Integrating the Arts into Science Teaching and Learning: a Literature Review

Kathryn Green, North Carolina State University
Dr. Kathy Cabe Trundle, Utah State University
Dr. Maria Shaheen, Primrose Schools

Integrating the Arts into Science Teaching and Learning: A Literature Review

Science is creative. Write it big, shout it loud, because the message is not getting through. (Howe, 2004, p.14)

The American educational system has experienced a recent and increased focus on Science, Technology, Engineering, and Mathematics (STEM), and researchers and practitioners have argued for equal emphasis on the arts as well. According to Hartle and colleagues, incorporating the arts into learning is considered important and useful for four basic reasons (Hartle, Pinciotti, & Gorton, 2015). First, all cultures demonstrate some sort of need for aesthetic beauty and harmony, making the arts culturally universal. Second, we process sensory information through the arts, which embodies the arts into a system of learning. A third reason is that in our 21st century multicultural world, the arts provide a language that everyone understands without need for translation. Finally, the arts "provide a natural, and intrinsically motivating medium for children to work 'in advance of themselves' to demonstrate a capacity to work 'as if' they are painters, scientists, presidents, or rock stars" (p. 294).

The importance of an increased emphasis on the arts has led to broadening STEM to include the arts. The term STEAM (Science, Technology, Engineering, Arts, and Mathematics) was introduced by Yakman, who realized that, "We live in a world where you can't understand science without technology, which couches most of if its research and development in engineering, which you can't create without an understanding of the arts and mathematics" (2012, p.15). The ability of art to inspire creativity in scientific thinking, educate young learners in a holistic manner, and offer another pathway for making and communicating meaning provide important reasons for integrating the arts into science learning.

Arts Integration Defined

The incorporation of the arts into teaching and learning is called arts integration (AI). The arts include both visual arts (paintings, sculptures) and performing arts (music, dance, drama). Science and art can be seen as opposites, but these two subjects also share commonalities. For instance, the skill of observation is very important in both science and the arts. It is important to remember that observations include more than simply using the sense of sight; they may also include our other senses, such as smell and touch (Trundle & Smith, 2017). Both scientists and artists develop keen powers of observation in their realms of study. Historically, many scientists were required to take lessons in drawing or painting "in the belief that whatever you haven't drawn, you haven't seen" (Root-Bernstein & Root-Bernstein, 2013, p.16). The emphasis on observations can be seen in both science and arts educational standards. The Next Generation Science Standards (NGSS) crosscutting concepts include guiding students as they use observational skills to describe patterns in nature (NGSS Lead States, 2013), while the National Core Arts Standards (NCCAS) emphasizes that students "perceive and describe aesthetic characteristics of one's natural world and constructed environments" through their art related experiences (NCCAS, 2014, p.5). Although a science lesson may culminate in an explanatory model, while an art lesson might end with an artistic creation, teachers and learners in both subjects focus on observing nature or human constructions.

Inquiry lies at the heart of both science and the arts (Nichols & Stephens, 2013). The process of inquiry, which is cyclical in both science and the arts, can involve posing a question, gathering data through observations, recording data, and analyzing or organizing data to form or identify patterns. The scientist or artist then examines the results, which can lead to more iterations of the inquiry cycle (Nichols & Stephens, 2013). Even though outsiders (i.e., general public) tend to focus almost exclusively on the final product (e.g., a piece of artwork, a new scientific discovery), they are misguided when they ignore or undervalue learning that takes place during the planning, investigation, and creative processes (LaJevic, 2013). In addition, both science and the arts share similar goals of solving problems creatively and exploring and describing the natural world (Poldberg, Trainin, & Andrzejczak, 2013; Nichols & Stephens, 2013). Integrating the arts into science teaching and learning allows students to practice thinking about the world through both scientific and artistic lenses.

Arts Integration Enacted

Integrating the arts into science teaching and learning usually happens in one of four styles (Bresler, 1995). In the *Subservient Style*, AI occurs in order to make the content more interesting, while playing a role subservient to the content. For instance, a Subservient AI lesson might include a student drawing a picture of animals that live in the tundra during a lesson on ecosystems. The *Subservient Style* allows teachers to cover the necessary content, while using non-traditional modalities (i.e., different from written or verbal). In the *Affective Style*, students receive the arts, but do not interact with or use the arts. The *Affective Style* of AI is useful when teachers want to set the mood in the classroom. For example, students might listen to quiet ocean sounds while studying for a test on waves. The *Social Integration*

Style of AI incorporates classroom curricula with the social functions of a school. *Social Integration* AI allows time for the students to create art to use in performances or community events. For example, students might make woodcut prints of animals (part of their science curriculum) to sell at a holiday art show for parents and community members. Finally, in the *Co-equal, Cognitive Integration Style*, a teacher with an extensive art background, or one who collaborates with art specialists leads the AI lesson. In a comprehensive, multi-day unit, a teacher might work with an art specialist to create a study of Periodic Table superheroes and supervillains that culminates with student creations of cartoon characters based on the characteristics of various chemical elements. Researchers and educators typically advocate for this type of AI experience; however, the *Co-equal, Cognitive Integration Style* is rarely found in the classroom (Bresler, 1995). Illuminating the benefits and obstacles encountered when using these AI styles is the main purpose of this literature review.

Methodology

This section will include the rationale behind this literature review, as well as the methods used to find and analyze the literature included.

Rationale

Arts are an integral component of both ancient and modern cultures. Art merits its own value and stand alone importance, and it has played an important role in the work of scientists. For instance, Einstein won a Nobel Prize in Physics, but his success was not based solely on knowledge gained in his Physics or Mathematics classes (Root-Bernstein & Root-Bernstein, 2013). Art and creativity played a large role in Einstein's development and education. He attended a school based on Pestalozzi's educational principles of learning with head, hand, and heart, and he developed habits of "imagining himself riding a light beam or falling in an elevator at the speed of light, the basis of thought experiments that yielded his revolutionary insights," (Root-Bernstein & Root-Bernstein, 2013, p. 17). Einstein provides just one example of how artists and scientists are not part of two different cultures, but instead "are part of one, common creative culture largely composed of polymathic individuals" (Root-Bernstein & Root-Bernstein, 2004).   Polymathic individuals, who hold a wide range of knowledge, are successful in integrated educational systems and workplaces that abound in our modern, global society. This focus on synthesizing art, science, and creativity led to the integration of the arts into STEM to create STEAM, which more accurately represents the relationship among these concepts.

While STEAM has been regarded as a big movement in education in recent years, this literature review did not generally focus on STEAM, but on arts integration specifically. The purpose of this literature review was to examine previously published research on arts integration into science teaching and learning specifically. The research questions that guided this literature review were:

1. What are the potential benefits of arts integration into science instruction or whole school curricula?
2. What obstacles might impede effective implementation of the arts into science teaching and learning?

All articles initially found were published in peer-reviewed journals and focused on arts integration into science classrooms or whole schools in Pre-K through 12th grade. Publications that focused on related topics, such as the evaluation of arts integration curricula or research on integrating arts into a single subject area other than science (e.g., math or language arts), were deemed not relevant for this literature review.

Keywords, Databases, and Selection Process

The first literature search was conducted using the ERIC and ProQuest databases with temporal parameters of 1980 to 2017. We chose the lower temporal parameter, because the early 1980s ushered in major changes in science education reforms as well as federal funding for science curriculum development and teaching innovations. Publications such as *A Nation at Risk: the Imperative for Educational Reform, Project 2061, Science for All Americans, Benchmarks for Scientific Literacy*, and the *Presidential Awards for Excellence in Mathematics and Science Teaching* renewed interest in innovative and creative ways to teach science (DeBoer, 2000). Choosing ERIC and ProQuest ensured that billions of pages of educational research literature were searched as these two databases are hosted by the two main educational research hosts, EBSCO and ProQuest. The following keywords were used in the searches: arts integration AND science AND education, arts integration AND science AND preschool, and arts integration AND science AND elementary education. The term arts integration, both with and without quotation marks, was used in the search. The keywords arts integration AND science AND education generated 403 articles when arts integration was used, and 44 hits resulted from the use of “arts integration”. The keywords arts integration AND science AND preschool produced 1,357, resulting in 18 additional relevant papers. Using the keywords arts integration AND science AND elementary education produced 99 results. After excluding articles that focused on research outside of the preK-12 spectrum and other non-relevant topics, 55 articles remained from the initial search of the ERIC and ProQuest databases.

Next, we targeted the journals that were most frequently represented in the database results, and we conducted a manual search of these four journals: *Journal for Learning through the Arts*, *Art Education*, *Primary Science Review* and *Arts Education Policy Review.* The top five science education ISI indexed journals were also manually searched for studies on arts integration. These journals included *Journal of Research in Science Teaching, Science Education, Studies in Science Education, International*

Journal of Science Education, and *Research in Science Education*. Finally, the authors used a snowballing approach to gather articles that were cited by authors of articles already included in the literature review. A total of 11 additional articles resulted from this second phase of the search process, yielding a total of 65 articles for inclusion in the review. All journals and the number of articles found in each journal are listed in Table 1.

Table 1

Journal search results

Journal	**Number of articles**
Journal for Learning Through the Arts	10
Art Education	4
Primary Science Review	4
Arts Education Policy Review	4
Early Childhood Education Journal	3
Studies in Art Education	3
International Journal of Science Education	2
Science and Children	2
Mind, Brain, and Education	2
Gifted and Talented International	2
Creative Education	2
Teaching Artist Journal	2
All other journals (25 titles)	1/journal = 25
Total	65

Analysis Methods

All 65 selected articles included in the study were identified as non-empirical (36 articles) or empirical (30). Non-empirical articles included those which were anecdotal (e.g., general reflections by a teacher on an AI lesson) or theoretical (e.g., the merits of integrating the arts). The authors read and summarized empirical articles in a matrix to search for and identify patterns about AI in the selected research. After identifying the main research results for each paper, we inductively aligned the papers into logical themes (such as “Benefits of AI” or “Teacher Needs”) based on results of the studies using the constant comparative method (Glaser & Strauss, 1967), at times placing articles within more than one theme. For instance, results from a study on a whole-school AI program were coded and placed in the categories of “Teacher Needs,” “Learning Gains,” and “Creative Thinking.” We then organized our review around themes that commonly appeared in AI research studies and repeated the same process with the theoretical articles.

Results

This literature review contained information about the benefits and obstacles associated with AI. First, we presented the contexts of the AI implementations including the ages and grade levels of the children, followed by a presentation of the major themes identified. For each theme, one or more studies are included as detailed examples of the research on arts integration found in this literature review. Studies included in this paper were chosen due to their stronger research design, results, and analyses. Articles that simply described a one-time arts integration event with no rigorous data collection or research design were read, but are not highlighted in this paper.

Age/Grade Study Focus

Implementation of AI programs has been effective across the PreK-12 continuum. Four studies described the effectiveness of AI in preschools (Brown & Sax, 2012; Cremin et al., 2015; Phillips et al., 2013; Winters & Griffin, 2014). Twenty studies illustrated how AI in science benefit students and teachers in elementary schools (Baker, 2013; Brouilette & Jennings, 2010; Cremin et al., 2015; Duma & Silverstein, 2014; Hardiman et al., 2014; Hendrix et al, 2012; Jakobson & Wickman, 2015; Klopp et al, 2014; Liu & Lin, 2014; Luftig, 2000; Lynch, 2007; Marshall, 2016; Nelson & Norton-Meier, 2009; Overton, 2004; Poldberg et al., 2013; Rufo, 2016; Scholes & Nagel, 2012; Stellflue, Allen, Gerber, & Boody, 2005; Webb & Rule, 2012). Five studies described the efficacy of AI into middle school science learning (Flores, 2005; Pruitt et al., 2014; Klopp et al., 2014; Shanahan & Nieswandt, 2009; Snyder et al., 2014), while only one study (Flores, 2005) discussed the benefits of AI programs in high school. While most of the studies focused on elementary school AI programs, the literature reviewed covered publications from classrooms ranging from PreK to high school.

Benefits of AI for Students

Learning gains. Implementation of AI programs has yielded learning gains with learners ranging from preschool through high school (e.g., Winters & Griffin, 2014; Duma & Silverstein, 2014; Snyder, Klos, & Grey-Hawkins, 2014). Research results indicated that AI increased students' science academic performance in the classroom (e.g., Hendrix, Eick, & Shannon, 2012; Phillips, Gorton, Pinciotti, & Sachdev, 2010; Poldberg, Trainin, & Andrzejczk, 2013), and state test performance (Duma & Silverstein, 2014; Snyder et al., 2014) as well as their use and understanding of science academic vocabulary (Webb & Rule, 2012; Winters & Griffin, 2014). See Table 2 for more details on each study.

A study with fifth-grade children highlighted how AI affected long-term retention of science learning (Hardiman, Rinne, & Yarmolinskaya, 2014). This research study took place at an urban elementary school where 83.5% of students were eligible for free and reduced lunches and all study participants were African-American. The students (N=97) who participated in the study were randomly assigned to a control or experimental group. Researchers developed two science units, astronomy and ecology, that integrated arts through music, visual arts, and performance arts lessons. Both the AI unit and the conventional unit were taught by classroom teachers trained for each unit. After analyzing pretest and posttest scores, Hardiman and her colleagues found that, while AI offered no significant effect on the initial posttest, AI had a significant effect on the delayed posttest ($p = .01$), with students in the AI intervention group being more likely to retain what they learned than those taught using non-AI instructional strategies. Students with "basic" reading skills had the largest gains with a mean retention rate that was .9 SD greater than that of other students (p.146). This finding was attributed to students' abilities to use other AI modes of learning in addition to reading and writing. Other studies found that arts integration was especially useful for students, such as English Language Learners, who needed a means of expression that was not dependent on their limited vocabulary (e.g., Brouillette & Jennings, 2010; Pruitt, Ingram, & Weiss, 2014).

Table 2

Descriptive summary of empirical studies reporting academic gains

Study	Sample	Study Focus	Intervention	Summary of findings
Brouillette & Jennings (2010)	K-2nd grade students (N=325), US	Student learning/ socioemotional development	Year-long, whole-school puppetry residency	Steady academic improvement
Duma & Silverstein	2nd-5th grade students	Standardized test scores	CETA-whole school reform	Increase in reading scores

(2014)	(N=725), US		model	on state tests
Hardiman et al. (2014)	5th grade students (N=82), US	Academic outcomes	AI instruction in three-week units	More retention in intervention
Hendrix et al. (2012)	4th and 5th grade students (N=38), US	Drama and conceptual learning	Drama-based AI intervention in science class	Higher gains in AI intervention group
Phillips et al. (2010)	3-4 year olds (N=181), US	Literacy Skills	PASELA (Promoting and Supporting Early Literacy through the Arts)	Improvements in literacy, and school-readiness skills
Poldberg et al. (2013)	2nd grade students (N=[a]), US	Scientific thinking and science literacy	"A New VIEW on Science" AI program	Increased performance across art, writing, science
Snyder et al. (2014)	Middle school students (N=703), US	State assessments	Whole-school AI implementation	Increased student achievement
Webb & Rule (2012)	2nd grade students (N=22), US	Science vocabulary	Transforming lifecycle figures into drawings	Students learned more science vocabulary
Winters & Griffin (2014)	Preschool and 2nd grade students (N=2 case studies), Canada	Music and science vocabulary	Musical intervention	Increased science vocabulary

Positive school climate. In addition to learning gains, five studies included in this literature review demonstrated that integrating the arts can positively influence classroom and school climates (Brouillette & Jennings, 2010; Brown & Sax, 2012; Chemi, 2014; Lynch, 2007; Snyder et al., 2014). The studies took place in a preschool, several primary schools, and a middle school. See Table 3 for more details related to the research questions, interventions, and a summary of the findings for each study about positive school climate. One study found the arts can naturally predispose people toward positivity and "generate an emotionally safe environment in which individuals can dare to experiment, learn and deal with complexity" (Chemi, 2014). Snyder and colleagues (2014) examined an AI program implemented in a low-performing middle school and found that AI led to a more positive school climate and a decrease in disciplinary suspensions. On the classroom level, students in AI classrooms demonstrated more positive emotions, higher abilities to regulate their own emotions, and greater capabilities to understand others' emotions (Brouillette & Jennings, 2010; Brown & Sax, 2012; Lynch 2007).

Table 3

Descriptive summary of empirical studies describing positive school climate

Study	Sample	Study focus	Intervention	Summary of findings
Brouillette & Jennings (2010)	K-2nd grade students (N=325), US	Socioemotional development	Whole-school puppetry residency	Decrease in behavior problems
Brown & Sax (2013)	Low-income preschoolers (N=205) and their primary caregivers, US	Socioemotional readiness in low income students	Daily AI	Increased positive emotion and emotional self-regulation
Chemi (2014)	K-6th graders (N=25 middle schoolers-Case 1, N=20 2nd grade-Case 2, N=150 3-13 year olds-Case 3), Denmark	Learning culture of school	One day AI, AI with animators, whole school intervention	High level of engagement
Lynch (2007)	3rd-5th graders (N=177), US	How meaning-making is supported	Whole-school AI at a magnet k-5 school	Created a safe atmosphere for risk-taking,
Snyder et al. (2014)	Middle-school students at a low-performing urban school (N=703), US	Behavior, school climate, engagement	Whole-school AI intervention with control school	Decreased suspensions, more opportunities for student to engage in and through the arts

Opportunities for higher-level thinking. Results from four studies indicated that AI offers students more opportunities for higher-level thinking (Cremin, Glauert, Craft, Compton, & Stylianidou, 2015; Duma & Silverstein, 2014; Luftig, 2000; Liu & Lin, 2014). Luftig's study of AI in primary schools found that creative thinking was facilitated by a school wide arts integration program (2000). Liu and Lin (2014) discovered that students in AI classes showed more divergent thinking, autonomy, and curiosity about science. Cremin and colleagues (2015) found that preschool students who were enrolled in AI programs asked more questions that drove scientific inquiries, while Duma and Silverstein (2014) found that an AI intervention encouraged students to approach ideas from multiple perspectives. Marshall created AI science projects that allowed students to "engage in a distinctive kind of thought that mingles analytical, logical, and linear reasoning with nonlinear and associative thinking [which is] central to art-making and core to inquiry" (2016, p. 17.) See Table 4 for information on each study, including the sample, research questions, intervention, and findings for each study related to higher level thinking.

Table 4

Descriptive summary of empirical studies reporting higher level thinking in students

Study	Sample	Study focus	Intervention	Summary of findings
Cremin et al. (2015)	3-8 year olds (N=218 narrative episodes), Western Europe	Synergies between inquiry-based science and creativity-based activities	Creative Little Scientists, explored the potential for creativity in math and science	Allowed young learners to function as creative young scientists
Duma & Silverstein (2014)	2nd-5th graders (N=725), US	Higher level thinking	CETA-whole school reform model	Students used higher level thinking skills more frequently
Liu & Lin (2014)	3rd-6th grade teachers (N=16), Taiwan	Teachers' views on scientific creativity	longitudinal PD on inquiry-based teaching	Teachers view divergent thinking, autonomy and curiosity as scientifically creative skills
Luftig (2000)	2nd, 4th, and 5th graders (N=615), US	Creative thinking	SPECTRA+ program (whole-school AI)	Creative thinking increased
Marshall (2016)	3rd grade student (N=1), US	Relationship between art and integrated thinking	Art as inquiry across the curriculum intervention	Helped students understand how subjects

				were integrated

Alternative modes of learning. In addition to offering opportunities for creative thinking, using AI also allowed students to process and demonstrate learning in creative ways using modes other than writing. Five studies in this literature review offered findings on how AI enabled students to learn in different ways (Flores, 2005; Pruitt, Ingram, & Weiss, 2014; Jakobson & Wickman, 2015; Lynch, 2007; Nelson & Norton-Meier, 2009). Jakobson and Wickman (2015) found that students in AI programs learned in both cognitive and aesthetic manners. Students in AI programs were able to effectively demonstrate their learning through non-written products (Pruitt et al., 2014; Lynch, 2007, Rufo, 2016). Table 5 includes the descriptive summary of the studies that focused on describing alternative modes of learning offered by AI.

Table 5

Descriptive summary of empirical studies describing alternative modes of learning

Study	Sample	Study focus	Intervention	Summary of findings
Flores (2005)	Middle and high school students (N=95), US	Arts infusion practices	Various AI projects	Reinforced learning through mental maps
Jakobson & Wickman (2015)	1st graders (N=14), Sweden	Aesthetic experience and science learning	AI lesson on leaves	Enhanced meaning making
Lynch (2007)	3rd-5th grade students (N=177), US	Supporting meaning making	whole-school AI at a k-5 magnet school	Allowed students to choose how to interact with content
Nelson & Norton-Meier (2009)	Kindergarten and 5th grade classes (N=[a]), US	Benefits of collaborative multi-modal learning events	Music intervention in science class	Memory mark left for students
Pruitt et al. (2014)	Elementary and middle	Interdisciplinary AI	Project AIM (arts	Students demonstrated

	school residencies (N=180), US		integration program)	learning through non-written products
Rufo (2016)	4th and 5th grade class (N=1), US	AI in a science fair	STEAM celebration initiative	Learners were empowered

Benefits of AI for Teachers. In addition to students, teachers also benefited from the use of AI (Bresler, 2011; Iiyambo, 2005). See Table 6 for information on the benefits listed in each study. When teachers participated in AI instruction, they often found that the benefits greatly outweighed the extra work required. Bresler (2011) studied arts integration with high school teachers who experienced profound changes in their self-images as teachers after collaborations with peers during an AI project. Instead of feeling like isolated teachers, alone in the classroom, they reported that after collaboration with other teachers they subsequently perceived themselves as being an integral part of a larger whole. When teachers collaborated with common goals in mind, leaders often emerged, as teachers recognized their contributions to the community of learners (Bresler, 2011). In a case study of science coordinators (N=6) who integrated arts into science teaching and learning in London primary schools, Iiyambo (2005) found teachers reported feeling more camaraderie and confidence. These teachers also appreciated the pedagogical benefits they received, including the ability to teach more rigorously and new strategies they used to reach learners (Iiyambo, 2005).

Table 6

Descriptive summary of empirical studies describing teacher benefits of AI

Study	Sample	Study focus	Intervention	Summary of findings
Bresler (2011)	High school case study (N=1), US	Qualities of successful integrations	AI classroom projects	Teachers felt part of a team, and status of arts teachers increased
Iiyambo (2005)	Science coordinators of 5-11 year old students, (N=6), UK	Teacher and student responses to AI	Various AI projects	Teachers reported more confidence and camaraderie, and learned new rigorous strategies to teach all learners.

Non-empirical articles suggested other potential benefits of AI (Brown, 2007; Fox & Diffily, 2000; Manner, 2002). For instance, a child's day can sometimes be filled with fragmented learning—a math lesson on addition, a physical education lesson on playing basketball, followed by reading about insects and identifying states on a map. Arts integration can be a step toward decompartmentalizing learning (Brown, 2007). Thinking of curriculum as discrete and compartmentalized is a disservice for learners, since teachers are preparing them for a very connected, interdependent world (Manner, 2002). In addition, the arts may aid children in strengthening control of their large and small muscles through actions such as dancing, painting, cutting, and modeling (Fox & Diffily, 2000).

Obstacles to Successful AI

Arts integration can present challenges. "Setting the stage for creative possibilities to thrive (in science education's context) requires a willingness to think differently about what science can mean and a similar openness to expanding the boundaries of what we consider to be science education" (Gershon & Ben-Horin, 2014, p. 6). Identifying opportunities to integrate the arts into science is not always easy for teachers. For example, case studies from primary classrooms in nine European countries showed that teachers often struggled to identify specific opportunities to integrate the arts or be creative in their science instruction (Cremin, Glauert, Craft, Compton, & Stylianidou, 2015). For example, Newton & Newton (2010a) studied 16 pre-service primary teachers and found that science class offered more opportunities for using creative thought than history or math classes, but not as many opportunities as arts classes. Some pre-service teachers believed that creativity was not clearly defined, while others thought young learners did not have a sufficient science comprehension level to allow for creativity.

Time and professional development were two factors that influenced the effectiveness of arts integration programs. Teachers needed both time to implement integrated lessons in their classrooms and extensive time for professional development and preparation (Lynch, 2007). Without teacher professional development, integrating creativity in the classroom may impose a heavy burden on teachers and staff. However, when teachers were provided effective training before an arts implementation program began, they developed positive views of arts integration programs and were able to successfully reach more learners during collaborative learning in the classroom (Duma & Silverstein, 2014). Table 7 offers more information about the studies regarding obstacles to successful AI.

Several misunderstandings also can present obstacles to successful AI. Aprill (2010) used his experience as the founder of the Chicago Arts Partnerships in Education (CAPE) to offer direction on arts integration. He explained that direct instruction and arts integration are often perceived as a false dichotomy. A lack of funding for public education creates a mindset of scarcity in which content areas compete with other content areas for funding, time, and importance (Aprill, 2010). The emphasis on standardized test scores causes subjects other than reading and math to be seen as less important. In order for arts integration to be regarded as equally important, it "needs to be properly conceived of as part of the whole culture of a school" (Aprill, 2010, p. 7).

Table 7

Descriptive summary of empirical studies on obstacles to AI

Study	Sample	Study focus	Intervention	Summary of findings
Cremin et al. (2015)	3-8 year olds (N=218 narrative episodes), Western Europe	Constraints when using creativity-based approach	Creative Little Scientists program	Time and policies were the largest constraints on teachers.
Fisher & McDonald (2004)	Elementary school case study (N=1), US	AI curriculum collaboration	Three-week integrated unit on weather	Needs included time, structured curriculum planning, collaboration, professional development

Lynch (2007)	3rd-5th grade students (N=177), US	Constraints on meaning-making	Whole school AI at a K-5 magnet school	Constraints include time, knowledge of both discipline-specific and general K-5 standards
Newton & Newton (2010a)	Study 1: pre-service primary teachers (N=16), UK	Teachers' definitions of creativity	AI	Arts offer more room for creativity than science.
Newton & Newton (2010a)	Study 2: primary teachers (N=23), UK	Teachers' ability to identify lessons which allow for creative thinking	Classroom activities	Some do not have a good working definition of scientifically creative
Newton & Newton (2010a)	Study 3: pre-service primary teachers (N=24), UK	Pre-service teachers ideas of creativity in science	Assessment of science events	No strong feel for what constitutes creative thought in science

Teacher Characteristics that Support Successful AI Programs

In addition to studies reporting benefits and obstacles of AI, several articles discussed why teacher characteristics and beliefs are important to successful AI. The articles found did not offer the same set of important teacher characteristics; instead, they posited different types of characteristics that encouraged success in arts integration. Teachers who are successful in AI often see themselves in five different roles (Hartle et al., 2015). First, they have creative self-efficacy and are able to see their own creative possibilities, because they believe all humans are creative. Teachers may need an artistic mentor in order to see themselves as creative. Second, teachers must view themselves as researchers who carefully collect data on how their children learn. Third, teachers must be able to act as designers, to use their awareness of concepts such as space and color to engage learners. Fourth, teachers must be able to act as co-constructors rather than directors of learning. A successful AI experience "involves the teacher, learners and work of art or art medium in what is referred to as 'third space'…where connections are made" (Hartle et al., 2015, p. 296). And finally, teachers must act as advocates for the arts by developing relationships with artists and other community partners. Teachers are able to use these five roles to increase learning and development in children (Hartle et al., 2015).

Once teachers have learned to identify opportunities for creative thinking, they must consider best practices for encouraging it. In Liu and Lin's (2014) investigation into primary science teachers' beliefs about scientific creativity, they identified three points around which the teachers' beliefs centered. First, most of the teachers recognized that they must emphasize autonomous and active learning. Next, teachers believed that inquiry-based learning must be prevalent, because students can be creative only when they are given the ability to solve a problem. Finally, primary science teachers believed that diverse, meaningful and enjoyable learning activities must be emphasized when designing creative learning environments (Liu & Lin, 2014).

Specific teacher characteristics are important when planning arts integration. For instance, experienced teachers were more likely to integrate arts into their curriculum than teachers with fewer years of teaching experience (Ozturk & Erden, 2011). Other studies found that teachers who possessed tenacity, flexibility, and perseverance reported feeling successful in an AI program (Bresler, 2011; Strand, 2006). In addition, successful AI teachers must be willing to adjust their mindset about teaching and learning science. For instance, Chemi (2014) found when teachers and artists collaborated to integrate the arts in pre-K through middle school, the artists felt that long periods of creativity were fundamental, whereas teachers tried to optimize their time, making the creative process more linear. Teachers who have been conditioned to move quickly from one activity to the other, filling every minute with productive activity, must recognize that lengthy creative processes are also valuable and effective for learning (Chemi, 2014). The idea that "viewing a painting for a few seconds [means] being able to relate to the artwork only on a shallow basis [while] artfulness is about enjoying the details, questioning, and engaging with the work of art, comparing it to other works or one's own personal life" (Chemi, 2014, p.381) can be successfully applied to science. In summary, teachers who are able to slow down and engage with science through arts integration can attain positive results with young learners.

Adjusting one's mindset is not a simple task. Teachers need substantial guidance, offered through carefully structured professional development and administrative support, before and during an AI experience. Based on pre/post test results, 160 primary teachers who participated in the Kennedy Center for the Performing Arts' AI professional development program (Changing Education Through the Arts) reported feeling empowered and valuing arts integration for young learners (Duma & Silverstein, 2014).

Table 8

Descriptive summary of empirical studies on teacher characteristics that facilitate AI

Study	Sample	Study focus	Intervention	Summary of findings
Bresler (2011)	High school case study (N=1), US	Qualities that make for successful AI with the core curriculum	AI classroom projects	Helpful teacher characteristics perseverance, listening skills, the ability to collaborate
Chemi (2014)	K-6th graders (N=25 middle school-Case 1, N=20 2nd grade students-Case 2, N=150 3-13 year olds-Case 3), Denmark	AI's influence on the learning culture of a school?	AI interventions	Difficult for teachers to add long periods for creativity
Duma & Silverstein (2014)	2nd-5th grade students (N=725), US	Effect of CETA	CETA-whole school reform model	Teachers who receive extensive professional and academic support are more successful
Liu & Lin (2014)	3rd-6th grade teachers (N=16), Taiwan	Teachers' beliefs about scientific creativity in the classroom context?	longitudinal PD on inquiry-based teaching	Teachers may need assistance with linking of the arts to science
Ozturk & Erden (2011)	Female preschool teachers (N=255),	Teachers' beliefs related to integrated curriculum	Self-reporting questionnaire examined teachers'	Few teachers integrated the arts with all subjects.

	Turkey		beliefs	More experienced teachers tended to integrate more frequently.
Strand (2006)	Case studies (N=2), US	Nature of collaboration and curricula when using AI	Collaboration with theater company and 4th grade class and summer gifted and talented program	Successful AI teachers had tenacity, flexibility, trust, and strong convictions

Limitations and Future Directions

This section will describe limitations encountered during the review of the literature about arts integration and will offer future directions suggested by the authors.

Limitations

The limitations for this literature review include the research methods used in the empirical studies. These studies employed various methodologies, ranging from single case studies to phenomenological studies to action research, and 63.8% of the studies were qualitative in nature. While some of the studies used multiple data sources (student observations, teacher interviews, field notes, student artifacts) to triangulate findings, many of the qualitative studies were narrative in nature. Although qualitative studies can describe the experiences of AI participants, they do not allow for generalizability or extrapolation.

Several methodological concerns justify a need for more rigorous empirical studies on integrating the arts into science teaching and learning. For example, many studies did not include comparison groups, and sample sizes were often small (N<25). The findings from Iiyambo's (2006) study on science coordinators, which included a sample size of six, have limited generalizability. In addition, the sample size of 38 4th and 5th grade students in a creative drama AI also limits the study's generalizability (Hendrix et al., 2012). The lack of comparison groups, large sample sizes, and other appropriate controls often make it difficult to assess the causal implications of AI, which is why they were not a focus of this literature review. Additional rigorous quantitative research is needed to determine verifiable results of AI in science classrooms.

Along with methodological concerns, another limitation of findings in this literature review was that in some studies, the arts were integrated into a whole school rather than specifically aimed at science teaching and learning. Therefore, it was difficult to determine the efficacy of AI when it was only implemented in science class. Also, many populations, such as special education students and English Language Leaners, were not part of most of these studies.

In addition to the concerns identified with the empirical studies, larger theoretical concerns exist. First, there are no universally agreed upon definitions of arts, creativity, or arts integration. Varied interpretations of these words make it difficult to operationalize variables when conducting empirical research on the effects of arts integration. Second, science and the arts can be placed at opposite ends of a continuum, which could cause teachers or learners to doubt that integration of the two would be successful.

Future Directions

The potential benefits of AI, for both teachers and learners, justifies further research. Overall, the results of this literature review show that AI is beneficial in encouraging students to think about science in different ways and to provide evidence of their science learning in a variety of products associated with visual and performing arts. In reviewing our findings, three implications merit consideration for science education researchers.

First, a significant question remains to be addressed: What are the most useful ways to provide professional development to pre-service teachers and in-service teachers on how to successfully integrate the arts into their science instruction? Only one study in the review focused on pre-service teachers who used creativity in their science instruction (Newton & Newton, 2010a). More research on pre-service teachers would assist teacher preparation programs in designing opportunities for pre-service teachers to learn how to effectively integrate the arts into their instruction. Establishing the importance of AI in science teaching and learning early in a pre-service teacher's career could increase the AI skills of these novice teachers.

A second significant question also needs to be addressed: How does AI affect classroom management and engagement issues? Two studies demonstrated that whole-school AI led to a steady decrease in school-wide behavioral issues (Brouillette & Jennings, 2010; Snyder et al., 2014).   One study found that students showed more positive emotions at a classroom-level while learning through AI instruction (Brown & Sax, 2012). More empirical research into how integrating the arts in science classrooms could lead to increased student engagement and decreased behavioral issues would surely benefit both teachers and learners.

Future research should also address how arts integration impacts students in poverty. One meta-analysis found that specifically integrating dramatic arts conferred positive results on disadvantaged students' grades, social skills and creative thinking (Robinson, 2013). Many interventions are designed to close the achievement gap that exists between learners, and perhaps more AI interventions could also serve this purpose. More research is needed so well-supported claims can be made about the efficacy of AI for all learners, including those in poverty and with special needs.

The research included in this literature review demonstrates that integrating arts into science can be beneficial for teachers as well as learners. When teachers are able to participate in quality training before AI and in supportive collaboration during AI, both students and teachers succeed in new arenas. No negative effects of AI on students, teachers, or staff were identified in this review. Continued research about AI in science teaching and learning will help teachers strive to make science creative and engaging for all learners.

References

Aprill, A. (2010). Direct instruction vs. arts integration: A false dichotomy. *Teaching Artist Journal, 8*(1), 6-15.

Bresler, L. (1995). The subservient, co-equal, affective, and social integration styles and their implications for the arts. *Arts Education Policy Review, 96*(5), 31-35.

Bresler, L. (2011). Integrating the arts: Educational entrepreneurship in a school setting. *Hellenic Journal of Music, Education and Culture, 2*(1), 5-17.

Brouillette, L., & Jennings, L. (2010). Helping children cross cultural boundaries in the borderlands: Arts program at Freese Elementary in San Diego creates cultural bridge. *Journal for Learning Through the Arts, 6*(1), 1-17.

Brown, S. (2007). An arts-integrated approach for elementary level students. *Childhood Education. 83*(3), p. 2-12.

Brown, E. D., & Sax, K. L. (2013). Arts enrichment and preschool emotions for low-income children at risk. *Early Childhood Research Quarterly, 28*, 337-346.

Chemi, T. (2014). The artful teacher: A conceptual model for arts integration in schools. *Studies in Art Education, 56*(1), 370.

Cremin, T., Glauert, E., Craft, A., Compton, A., & Stylianidou, F. (2015). Creative little scientists: Exploring pedagogical synergies between inquiry-based and creative approaches in early years science. *Education 3 - 13, 43*(4), 404-16.

DeBoer, G. E., (2000). Scientific Literacy: Another Look at Its Historical and Contemporary Meanings and Its Relationship to Science Education Reform, *Journal of Research in Science Teaching*. *37*(6), 582-601.

Duma, A., & Silverstein, L. (2014). A view into a decade of arts integration. *Journal for Learning through the Arts, 10*(1), 1-18.

Flores, M. (2005). The alchemy of art. *The Science Teacher*, *72*(1), 48.

Fox, J., & Diffily, D. (2001). Integrating the visual arts--building young children's knowledge, skills and confidence. *Dimensions of Early Childhood, 29*(1).

Gershon, W., & Ben-Horin, O. (2014). Deepening inquiry: What processes of making music can teach us about creativity and ontology for inquiry based science education. *International Journal of Education and the Arts, 15*(9).

Glaser, B., & Strauss, A. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago: Aldine Publishing Company

Gullatt, D. (2008). Enhancing student learning through arts integration: Implications for the profession. *The High School Journal, 91*(4), 12-25.

Hartle, L. C., Pinciotti, P., & Gorton, R. L. (2015). ArtsIN: Arts integration and infusion framework. *Early Childhood Education Journal, 43*, 289-298.

Hendrix, R., Eick, C., & Shannon, D. (2012). The integration of creative drama in an inquiry-based elementary program: The effect on student attitude and conceptual learning. *Journal of Science Teacher Education, 23*, 823-846.

Howe, A. (2004). Science is creative. *Primary Science Review, 81*, 14-16.

Iiyambo, R. (2005). Planning a creative science curriculum. *Primary Science Review, 88*, 16-20.

Jakobson, B., & Wickman, P. (2015). What difference does art make in science? A comparative study of meaning-making at elementary school. *Interchange, 46*(4), 323-343.

Klopp, T, Rule, A., Schneider, J. & Boody, R. (2014). Computer technology-integrated projects should not supplant craft projects in science education. *International Journal of Science Education*, *36*(5), 865-886.

LaJevic, L. (2013). Arts integration: What is really happening in the elementary classroom? *Journal for Learning through the Arts, 9*(1)

Liu, S., & Lin, H. (2014). Primary teachers' beliefs about scientific creativity in the classroom context. *International Journal of Science Education, 36*(10), 1551-1567.

Ludwig, M., Marklein, M. B., & Song, M. (2016). Arts integration: A promising approach to improving early learning. *American Institutes for Research. Retrieved November*, *5*, 2016.

Luftig, R. (2000). An investigation of an arts infusion program on creative thinking, academic achievement, affective functioning, and arts appreciation of children at three grade levels. *Studies in Art Education*, *41*(3), 208-227.

Lynch, P. (2007). Making meaning many ways: An exploratory look at integrating the arts with classroom curriculum. *Art Education, 60*(4), 33-38.

Manner, J. (2002). Arts throughout the curriculum. *Kappa Delta Pi Record, 39*(1), 17-19.

Marshall, J. (2016). A systems view: the role of art in education. *Art Education*, *69*(3), 12-19.

National Coalition for Core Arts Standards (2014).Retrieved from

http://www.nationalartsstandards.org/

Nelson, S. D., & Norton-Meier, L. (2009). Singing in science: Writing and recording student lyrics to express learning. *Journal for Learning through the Arts, 5*(1).

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Retrieved from http://www.nextgenscience.org/

Newton, L., & Newton, D. (2010a). Creative thinking and teaching for creativity in elementary school science. *Gifted and Talented International, 25*(2), 111-124.

Newton, L., & Newton, D. (2010b). What teachers see as creative incidents in elementary science lessons. *International Journal of Science Education, 32*(15), 1989-2005.

Nichols, A. J., & Stephens, A. H. (2013). The scientific method and the creative process: Implications for the K-6 classroom. *Journal for Learning through the Arts, 9*(1).

Overton, D. (2004). A creative science experience. *Primary Science Review*, *81*, 21-24.

Ozturk, E., & Erden, F. T. (2011). Turkish preschool teachers' beliefs on integrated curriculum: Integration of visual arts with other activities. *Early Child Development and Care, 181*(7), 891-907.

Phillips, R., Gorton, R., Pinciotti, P., & Sachdev, A. (2010). Promising findings on preschoolers' emergent literacy and school readiness in arts-integrated early childhood settings. *Early Childhood Education Journal*, *38*(2), 111-122.

Poldberg, M., Trainin, G., & Andrzejczk, N. (2013). Rocking your writing program: Integration of visual art, language arts, and science. *Journal of Learning through the Arts, 9*(1), 1-17.

Pruitt, L., Ingram, D., & Weiss, C. (2014). Found in translation: Interdisciplinary arts integration in Project AIM. *Journal for Learning Through the Arts*, *10*(1), 25-38.

Robinson, A.H. (2013). Arts integration and the success of disadvantaged students: a research evaluation. *Arts Education Policy Review*, *114*, 191-204.

Root-Bernstein, R., & Root-Bernstein, M. (2004). Artistic scientists and scientific artists: The link between polymathy and creativity. In R. J.

Sternberg, E. L. Grigorenko & J. L. Singer (Eds.), *Creativity: From potential to realization* (pp. 127-151). Washington, DC, US: American Psychological Association.

Root-Bernstein, R., & Root-Bernstein, M. (2013). The art and craft of science. *Educational Leadership, 70*(5), 16-21.

Rufo, D. (2016). STEAM-ing up the science fair. *Art Education*, *69*(4), 12-16.

Scholes, L, & Nagel, M. (2012). Engaging the creative arts to meet the needs of twenty-first-century boys. *International Journal of Inclusive Education*, *16*(10), 969-984.

Shanahan, M-C., & Nieswandt, M. (2009). Creative activities and their influence on identification in science: three case studies. *Journal of Elementary Science Education*, *21*(3), 63-79.

Snyder, L., Klos, P., & Grey-Hawkins, L. (2014). Transforming teaching through arts integration: AI implementation results: Middle school reform through effective arts integration professional development. *Journal for Learning through the Arts*, *10*(1), 1-24.

Stellflue, P., Allen, M., & Gerber, D. (2005). Art and science grow together. Science and Children, *43*(1), 33-35.

Strand, K. (2006). The heart and the journey: Case studies of collaboration for arts integrated curricula. *Arts Education Policy Review*, *108*(1), 29-40.

Trundle, K. C., & Smith, M. M. (2017). A hearts-on, hands-on, minds-on model for preschool science learning. *YC Young Children*, *72*(1), 80-86.

Webb, A. N., & Rule, A. C. (2012). Developing second graders' creativity through literacy-science integrated lessons on lifecycles. *Early Childhood Education Journal, 40*, 379-385.

Winters, K. & Griffin, S. (2014). Singing is a celebration of language: Using music to enhance young children's vocabularies. *Language and Literacy, 16*(3), 78.

Yakman, G. (2012). Recognizing the A in STEM education. *Middle Ground, 16*(1), 15-16.