing technological and scientific competencies rather than social emotional skills (Huang and Healy 1997).

Social emotional learning life skills

The major objective of most SEL programs is to improve students’ social-emotional competencies in order to enhance their academic performance and psychological adjustment, both of which fulfill important roles within the culture (Durlak, Weissberg, Dymnicki, Taylor, and Schellinger 2011). We based the design of the SEL component of our program on the idea that the infusion of science education with SEL will contribute to development of the social, emotional, and relational skills necessary for the creation of partnerships and collaborations important to science learning.

Program development and description

We began by conducting an extensive literature review of existing models of STEM programming and the neuroscience of learning. To better understand how infusing strategies and techniques that have been proven to equip young children with twentyfirst century competencies could be incorporated into our program, we next reviewed experiential learning programs. The team conducted a year-long feasibility study to assess the need for the program in the local area. We then conducted pilot sessions during the summer of 2013 to gauge interest in the program and to better understand how the STEAM SEL approach would work in practice. This initial effort involved visits to local schools as well as interviews with elementary school children, parents, school principals, elementary school science teachers, and other school staff. We learned that there were inadequate resources beyond the school environment to supplement classroom learning with hands-on science applications and social emotional content. We also learned that, even for academically talented children, many parents perceived a lack of freedom for their children to direct their own learning in their science classrooms.

It was also important for the staff to be relationally competent and skilled at providing an inquiry-based learning environment. High-quality programs tend to have positive staff–child relationships, include a diverse array of developmentally appropriate activities that provide opportunities for skill-building, and incorporate flexible programming that allows student autonomy and individualized choice in activity selection (Beckett, Hawken, and Jacknowitz 2001). Initially, children participated in a program that included a combined science, technology, engineering, art, math, and social emotional life skills (STEAM SEL) curriculum during 2-week sessions. Between 8 and 12 children participated in each session, with many children returning for additional sessions, which had different themes. Below, we briefly describe current program components. Specifics of each session and its associated elements are detailed in a manual available from the second author.

The objective of the curriculum is to provide students from kindergarten through 8th grade with the opportunity to learn social emotional competencies while working on hands-on STEAM experiments, projects, and activities. The program allowed students to explore and learn outdoors, a natural laboratory for learning about science. Because people attach meaning and emotions to environments, learning about emotions and social relationships may encourage children's interest in science and other STEAM-related academic content (Semken and Freeman 2008). Initially, we implemented the project in a suburban after-school program in a mid-sized city. The premise of the program that learning SEL strategies and skills while working on STEAM projects creates meaningful connections between children. Children's self-efficacy in relation to what they are doing, exploring, building, and/or creating. Before each session began, parents were surveyed in an effort to personalize approaches for each student. This information helped us to guide students towards personal projects that excited them. After each class, parents received emails that provided them with a summary of the day's activities. Emails included pictures, videos, and other resources that parents could use help their children continue learning at home.

We designed the program so that each child had the opportunity to try every activity. We allowed at least 1.5 h of one-on-one time per child to address individual needs and used in whatever way children chose. Examples of how this time was used for individual children included the instructor providing scaffolding and support to help with project development or execution (e.g., developing a prototype of a solar-powered car), working with students to plan and/or organize, or otherwise engage children in the activities beyond the group. We offered ample outdoor experiences and at least one unstructured free play period outside and at least one structured outdoor learning experience per day. Initially, this time emulated the recess period offered during the regular school day. Interestingly, however, many children used their free time to work on projects in collaboration with their peers. Although we do not identify as a "tech" camp, innovative uses of technology were embedded during most sessions and participants were provided opportunities to try new technologies, including 3D printing and Google glasses. There was also at least one expert guest speaker per session. Instructors worked in partnership with the speaker to provide a hands-on experience directly related to the topic. Finally, participants could use the style of learning that was most appropriate to them (e.g., written, oral, pictorial, and hands-on formats, etc.).

Program development team

The project team included a non-profit specialist, with academic training in economics, early childhood education, and business, a Ph.D. candidate in geography, a master's level expert in curriculum design, and a doctoral-trained expert in social and emotional development. In addition, a former GK-12 STEM Education Fellow with the National Science Foundation, who was also a professor of science education and part of the national team who developed the Next Generation Science Standards (2013), was also part of the development team.

Overall description of the curriculum

For each session, there were four phases: preparation, application, presentation, and assessment, which were designed to mirror best-practices in curriculum and instruction. The preparation phase introduced students to the theme of each session to encourage a deep and collaborative inquiry into the topic. The application phase was activity-based and focused on specific tasks and actions that required students to apply the knowledge gained in the previous phase of their projects. The presentation phase required students to complete collaborative and/or public presentations of their work to the larger group. We tasked participants with developing and discussing applications for how their ideas could be used. The assessment phase included activities and assignments focused on assessing students' conceptual understanding of the material presented in the sessions.

Program sessions

The program launched with three themed sessions. The first session, labeled *Science Magic*, focused on teaching children about biology and chemistry in the context of fun, science-based 'magic tricks'. It also addressed environmental issues of location and community. Participants created a magic show that they presented to a live or virtual audience and displayed projects and activities aimed at helping to improve the environment. During the second session, *Innovation Lab,* participants learned about engineering, building, physics, and materials science as they designed new inventions. Participants worked on prototypes of invention ideas and planned and made a 'prototype pitch', either on video or in person to showcase their ideas for compassionate and socially just innovations or inventions. In the third session, *Amazing Race around the World,* participants selected countries of interest, for which they explored the music, food, costumes, language, and art. Participants learned about environmental science, civics, technologies, and other topics as they created their own 'micro-nation'. Students shared their experiences with a live audience or via video.

Later sessions included age differentiation in the curriculum and added new themes such as nutrition, health, sustainability, and empathetic engineering design. During *Kitchen Chemistry*, participants prepared basic recipes as a strategy for learning about nutrition and connecting the science of food to recipe creation and cooking and identify and address a relevant social challenge. Students examined and developed innovative strategies for preparing and presenting food and worked in teams on food-related inventions. All students collaborated to develop and perform in their own cooking show.

After-school sessions followed the initial launch. These sessions ranged in duration from 1 to 1.5 h and were weekly, ranging from 6 to 14-week sessions. Each class typically featured an SEL life skill paired with a STEM concept and a hands-on activity. During an *Eco-Schools* session, children conducted audits and experiments to learn about the environmental conditions at their schools. They also completed at least one activity to meet a challenge in response to the audits, communicated their findings to peers, designed an eco-plan, and presented their plans to school administrators. The *Superheroes of Science* session focused on the scientific method and introducing students to eminent scientists and their contributions. The objective of the *Mission: POSSIBLE* session was to connect children to real-life scientists and engineers who discussed how they used life skills in their daily application of the Engineering Design Process.

Curriculum evaluation

Each session provided students with opportunities to develop solutions to science-related challenges through hands-on learning and practical applications. All sessions included a problem-based activity that allowed students to model and use real-world scientific practices. We were interested in determining expert perceptions of the program and its associated components as part of our ongoing curriculum development. Below, we provide an analysis of responses, followed by a discussion of lessons learned and suggestions for program modification.

Feedback on STEAM elements

Because the *Innovation Lab* was the most popular program, we asked 20 baccalaureate, masters, and doctoral-level trained subject-matter experts to review the specific materials and activities associated with the sessions. Fifteen were female, five were male, and all but two were White. Using the rubric developed by Jeannie Purcell, Deborah Burns, Carol Ann Tomlinson, Marcel Imbeau, and Judith Martin (2002), the program was evaluated on: clarity of objectives, nature of objectives, learning activities, instructional strategies, assignments and student products, resources, alignment of curricula components, opportunities for talent development, and nature of differentiation. Each element was rated on a 4-point scale, with "4" representing the highest quality ($\alpha = .76$). Mean ratings for the STEAM elements ranged from 3.45 to 3.75. Experts rated the nature of the objectives and alignment of specific components particularly high (see Table 1).

STEM experts also provided open-ended feedback on the session. One expert wrote that "I particularly liked the prompts that were given to teachers to engage" and that "The objectives for learning apply to many types of science." Another commented that "The open-ended assignments encourage students to think and complete their ideas." A significant number of the experts wrote that they enjoyed the lessons on the science of sound, land use and pollution, and energy conscious-building. Experts also agreed that the opportunity to participate as active learners was a critical and positive feature of the program.

Other comments were not as positive. One expert wrote that "Although specific and well-thought out objectives are included for some lessons, there are some places in the curriculum that need more detail." Another wrote: "I am concerned that some of the

Table 1 Mean expert ratings for the STEAM elements

Variables	*M*	SD	Range
Clarity of objectives	3.65	.59	2–4
Nature of objectives	3.75	.55	2–4
Learning activities	3.55	.69	2–4
Instructional strategies	3.60	.50	3–4
Assignments and student products	3.45	.69	2–4
Resources	3.47	.51	3–4
Alignment of curricula components	3.74	.73	1–4
Nature of differentiation	3.47	.61	2–4

concepts and terminology used in the activities may be too advanced for some of the younger participants." There was also some concern that the scavenger hunts, in particular, did not include appropriate information about each found object and its meaning.

Feedback on SEL elements

Researchers have suggested that approaching science concepts with emotion and sympathy/empathy and with a focus on character development and global citizenship may improve individual's capacity for and interest in science learning (Lee, Chang, Choi, Kim, and Ziegler 2012). The use of positive emotions in science is associated with both teacher and student goals. Participation in science activities also create opportunities for the arousal of positive student emotions that can be directed towards learning goals and appropriate peer collaborations (Milne and Oriento 2007). Moreover, personal value of science, enjoyment of science, and interest in learning science are all associated with positive achievement emotions (Ainsley and Ainsley 2011). Affective imagination can be also operate to teach young students science concepts (Fleer 2013).

Using an adaptation of the rubric developed by Jessie Ee, Mingming Zhou, and Isabella Wong (2014), experts in SEL considered the Social Emotional Life Skills components of the program. Experts consisted of four Ph.D. trained developmental psychologists and two master's level school psychologists. Each of them rated thirteen program elements. See Table 2 for a complete list of program features that were rated on a 4-point rating scale that ranged from "1" *unsatisfactory* to "4" *expert* ($\alpha = .92$). Ratings ranged from 2.50 to 3.83, with the lowest rating assigned to *opportunities for collaboration and critical analysis* and the highest rating assigned to the *infusion of SEL Life Skills into the science component of the program.*

We also reviewed experts' curriculum notes to examine whether common themes or issues, including threats to implementation emerged. One reviewer wrote that: "Overall, the programming is impressive and covers many aspects of children's functioning." However, this same expert also noted: "There are three key messages that are implicit in many of the activities that could be made more explicit. The first is that emotions are important. The second is that emotions are valuable information that we often ignore. Emotional intelligence is using our emotional experience and knowledge of ourselves and others to achieve our personal and social goals). The third is that *all* emotions matter (i.e., unpleasant or negative emotions like sadness are often how we connect with people, a component of empathy; anger can be used to help us advocate our needs)."

Table 2 Mean ratings for the SEL elements

Variables	*M*	SD	Range
Use of open-ended questions	3.60	.55	3–4
Address self-awareness	3.33	1.03	2–4
Address social awareness	3.33	.52	3–4
Address self-management	3.33	.52	3–4
Address relationship management	3.50	.55	3–4
Address responsible decision-making	3.50	.58	3–4
Age/ability/appropriateness of activities	3.17	.75	2–4
Logical sequence of lesson structure	3.00	.89	2–4
Use of media/resources	3.40	.55	3–4
Time management	3.60	.55	3–4
Lesson recapitulation	3.00	.82	2–4
Opportunities for collaboration	2.50	.71	2–3
Opportunities for critical analyses	2.50	.71	2–3
SEL infusion in science learning	3.83	.41	3–4

Another reaction was that: "There are three SEL/Social Emotional (SE) skill frameworks presented in the curriculum. When presented together, the three frameworks may lead to confusion (e.g., what skill is this? How are the skills related? What is the goal of the lesson and how do I measure student progress?). To illustrate, the specific social emotional skills (i.e., identity, confidence, empathy, communication, self-regulation, appreciation) fit within the broad CASEL-5. The skills of emotional intelligence contribute to the higher-order, but still specific social emotional skills (e.g., identity: recognition and expression; confidence: recognition and understanding; empathy; communication: labeling and expression; self-regulation; appreciation: recognition, understanding, expressing)." In terms of SEL infusion into the science component of the program, another expert wrote that: "The opportunities to infuse SEL in the STEAM activities are endless. The focus should be on how the SEL skills help to accomplish self (e.g., overcoming frustration, coping with disappointment, managing anxiety) and social goals (e.g., team-work, cooperation). I would like to see, for a given activity, what are the necessary self and social skills needed both before and after to be successful?"

Instructors' feedback on social emotional learning content

Teachers also provided feedback about the SEL component of the program. They were asked to respond to several questions, including: Why are social emotional competencies such as self-awareness, self-management, social awareness, relationship management, and responsible decision-making important for our students?, What are the indicators of a socially and emotionally competent/incompetent student?, What are the benefits of infusing SEL into the curriculum, What do you think can hinder the effective implementation of SEL in the curriculum, How do you see your role in trying to infuse SEL into STEAM lessons?, How confident are you in infusing SEL into the lessons?, Of the lessons taught, which do you find most easy to infuse with SEL? Why?, Which SEL competencies do you find most relevant and easy to illustrate? Why?, and Do you believe that by infusing SEL skills into your lessons, your students will become more socially and emotionally competent? Why or why not?

Although not all teachers answered all of the questions, responses were generally positive, with teachers writing that: "SEL Life Skills are the skills that are needed for navigating life effectively" and "A socially and emotionally competent student is capable of thinking critically, is confident enough to collaborate and to communicate effectively." Another teacher wrote: "A lack of guidance in how to reinforce SEL Life skills can hinder the implementation of the program. I think the only way for people to become competent at anything is to practice." Another commented that "Helping me to focus on developing more hands-on building lessons will help me improve my own social emotional competence, which will radiate out to the students."

Student feedback

After completion of the 2014 and 2015 sessions, participants provided their perceptions of program experiences. Interviews were videotaped and later transcribed. Children were asked: "What did you like the most?", and "What did you learn?" Fifty-seven percent of the children completing the program in 2014 identified at least one twentyfirst century life skill during their interviews. This number increased to 90% in 2015. For example, in response to the question "What did you learn during this session?", participants responded "empathy", "to never give up and keep trying", "I can do better with a partner", and "I learned to motivate myself".

Additionally, 89% of the participants listed at least one hands-on STEM experiment as among the things they had learned. During 2015, 100% of the children mentioned at least one experiment. One student mentioned: "I love making space crafts" and "I am a lot smarter than I thought before I started". Another student commented that: "There is more to science than just doing experiments." Finally, one student responded to the questions by stating "I want to be the world's greatest scientist."

Reflections

Post-lesson interviews were also conducted to provide the opportunity for teachers/instructors to comment on ease of implementation and perceptions of students' learning and motivation (x = 6). Respondents were allowed to comment on any or all aspects of the curriculum. Results are also presented as a descriptive narrative and predominant themes are discussed and are accompanied by specific quotes that illustrate the theme. A common theme that emerged from these reflections was that there was not adequate time for students to complete their reflective exercises. Specific comments were: "The introduction to the *You and Me Landscape* included too much information for the time period. There was no transition to reflective time", "Going over the *You and Me Landscape* did not allow us to get to the Empathy activity, although we did start talking about feelings", and "I had to alter some the planned activities so that there was a bit more unstructured time for reflection."

There were also comments about children's applications of social emotional content during the sessions. For example, one teacher wrote that "I thought that the *Star Sky* activity was useful in illustrating reflect and empathy" and "The mood meter illustrated the links between feelings and behavior. It is important that children retain their sensitivity to diversity-in people and in nature." Finally, ideas about other activities that could become part of the curriculum were offered. One teacher wrote: "I like the idea of writing letters of appreciation to each other; next time, I would structure it so that children would have to remember someone else's special skill" and "I think it would be good to include an explicit discussion of social and ethical norms."

Next steps: challenges and opportunities

The development of an effective science curriculum requires attention to individual differences in interest, engagement, and competency. A high quality program should include a variety of learning experiences and instructional and assessment approaches that cater to these differences (DeJarnette 2012). Less formal science learning environments present the opportunity to delve deeply into STEAM concepts than what is possible in the traditional school context (Mohr-Schroeder et al. 2014). In this paper, we described an innovative approach to elementary science curriculum design, the objective of which was to provide a cost-effective and student-centered program for teaching science, with particular attention being given to the role of social emotional competence.

We developed the program through an action research project, which drew together science professionals, curriculum specialists, program design professionals, and experts in social emotional learning. These professionals recognized the need for the development of a student-centered and flexible science curriculum that integrated social emotional skills. Action research is a systematic approach to investigation that contributes to the identification of effective solutions to problems individuals confront in their everyday lives (Stringer 2007). Action research capitalizes upon reflective capacity (Hart and Bond 1996). Although it has sometimes been described as ambiguous (Evans, Lomax, and Morgan 2000), we wanted to emphasize the action rather than the research component of the project because curriculum can be improved through this method (McKernan 2013). Of particular interest was the development of the curriculum itself and obtaining feedback for redesign and continued and successful program implementation. We were committed to highlighting the contributions of school administrators, teachers, experts in science education and social emotional learning, and elementary school children through critical reflection and thinking (Kemmis and McTaggart 2005).

As mentioned earlier, preparing students with twentyfirst century skills facilitates their learning and promotes the development of skills and competencies that contribute to the development of universal collaborative skills, STEM leadership ability, and employment later in life (Pellegrino and Hilton 2013). In addition to a focus on academic skills, twentyfirst century schools are also concerned with social and emotional learning (Gueldner and Feuerborn 2016). Emotions are embedded in social interactions and are a significant component of learning and instruction in general (Sansone and Thoman 2005). Learning involves surprise, revelation, delight, and sometimes anger (Rosiek 2003), all of which are associated with school performance and decision-making (Grace and Ratcliffe, 2002). Emotions are also an important factor in how individuals interact with the environment (Ulrich 1983) and are fundamental to academic achievement (Pekrun, Elliot, and Maier 2009) and the success of science education (Newhouse 1990). Being socially and emotionally competent makes it easier for students to take risks, speak out in class, offer ideas for the learning group to consider, and to initiate a different line of reasoning (Ben-Avie, Haynes, Ensign, and Steinfeld 2003). Incorporating social and emotional content into science learning will help students learn that they live in a social world (Reiss 2005).

Overall, our work demonstrated that the integration of the science and social and emotional learning concepts to create a holistic STEAM SEL program is an interesting approach to science learning. The content, organization and delivery of the curriculum was well-developed and generally well-executed. In terms of the STEAM elements of the program, mean expert ratings ranged from 3.45 to 3.75. Experts rated objectives and alignment of specific components particularly high. On the other hand, differentiation of instruction, assignments and student products, and resources received the lowest ratings, although these too were relatively high. The goal of differentiated instruction is to cater the learning activities and assignments to a wide range of learners, including those that are academically talented as well as those who are less able (George 2005). Creating a differentiated learning environment allows learners to access the curriculum in various ways and at their own level of competence (Sisk 2009). The program we offered was accessible to students from a variety of backgrounds and, interestingly, was not adjusted to specific learning levels, except with regard to age/grade. We suspect that the ratings for the assignments and student products reflect this lack of differentiation as well, which may explain the lower ratings for this aspect of the curriculum. However, the program is still under development and some material, personnel, and other program resources present opportunities for improvement. Although the program is currently partially supported by local private and public schools, the program is also tuition-bearing and additional financial support would enhance our efforts.

Reviewers rated the SEL content of the program relatively high, particularly with regard to its infusion with STEAM-based elements. However, opportunities for collaboration, critical analysis, and sequence of lesson structure received lower ratings than other curriculum elements. In retrospect, many of the assignments and activities in this area are individually rather than group-focused. The understanding and regulation of emotion at both the individual and group levels are important for successful peer collaboration (Järvenoja and Järvelä 2009). However, collaboration presents more social emotional challenges than conventional individually based learning situations, so it is important that we modify this component of our program. Expert ratings also suggested to us that the curriculum should include more opportunities for students to evaluate the outcomes of their social interactions and behaviors through critical and reasoned thought. The curriculum includes many activities, but perhaps not enough spontaneity as to encourage critical evaluation of the decision-making process used in forming a response as well as the behavior itself. The SEL content needs additional work with regard to sequencing of lessons. Experts wrote that there was a lack of integration among the lessons and activities. This may signal the need for more work on the conceptual framework of this portion of the program as we used materials from multiple evidence-based sources in a cascading fashion to create content. Still, we received many positive comments and the mean ratings on most of the elements the SEL content were relatively high. Experts, teacher, and students all indicated that SEL was an intentional part of the learning experience and that infusing science education with social emotional learning content was an excellent idea.

There are clearly limitations to this paper. First, we based our program assessment on teacher, student, and expert feedback. Second, we have yet to collect evidence of the effectiveness of the program. This requires a randomized control study. However, the intention of this paper was not to determine the program's generalizability. Rather, our objective was to gather information to further improve and enhance the program. Our hope is that our efforts can serve as a demonstration program to inform programming decisions for others interested in developing similar skills and competencies in their participants. The curriculum has gone through several iterations to allow for greater flexibility among teachers and participants in planning and participating in daily activities. We remain excited about the possibility that, when social emotional information is infused with science content, students have more opportunities to become interested and engaged overall and, in science, in particular. To address this hypothesis, we are planning an empirically based quasi-experimental study to assess the effectiveness of the current iteration of the program.

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