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The Integration of Creative Drama in an Inquiry-Based Elementary Program: The Effect on Student Attitude and Conceptual Learning

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Abstract Creative drama activities designed to help children learn difficult science concepts were integrated into an inquiry-based elementary science program. Children (n = 38) in an upper elementary enrichment program at one primary school were the participants in this action research. The teacher-researcher taught students the Full Option Science System™ (FOSS) modules of sound (fourth grade) and solar energy (fifth grade) with the integration of creative drama activities in treatment classes. A 2 × 2 × (2) Mixed ANOVA was used to examine differences in the learning outcomes and attitudes toward science between groups (drama and non-drama) and grade levels (4th and 5th grades) over time (pre/post). Learning was measured using the tests included with the FOSS modules. A shortened version of the Three Dimension Elementary Science Attitude Survey measured attitudes toward science. Students in the drama treatment group had significantly higher learning gains ($F = 160.2, p < 0.001$) than students in the non-drama control group with students in grade four reporting significantly greater learning outcomes ($F = 14.3, p < 0.001$) than grade five. There was a significantly statistical decrease in student attitudes toward science ($F = 7.5$, $p < 0.01$), though a small change. Creative drama was an effective strategy to increase science conceptual learning in this group of diverse elementary enrichment students when used as an active extension to the pre-existing inquiry-based science curriculum.

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Introduction

The National Science Education Standards acknowledge that scientific literacy through the understandings of the science content standards "cannot be achieved by any single teaching strategy or learning experience" (National Research Council (NRC) 1996, pp. 34–35). Inquiry, though the preferred approach for science education, should not be the only single approach to science teaching and learning. Research supports the need for multiple teaching strategies in order to better address the learning and behavioral needs of elementary children (Baker 2005). The role of language, especially for young children, plays a key role in developing science literacy (Tippett 2009). Language requires social interaction where learners construct scientific meaning as they interpret and reflect upon events through previous knowledge. Social constructivist models of teaching emphasize the need for collaboration and dialogue between teachers and students (Kim 2001). Knowledge is socially constructed, negotiated, validated, and communicated in conversations between teachers and children while pursuing transactional discourse about meaning in science. Conceptual learning among children stresses the need for teachers to monitor children's views, bringing them to open discussion of science based on evidence toward more fruitful conceptions (Hewson and Hewson 1988; Tytler 2002). To understand science conceptually both the learner and the teacher must be able to successfully anchor and bridge conflicting views or alternative conceptions during instructional time in order to assist children in explaining, communicating, and predicting science phenomena (NRC 2000). In this process alternative conceptions held by elementary children are the catalysts for further development of accepted conceptual learning in science (Pine et al. 2001).

Creative drama, as a method to teach and authentically assess science, follows a social constructivist model that mirrors the process of teaching for conceptual understanding. Creative drama in science helps students communicate ideas, reason critically, and work cooperatively with others in a social group (Braund 1999). The practice of creative drama has been defined by Davis and Belm (1978) as an improvisational, non-exhibitional, process-centered form of drama in which participants are guided by a leader to imagine, enact, and reflect upon human experience. Examples of creative drama include role-playing, improvisation, pantomime, and script writing. In science, creative drama becomes the structured lesson tool that allows for student exploration into the abstract and sometimes difficult concepts of science in order to learn science (Braund 1999; Kamen 1991; Osmond 2007). Emphasis and attention is given to knowing the students' deeper conceptual understanding about science. Students must tap into their ideas and conceptions of the science phenomenon under study as they act it out in some fashion before the class. The dramas often act as creative models of science that rely upon student imagination for better understanding scientific phenomena that cannot be seen, such as in energy transfers (Taber et al. 2006). Use of creativity and imagination in modeling in science is an essential part of how science works (Walsh and Edwards 2009). Indeed, scientists' development and use of analogies to explain scientific concepts have long been viewed as a creative process essential to scientific understanding (DeCruz and DeSmedt 2010; Martin 2010). Also, creative drama fosters high levels of student engagement with ideas through collaboration with peers. It is based on constructivist ideas about the nature of language and thought with deeper understanding in science based on using kinesthetic awareness (Osmond 2007).

To illustrate the potential of creative drama to learn science, teacher-researcher Linda Perkovic (1997) explains how her students came to learn about electric current in order to build further understanding:

> The room was quickly rearranged, students became electrons. These electron-students walked around as if in a circuit. Chairs (resistors) were then added into the circuit and students had to slow down to climb over them. Therefore, they quickly obtained the image of electric current as moving electrons and resistors as things which slow down the flow of electrons. They then proceeded to act out what happens when the dial on the transformer was turned up. The function of the ammeter was then introduced by having one student take on the role of an ammeter and count the number of electrons (students) that passed a point in time. (Aubusson et al. 1997, p. 570)

Moving beyond the models and diagrams often used in science texts, the students in this scenario were able to grasp and understand electric current in a more personal and 'affective' way, involving physical movement and role-playing to create the analogy of moving electrons in a circuit (Aubusson et al. 1997). This active, experiential learning is the foundation for conceptual change models of teaching science.

There is a need to further study the elementary classroom and teaching methods that nurture and reflect inquiry, debate, creativity, and the principles of conceptual change models in science teaching (NRC 2007). Creativity has been one of the tenets of the nature of science in how scientists explain and understand phenomena through models and theories (Lederman 1992). Duveen and Solomon (1994) have shown that students find creative dramatic role-playing in science "memorable," and can employ it in order to construct authentic meanings of the nature of science (p. 576) as well as improve conceptual understanding of science. Creativity development through creative drama is important in problem solving and can lead to scientific findings (Sternberg 1988). Shanahan and Nieswandt (2009), addressing the need for creativity in the science classroom, expressed the following:

> If we are attempting to prepare students to understand and use science either as professionals or as informed responsible citizens, then it seems very surprising that something deemed essential to both professionals in science and to the development of the discipline itself is not more thoroughly addressed in science education. Science students need to know that scientists are creative individuals who use their imagination to discuss, explain, and hypothesize in science. (p. 6)

The purpose of this action research study (Mills 2000) where the classroom teacher was the principal researcher of her practice was to investigate if an inquiry-based science curriculum could be empirically enhanced with the integration of creative drama activities. A quasi-experimental approach included control and treatment classes. More specifically, the purpose of this research was to determine if there were differences in science learning outcomes and attitudes toward science when creative drama was integrated into an inquiry-based science curriculum: (a) between treatment and control groups, (b) between grade levels, and (c) over time.

Literature Review

Ward (1957) long ago related the idea that creative drama is an activity for the whole child that grows from "not having knowledge poured in by the teacher, but rather from participating in activities that challenge his deepest interest and highest powers" (p. 17). Children had the opportunity to express ideas through experiences in "thinking on their feet" (Ward 1957, p. 8). Children's abilities in oral communication and debate of one's ideas, skills generally needed by citizens living in a democracy, are enhanced as they engage in expressing ideas through creative dramatics (Ward 1957). This ability to "think on one's feet," as Ward expressed, would also be an important process skill for elementary students in science classrooms where debate and communication of ideas are encouraged based on evidence and inquiry (NRC 2007). Research supports the wealth of benefits and particularly the academic gain to students and schools who are supported in the arts (Catteral et al. 1999; Gullatt 2007). Findings support that "the performing arts and visual arts challenge students to use reasoning skills, draw conclusions, and formulate ideas" (Gullatt 2007, p. 212). Today, science reform is calling for best practice methods that facilitate the development of these same skills in science learners (NRC 2007).

Social constructivism holds that the nature of knowledge is not fixed and transmitted by a single authority figure, but knowledge is socially constructed, and reality is created during physical and social activity (Cole 1978). Creative drama supports the social constructivist paradigm that the learner makes meaning through firsthand experience in a social setting with an informed facilitator. When applied to science education, creative drama can foster the learning process in science by adapting and applying acquired knowledge from hands-on lab experiences to new problems and settings (Ariel 2007). Creative drama helps students to clarify and monitor their science learning through discourse and feedback because students, along with their teachers, are actively evaluating their understandings, seeking clarification and feedback from the teacher and each other as they engage in creating the science drama (Ariel 2007; Kamen 1991). Activities associated with creative drama such as pantomime and improvisation can create a transactional learning pathway in order to help students build deeper understanding of concepts. Shared meanings enhanced by pantomime and improvisation which are grounded on prior knowledge will lead the teacher-facilitator to help students construct deeper understanding of concepts while clarifying alternative conceptions in science. Creative drama also utilizes kinesthetic awareness to better understand disciplinary content (Osmond 2007). Pantomime, for example, engages the kinesthetic learner while providing the drama facilitator a vehicle to transport conversation among and with students. According to Wee (2009), using the body expressively is not encouraged in school; instead, academic subjects and cognitive development are given greater emphasis.

Much of what researchers have published about creative drama and its creative component supports its use as an instructional strategy in helping students use higher level, critical thinking skills in order to learn science at a deeper level (Ariel 2007; Kamen 1991; Walsh and Edwards 2009). Kamen (1991) describes creative drama as a spontaneous group process that uses imaginative play-acting to help students and teachers actively explore, while applying meaning to many abstract science concepts. In his study, children had positive gains in science achievement through teacher-led creative drama activities (Kamen 1991). Much like the approach to science teaching inherent in conceptual change learning, creative drama can be a tool for deeper learning that seeks to involve the student in an active approach to explain evidence and to relate ideas to prior knowledge in order to develop important insights in science (Metcalfe et al. 1984).

Aubusson et al. (1997) found that students who had shown little interest in school science, and those that preferred a kinesthetic approach to learning, used dramatic role-playing with effective results in science understanding. Additionally, they found that in non-threatening, science-friendly classrooms, shy students, who would not otherwise engage in higher level thinking discourse, acquired a means to express and think aloud about science (Aubusson et al. 1997; Ladrousse 1989). Role-playing clarified and supported the learning of students who were at different levels of understanding:

> …Students operated in three ways as the role-play allowed students with different understanding and different aptitudes to learn in different ways. Firstly, for some students role-play was a way of demonstrating understanding that they already had about science phenomena. These students, for example, already understood the electric current or gaseous exchange and they could apply this understanding in a role-play. Secondly, it was a mechanism students could use to construct an understanding about science phenomena. The students discussed and refined their ideas as they developed better role plays. And thirdly, it provided experience which modeled scientific phenomena initially not understood. (Aubusson et al. 1997)

In another research study, creative drama was found to provide an alternative science learning strategy to lower achieving students in developing deeper scientific understanding (Metcalfe et al. 1984). Students were better able to relate ideas to previous knowledge and experience by relinquishing an egocentric viewpoint of looking at things while participating in creative role-playing in science. The study concluded that deeper meaningful learning, as opposed to surface learning, had occurred as demonstrated by student acquired expertise in explaining evidence and conclusions, while relating the ideas to previous knowledge and experience (Metcalfe et al. 1984).

This action research study set out to determine if creative drama's impact on conceptual learning and attitudes toward science could meaningfully enhance an already existing inquiry-based elementary program at this school that utilizes Full Option Science System (FOSS™) kit-based curricula and materials. As an action research study, the classroom teacher was the principal researcher of her own practice in wanting to test out a promising innovative approach to active learning (Mills 2000). It was hypothesized that the integration of creative drama activities would help children's deeper understanding of the conceptual ideas taught through the FOSS™ curriculum as well as improve attitudes toward science. As a form of action research, this research study could "both solve practical problems and contribute to scientific theory" (Bray et al. 2000, p. 34) regarding the use of creative drama in science classrooms. Research supports the improvement of children's achievement and attitudes toward science when using a hands-on approach like the FOSS™ curriculum in elementary grades over traditional approaches (Foley and McPhee 2008; Frederick and Shaw 1999; Leach 1992; Ruby 2006; Young and Lee 2005). But, could achievement and attitudes improve further through the integration of a *second* active means of student engagement as Aubusson et al. (1997) suggest? It was further theorized by the researcher that the process of doing creative drama shared many of the same objectives of teaching science based on conceptual development models which stress discourse, inquiry, problem solving and the interchange of student ideas about science.

Theoretical Framework for Use of Creative Drama

Current effective instructional practices call for teachers to develop deeper conceptual learning in students while utilizing meta-cognitive strategies or the skill of knowing how to learn by monitoring progress and practicing self-evaluation (NRC 2000). Current teaching models in science that can help students monitor progress through continuous evaluation include models like the Glasson Learning Cycle (Glasson 1993; Tytler 2002). Glasson has offered a learning model that is more in line with social constructivist theory as a guide for current best practice in science thinking (See Table 1). The important aspect of this model is that students' prior ideas are taken into consideration which invites students to reflect on their understanding, to test their ideas and to change views, if needed, based on scientific discourse and evidence. This model was selected over other models of the learning cycle because of its reliance upon student discourse, presentation, and debate in each step of the learning process. It has a component of building consensus with others in the learning community, which is primarily social in nature.

When applied to the use of creative drama, the Glasson Learning Cycle provides a framework for structuring the creative drama experience and lessons. After initially completing a series of inquiry-based lessons on a specific science concept, students come together as a small class or in groups to prepare a creative drama depicting the concept in action. Students work together to first discuss their ideas for dramatizing a science concept or idea as the 'preliminary' phase of the Cycle. They formulate their drama based on collaborative student thinking and class consensus developed from previous science lessons on this concept. They then act out their drama as the 'focus' phase. Through their presentation the teacher facilitates dialogue and discussion on the nature of their depiction of the concept in question. This is the 'challenge' phase of the Cycle. Lastly, in the 'application' phase, students meet again to refine their drama to better reflect scientific views as discussed as a class.

The creative drama activities implemented in the study were introduced after the students had some inquiry-based experience with the targeted science concepts

Table 1 Glasson's learning cycle

Phase	Teacher activity	Pupil activity
Preliminary	Explores student views and classifies these Explores literature about science views and evidence which challenges student alternative conceptions	Completes surveys or activities designed to identify existing ideas
Focus	Establishes a context. Provides motivational experiences. Ask open-ended questions of individuals. Interprets and clarifies student's views.	Becomes familiar with materials used to explore the concept. Clarifies own view to the class or group through discussion or poster display
Challenge	Facilitates exchanges of views. Ensures all views are considered. Keeps discussion open. Suggests demonstrations or experiments as necessary. Presents the evidence from the scientists' views. Accepts the tentative nature of the students' reactions to the new view.	Considers the view of others in the class, evaluating these. Tests the validity of different answers by seeking evidence. Compares the science view with views of students.
Application	Contrives problems which are simply and elegantly solved using the accepted science view. Assists students to clarify the science view, asking that it be applied to a range of situations. Teacher joins in, stimulates and contributes to discussion of solutions to problems. Helps in solving advanced problems.	Solves practical problems using the concept as a basis. Presents solutions to others in class. Discusses and debates merits of the science view, and critically evaluates its use in different situations. Suggests further problems arising from the application of the science view.

using the FOSS™ curricula. Creative drama activities related to the science content of the investigations in two different FOSS™ modules, *The Physics of Sound* and *Solar Energy,* and were integrated within each module (See Appendix 1). The teacher developed and modeled the initial creative drama activities for each module, emphasizing storytelling and role-playing. Afterwards, students created their own stories and skits for acting-out through role-playing and improvisation.

Methods

Participants and Context

The instruction took place in the fall semester of 2010 in an elementary school located in a small town in the southeastern region of the United States. Students designated as receiving free and reduced lunch make up 61.6 % of the population. The elementary school where the research took place is designated as a Title One school. The consented participants in this study consisted of 38 students identified as

Table 2 The gender and ethnic composition of the fourth and fifth grade study population

	Male			Female		
	Caucasian (%)	African American (%)	Asian Pacific Islander (%)	Caucasian (%)	African American (%)	Asian Pacific Islander (%)
Grade						
4th grade	35	25	10	20	10	0
5th grade	35	15	0	15	30	5

'talented and gifted' by the school system. They were pulled from their self-contained classrooms once each week for a 95-min enrichment class. Participants were in two enrichment classes of fourth (N = 22) and two enrichment classes of fifth (N = 16) grade students, ages nine and ten respectively. One class in each grade served as the treatment group where creative drama activities were integrated into the teaching of an inquiry-based curriculum. This curriculum was part of the inquiry-based science program in the self-contained classrooms at this school. In this study, the enrichment students in fourth grade classes studied the FOSS™ *Physics of Sound* module while the fifth grade enrichment students studied the FOSS™ *Solar Energy* module. Neither of these modules had been taught in any of their self-contained classrooms before or during this study. The ethnic and gender breakdown of the participating students is in Table 2.

Selection of students for the gifted and talented classes for instruction is based on Joseph Renzulli's model of school-wide enrichment. This type of enrichment program is a state-approved alternative program to Individualized Educational Plans (IEP) used in traditional talented and gifted programs. Renzulli's school-wide model targets three areas of behavioral dispositions used in the identification of talented and gifted students: Creativity, above average ability, and task commitment (Renzulli 1977). The school's teachers and enrichment specialist identify children as talented and gifted. Parents/guardians are informed of the selection, and permission letters are sent home requesting parental consent to serve the student in the enrichment program.

The primary researcher in this study, who taught the FOSS™ units on sound physics and solar energy as well as the creative drama activities, was the enrichment teacher for fourth and fifth grade students. This teacher held teaching certification in elementary education and in drama and speech communication. She was also an experienced teacher in the use of the FOSS™ materials. As the teacher in this study, her primary task was to make certain that the creative drama activities were connected to the science concepts taught in the inquiry modules. In addition, through the exchange of ideas and questioning of students, the teacher served to clarify the drama activity while guiding the students to connect the science to the role-playing they were undertaking. The teacher used the "drama coach as facilitator approach" whenever students wrote skits, improvised songs, and in the case of the fourth grade class, developed an original puppet play on how vibrations or sound waves need a medium through which to travel. This teaching approach meant the teacher encouraged student creative thinking and action, and helped redirect their efforts as needed. Otherwise, the students improvised their own skits, puppet play, raps, creative movement, music, characters, and props in revealing their understanding of the science phenomena investigated in the FOSS™ modules.

Data Collection and Analysis

This quantitative study used a quasi-experimental, pre/post design for measuring student achievement and attitudes toward science. The teacher also kept daily field notes on her students in the treatment classes when they were implementing creative drama lessons. These notes were recorded during and after enacted lessons. The teacher particularly noted points of dialogue and thinking between the students (e.g., conversations) and her thinking and interactions with the students in facilitating student dramas. Selections from these notes were used to create sample episodes of these interactions to help understand the nature of the creative drama lessons in practice and add greater validity to what took place in the classroom. In this regard, this action research study was more pragmatic than a strict traditionalist approach that would rely solely on quantitative data (Bray et al. 2000).

A $2 \times 2 \times (2)$ Mixed ANOVA was used to examine differences in the learning outcomes and attitudes toward science between groups (drama and non-drama) and grade levels (4th and 5th grades) over time (pre/post). Gender and race were not considered in the analysis because of the lower overall numbers of participants. All data were analyzed using the Statistical Packages for the Social Sciences (SPSS) computer software (version 19.0). A significant level of 0.05 was set for statistical analysis. The independent variables in this research are defined as group and grade. The dependent variables in the study are defined as science learning outcomes and science attitudes as measured by the FOSS™ pre and post-test in sound physics and solar energy, and the Three Dimension Elementary Science Attitude Survey (TDSAS), respectively.

Participants in Group A (treatment classes) and Group B (control classes) of the study were members of the small group enrichment classes and attended morning or afternoon classes based on the school's master scheduling of small group enrichment. Drama treatment groups (Group A) consisted of one fourth grade class ($n = 9$) and one fifth grade class ($n = 10$) of small group enrichment students. The study's non-drama control groups (Group B) consisted of one fourth grade small group ($n = 12$) and one fifth grade small group of enrichment students ($n = 7$). Students were not assigned to these classes by random assignment, but were pre-enrolled following routine scheduling by the administration.

All fourth grade participants were taught eight investigations in the physics of sound and all fifth grade participants were instructed in eight investigations in solar energy. Two investigations per class were taught in a seven-week time frame to the treatment groups and the control groups. To ensure that the science lessons were identically taught in treatment and control classes for fourth and fifth grades, the teacher followed the exact script and sequence of lessons provided in the teacher's guide for the FOSS™ modules in each grade. Only the drama treatment groups received the creative drama integration after each FOSS™ investigation and before beginning the next investigation (see Appendix 1 for further details). Lesson plans for each of the four classes documented this enactment. While the treatment classes were integrating creative drama after the completion of FOSS™ activities, the control classes participated in more traditional follow-up discussion about their learning from the kits that included a summary and review session. Such sessions often included games for review of key concepts and terms from the modules.

The FOSS™ pretest assessment for sound physics was administered to the fourth grade treatment and control groups prior to the science instruction in the investigative modules. The same posttest was repeated at the conclusion of the eight investigations. The TDSAS survey measuring student attitudes toward science was given to the students at the beginning and then again at the end of the investigations. This pre/post design procedure was the same for the fifth grade treatment and control groups in the study of solar energy.

In order to reduce teacher bias in the scoring of tests, an outside colleague whited out the names of the students and other identifying information on tests prior to evaluation by the teacher. Tests were assigned numbers. The tests were evaluated based on the scoring guide and rubrics supplied by the FOSS™ teacher's guide. The teacher followed strict adherence to the FOSS™ scoring guide's exact wording and numerical rating values for consistency. These nominal ratings ranged from a high of 4 on short answer items to a high of 2 on forced-choice items with justification. These few choices for scoring (4, 3, 2, or 1) with their associated descriptions made scoring simpler for each item response because of clear differences between few categories. In addition, a second reviewer checked this scoring for each test to check the teacher's adherence to the scoring guide. This helped to ensure greater validity to the scoring.

Instrumentation

FOSS Tests

The instrumentation used in this study included the Full Option Science System™ (FOSS) Pre/Posttest and the Three Dimension Elementary Science Attitude Survey (TDSAS) (see Appendix 2). FOSS is an ongoing, 20-year, research-based science curriculum for grades K–8 developed at the Lawrence Hall of Science, University of California at Berkeley. The Physics of Sound Pre/Posttest survey analysis (N = 307) revealed Cronbach's Alpha at 0.73. Item separation reliability is reported as 0.944. The Solar Energy pre/posttest survey analysis (N = 148) showed Cronbach's Alpha as 0.74. Item separation reliability is reported as 0.978 (K. Long, personal communication, July 5, 2011). In the present study, Pearson's Correlation revealed test–retest reliability of the FOSS pre/post survey instrument as acceptable at 0.713 ($p < 0.001$).

The Pretest/Posttest Surveys in both FOSS kits used in this study contain coding guides for each science concept taught in the FOSS Investigations. The coding guides contain model student responses. The higher numbers are connected to a more complete student answer. Numerical values for *The Physics of Sound* have a possible total of twenty points and numerical values for Solar Energy has a possible of twenty-five points.

TDSAS Attitude Survey

A shortened version of the Three Dimension Elementary Science Attitude Survey (TDSAS) was administered to the elementary students in this study (Zhang and Campbell 2010). The TDSAS is a five-point likert scale science attitude survey based on the tripartite theory of attitudes and consisted of three constructs: Student affective feeling about science, student cognitive judgment of science based on values and beliefs, and student behavioral tendencies in learning science. Internal consistency and internal reliability measures using Cronbach's Alpha for the three TDSAS subscales ranged from 0.65 to 0.83, which is considered moderate internal consistency (Bland and Altman 1997). The decision to use the TDSAS was based on several research findings that suggest student science attitudes are linked to student achievement and motivation in taking science courses and pursuing science related careers (Alsop and Watts 2003; Haladyna et al. 1982).

Twelve of the original 28 items were selected for this study with equal numbers in each construct category. Questions 5, 6, and 12 on the TDSAS survey were reversed for consistency. The decision to shorten the survey was based on targeting the 'best' questions for the context of this study population and to reduce the time required to take the survey. In the present study, Pearson's Correlation revealed a test–retest reliability of the shortened TDSAS survey instrument as acceptable at 0.613 ($p < 0.001$). Cronbach's Alpha revealed acceptable internal consistency ($r = 0.752$, $p < 0.001$). Thus, value validity could be claimed for the shortened instrument, even though construct validity could not be claimed. Participating students completed all items.

Results

The primary goal of the study was to determine if the inclusion of creative drama as an integration into an existing inquiry-based science program improved students' understanding of science and attitudes toward science better than the inquiry-based program alone. The analysis sought to determine if there were any significant differences in learning outcomes and science attitudes between groups (treatment and control), between grade (fourth and fifth), and between group and grade. The study included the additional aim of determining if the inclusion of creative drama in science instruction increased positive attitudes toward science significantly better over time than inquiry-based instruction alone. Lastly, in describing the nature of student and teacher interactions and dialogue through the creative drama process, classroom episodes based on teacher field notes were selected from the teaching of the concepts from the FOSS™ investigation, *Good Vibrations*. These episodes were rich in description of the typical interactions in creative drama enactment.

Learning (FOSS)

The FOSS and TDSAS descriptive summary in Table 3 reports the changes in learning outcomes and the TDSAS attitude changes as mean scores over time. Overall, there was a significant main effect for grade level ($F = 14.3$, $p < 0.001$)

Table 3 FOSS and TDSAS descriptive summary

	FOSS		TDSAS	
	Pre Mean (SD)	Post Mean (SD)	Pre Mean (SD)	Post Mean (SD)
Group A (drama)				
4th grade	24.7 (4.4)	35.0 (3.0)	33.6 (2.9)	32.5 (5.9)
5th grade	21.9 (3.9)	31.1 (5.1)	32.6 (3.7)	31.3 (3.9)
Group B (non-drama)				
4th grade	25.4 (4.0)	32.0 (4.3)	33.7 (3.0)	31.7 (4.4)
5th grade	20.7 (3.4)	25.4 (2.5)	33.0 (3.3)	30.2 (5.3)

Table 4 Summary of mixed ANOVA findings

Effect	Learning outcome (FOSS) *F*	Science attitude (TDSAS) *F*
Group (drama/non-drama)	3.7	0.07
Grade level (4th/5th)	14.3***	0.78
Group × grade level interaction effect	0.93	0.001
Time (pre/post)	160.2***	7.6**
Group × time interaction effect	11.3**	0.77
Grade level × time interaction effect	1.4	0.13
Group × grade level × time interaction effect	0.10	0.03

$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)

Table 5 FOSS test summary

Group	FOSS pre	FOSS post	Change
A = drama	23.3	33.0	9.77
B = non-drama	23.0	28.7	5.67

with students in grade four achieving significantly greater learning outcomes (M = 29.2) than students in grade 5 (M = 24.8). There was also a significant increase in learning over time ($F = 160.2$, $p < 0.001$), increasing from 23.1 (SD = 0.67) on the pre-test to a mean of 30.9 (SD = .66) on the post-test. This difference over time, however, was dependent on the instructional group as evidenced by the interaction effect between time and group ($F = 11.3$, $p < 0.01$). More specifically, students in the drama treatment group (Group A) increased their science learning significantly more than students in the non-drama control group. Table 4 provides the effect summary of the ANOVA findings. The changes for each treatment group (summarized in Table 5) indicate a 9.8 point increase for students in the treatment group (Group A) compared to a 5.7 point increase for students in the control group (Group B).

Science Attitudes

Science attitude data in this study reported a slight decrease of 1.8 in overall attitude scores over time for all groups from a pre survey mean of 33.3 (SD = 3.1) to a post survey mean of 31.5 (SD = 4.8). The overall change from pre to post although small was statistically significant ($F = 7.5$, $p < 0.01$).

Good Vibrations: Classroom Episodes

In one classroom episode in this study, which was sequenced after the FOSS™ investigation of *Good Vibrations*, the conversations overheard by the teacher as the students planned and organized their skits on how sound travels revealed much of what the students were thinking and understanding about sound vibration investigations. The language of science was at full play when the abstract idea of a sound wave came up. As the children discussed what they were going to act out, they were reminded that a sound vibration and a sound wave were one and the same thing. One student declared, in all seriousness, that it was not the same kind of wave when you tell your mother good-bye. Rather, "it is a science meaning of the word sound wave!" [Teacher field notes] Very often for children trying to learn science, it can be a style of language that does not match everyday talk.

Dramatizing the science concepts by the children led to the connection that a sound wave is a rapid back and forth motion that produces sound. From this idea came the realization that they could pretend to be sound sources and jump back and forth while shaking their arms. Listening to the conversation at this point, it was clear that teacher intervention could move the mental image of sound vibration further by asking, "How could you act out a vibrating sound source being directed through air?" [Teacher field notes] As the children decided to role-play air molecules, they experimented with the best way to present their model. This consisted of deciding on the best way they could use their bodies to show molecules being pushed on other molecules causing the sound to travel out from the source in all directions.

In another point of entry, the teacher asked the students how they could visually demonstrate a slow moving sound source vibration. Without hesitation, one member of the class suggested that "our bodies could be vibrations and act out the slow rate of vibration by putting every body movement in slow motion like in a movie!" [Teacher field notes] The children lowered the pitch of their voices to suggest the rate of a low-pitched sound. They then proceeded to experiment with what a lower pitch vibration might look like (if you could see it) by slowing down and exaggerating the body movement of "running in place" while swaying the torso and arms as if in a slow motion movie. At this point in the process it was noted in the researcher's field notes the importance of the teachable science moment in facilitating group discussion on how the rate of vibration affected pitch based on the observations of the FOSS tone generator. The children's reactions and conversation provided data for reflection and recall of the importance of intervention at such teachable moments in order to keep the role playing and "science talk" on task. In a subsequent lesson, the teachable moment came as a delightful surprise to the researcher when the students looked into the built-in speakers of the classroom electric piano keyboard and called out, “Look the dust in the speaker hole is jumping around and vibrating when Julia plays!” [Teacher field notes].

Discussion

Creative drama in this study as in others (Aubusson et al. 1997; Ariel 2007; Kamen 1991; Metcalfe et al. 1984) was an effective extension activity that can increase student learning in science. Although this study was conducted in special enrichment classes for gifted students, it could be applied to regular education classrooms, particularly with lower achieving students (Metcalfe et al. 1984). Indeed, the FOSS™ program utilized as the inquiry component of the lessons in this study is designed for use with all children in science classrooms. In this study, significant learning gains occurred for the creative drama classes above expected gains from the FOSS™ inquiry-based science curriculum that is shown to increase student achievement (Frederick and Shaw 1999; Leach 1992; Ruby 2006; Young and Lee 2005). Creative drama provided an additional means of active learning through a creative modeling approach that readily engages students in thinking about abstract concepts in science (Aubusson et al. 1997; Osmond 2007; Taber et al. 2006; Walsh and Edwards 2009). Ariel (2007) found that creative drama helped students to remember both scientific process and vocabulary because of the affective and kinesthetic nature of learning through creative drama:

> Creative drama is a tool that promotes understanding and does not emphasize memorization. Students remember process and vocabulary that they use in their skits or in the creative drama games because creative drama affects students through all senses and multiple intelligences. (Ariel 2007, p. 133)

As Ariel suggests, strategies like creative drama that promote understanding rather than memorization in science reveals one aim of conceptual models for learning. Students construct and re-construct their knowledge from the creative drama experience while seeking understanding of scientific phenomena (Davis 2003). Specific creative activities in the drama formats of skit writing and improvised role playing performed by children can help teachers and their students uncover student ideas and understanding in science. For example, uncovering a student’s initial idea about the nature of waves in science versus everyday understanding or the realization that a sound wave is a back-and-forth movement of matter. Once uncovered, students’ conceptions can be interrogated through dialogue, discussion, and debate among students in order to help lead students to more complex understandings (Hewson and Hewson 1988; NRC 2007). The role of the teacher in taking advantage of teachable moments or fruitful moments in impacting student thinking and subsequent action is critical in this process, particularly in linking dramatic action to scientific phenomena. The Glasson Learning Cycle provides an appropriate framework for structuring student-centered dialogue in the creative drama process from initial ideas to challenging emergent learning and ultimately deeper understanding and application (Glasson 1993; Tytler 2002).

In conceptual learning models of teaching, priority is given to the value of exploration in science which precedes and supports children’s efforts to explain and make meaning of the science content either in concept discovery or extensions supported through conversations between the teacher and student (Gallagher 2007; Glasson 1993; Kim 2001). Conceptual learning models also provide opportunities for the identification and resolution of alternative frameworks in science that may impede further development and growth in science (Georghiades 2000; Pine et al. 2001). For example, students must understand the nature of waves and their effect on matter before they can begin to deeply understand the nature of frequency and pitch. The nature of what happens when students engage in role playing as a necessary component of making abstract science phenomena understandable is that students *and* teachers often engage in the conversations and language interchanges that uncover understanding as well as identification of any alternative conceptions students may have in science (Kamen 1991). The model development and language engagement of role-playing, skit making and improvisation that define the creative drama format provides additional opportunities between teacher and student for learning science as a communal creative process (Martin 2010), above-and-beyond the use of hands-on materials in inquiry-based curricula. The result is an additional strategy that offers deeper science learning aimed toward fuller meaning and understanding of abstract science concepts. Such a strategy could also benefit English Language Learners in understanding science through inquiry and drama, the visual and kinesthetic aspects of it.

In this study, students in the fourth grade outperformed students in the fifth grade in learning gains. The lower learning gains made by the fifth grade students may be in part due to the more difficult nature of the concepts and skills that made up the solar energy curriculum. Test results revealed that fifth grade students in both the treatment and control classes had difficulty in interpreting and sequencing the shadow illustrations in the FOSS™ Solar Energy module. These illustrations tested understanding of shadow length changes from sunrise to sunset. Additionally, fifth grade students had difficulty on two items requiring the utilization and application of graphing skills. These skills were not re-emphasized through creative drama, which works better with re-enacting concepts. Learning still improved for all but one of the fifth grade students who declined one point.

All students across grades showed a slight decline in attitudes toward science. The decrease in positive attitudes toward science across grades, although small, was statistically significant. Generally, science attitude statements remained close to the top end of the TDSAS scale (4 or 5) with five representing the highest positive rating a statement could be given. This result (pre and post) could likely have been influenced by the pre-existing high positive attitudes toward the nature of the inquiry-based curriculum used by the school. Maintaining the same high positive attitudes across time during the school term could be problematic. Past research in using FOSS™ modules also show mixed results in surveying children's attitudes toward science (pre and post) depending upon the time of year (Frederick and Shaw 1998, 1999). Frederick and Shaw found increases in fourth grade students' overall attitudes toward science when instruction was early in the school year (1999) when compared to later in the school year (1998). Also, Ornstein (2006) in a large-scale study ($N = 786$) of attitudes in hands-on versus traditional classrooms found that student surveys were completed too early in the school year. He conjectured that the surveys reflected student attitudes from their previous year's science classroom. In our study, children completing the pre-survey may have been thinking about their previous or current experience in science classrooms in this school which used a hands-on program including FOSS™ as well as Science and Technology for Children (STC™) materials. This would account for very high initial attitude scores that declined slightly as the term progressed to the end. In addition, analysis of paired scores in this study suggests possible outliers that could have skewed the data to an average decline. For example, one fourth-grade student had an overall steep decline (-14) in attitude while showing a strong learning gain (+15).

However, positive achievement results in the use of creative drama show promise in the potential improvement of attitudes toward science over time. With an intervention strategy like creative drama, students can begin to build on their cognitive and affective strengths in science, including creativity, which can lead to continued greater achievement in science understanding. These achievement gains may be more pronounced in lower achieving students than in the gifted student population in this study. Quality science learning environments, particularly ones utilizing inquiry and higher level thinking, can lead to more positive attitudes toward science (Craker 2006; Ornstein 2006). Attitudes are learned behavior, and because they are learned they can be subject to change (Koballa 1989).

Conclusions

This study examined the effects of using creative drama as an extension within a well-known and widely used inquiry curricula, FOSS™ *Physics of Sound* and *Solar Energy*. Learning outcomes support the use of creative drama as an effective strategy when appropriately implemented and integrated within the FOSS™ materials. The study's data analysis showed significant main effects for grade level and time. Students in fourth grade had a significantly greater learning outcome than students in fifth grade. This may be explained by the greater difficulty of the concepts and skills required in the solar energy curriculum used in fifth grade. Also, students in all grades significantly increased their learning over time in this study. This is likely due to the nature of strong inquiry-based curricula used. Most importantly for this study's intent, there was also a significant increase in learning over time for the drama treatment classes over the non-drama classes.

Though not a big change, the science attitude data in this study revealed a slight decrease over time in student attitudes toward science. This was true across groups and grade level. The small decline revealed by the TDSAS attitude survey may have been influenced in part by a few strong outliers and the nature of the school's existing inquiry-based science program leading to initial high attitude scores. These lower post-survey scores were still at the high end of the attitude survey and showed that these participants' attitudes toward science were still very positive.

Appendix 1

See Tables 6 and 7.

Table 6 FOSS physics of sound module matrix with creative drama activity integration

Investigation	Science content	Thinking processes	Creative drama activity
1. Dropping in	Objects can be identified by the sounds they make when dropped Sounds have identifiable characteristics Sounds convey information Sound is caused by vibrations A sound source is an object that is vibrating A sound receiver detects sound vibrations	Observe sounds made when dropped Communicate with others making a code Compare sounds to develop discrimination	Science Theatre: Students act out the dramatic narrative, The Real Story of Sound" using pantomime, improvisation and created dialogue with action accompanied by baritone ukulele
2. Good vibrations	Sound originates from vibrating sources Pitch is how high or low a sound is Differences in pitch are caused by differences in the rate at which objects vibrate Several variables affect pitch including size (length) and tension of the source material	Observe that sound originates from a vibrating source. Compare high, low, and medium pitched sounds Record observations on sound. Relate the pitch of a sound to the physical properties of the sound source	Students observe tuning of baritone ukulele using tuning pegs of the instrument. Sing simple song accompanied by teacher. Students explore and observe plucking of strings on classroom autoharp. Students observe tension applied to a dulcimer instrument. Observe and describe strings in school piano when instrument is played Science Theatre: Students pretend to be strings of a cello, vibrating slowly with improvised body movements (kinesthetic/learners) Students pretend to be strings of a smaller instrument (example: violin or ukulele with short strings) vibrating faster producing higher sounds. Students pretend to be aliens using voices with slow moving vocal chords that have big spaces between the chords to produce a lower sound. Aliens with fast moving vocal chords and smaller spaces between the vocal chords produce higher sounds. Body warm-up and movement accompanied by CD music and classroom keyboard

Table 6 continued

Investigation	Science content	Thinking processes	Creative drama activity
3. How sound travels	Sound travels through solids, water, and air	Sound travels through solids, water, and air	When a sound source is demonstrated and called out (example: banging cymbals together, shaking a rain stick, striking finger symbols, a tuning fork)
	Sound vibrations need a medium to travel	Sound vibrations need a medium to travel to travel	Students pretend to be sound waves moving out in all directions
	Sound that is directed travels better through air	Sound that is directed travels better through air	Students pretend to be sound waves using their energy to pass through a medium
	Our outer ears are designed to receive, focus, and amplify sounds	Our outer ears are designed to receive focus, and amplify sounds	Students pantomime passing through a solid, liquid and a gas
			Students pretend to be molecules in the medium being pushed (Gently) on the molecules next to them
			The molecules cause the sound to travel out from the source in all directions. A cooperative sound wave can be made using students as molecules compressing together then spreading apart as they travel across the floor of the activity building
			Students pretend to be tones of sound (e.g. A live Rock Band) all wanting to be measured through air at the Decibel Gym (Activity Building) Here are the teams of sound: Rustling Leaves (10), The Whispers (20), The normal Conversations, (65) The Cars Without Mufflers (100), The Live Rock Concert Trio (120). Sound volume or intensity (how soft or loud) is measured in decibels

Table 6 continued

Investigation	Science content	Thinking processes	Creative drama activity
4. Sound challenges	Several variables affect pitch, including size (length), tension, and thickness of the source material Sound can be directed through air, water, or solids to the sound receivers The medium that sound passes through affects its volume and the distance at which it can be heard	Observe that the outer ear is designed to receive sounds Compare different ways of amplifying sounds and making them travel longer distances Record observations of how sound travels Report findings in a class presentation	After pretending to be tones of sound and using pantomime, the students must then come up with a method using the medium of a solid in order to decrease the volume of the decibel level of the teams of sound. Examples: rustling of leaves (a blanket over the leaves, mulching the leaves for the compost pile, raking the leaves and placing them in a burlap bag that can be carried as mulch to the compost pile), Whispers and conversations (putting your hand over your mouth) Cars without mufflers, (pantomime building a fence sound barrier on the interstate, pantomime a mechanic getting under a car to attach an automotive muffler) rock concerts (putting ear plugs in your ears, pantomime turning down the intensity on the amplifier, pantomime a teenager and create dialogue explaining to your parents why you are deaf.) Other ideas will be acted out by students as they brainstorm scenarios of ways to make sound waves travel further Students improvise a script of dialogue that has the main character, Dr. Heargood, accompanying several tourists through the human ear. Each child, after outside research, will play the ear parts. Each ear character presents a "This is your Life" biography of the ear part's life (theatre concept-Personification of ear parts and how they work in the human body told as a story (play) written by the children

Table 7 Solar energy module matrix with creative drama activity integration

Investigations	Science content	Science processes	Creative drama activity
1. Sun tracking	Shadows are the dark areas that result when light is blocked The length of shadow depends on the position and orientation of the Earth relative to the sun The length of shadows on earth change as the sun's position in the sky changes during the day	Observe and compare shadows over time. Organize information and communicate results. Relate the position of the sun to a shadow's shape and direction	Body warm-up and movement accompanied by CD music and classroom keyboard Students will act out "Grandmother Spider Steals the Sun" a Cherokee fictional adventure in which the main characters experience the sun's energy and the position of the earth relative to the sun. (FOSS Module Story)
2. Heating the earth	Change of energy from one form to another or the movement of energy is called energy transfer Energy from the sun is absorbed and released by different materials at different rates A heat sink is a material that can absorb a large amount of heat for its volume and release the energy slowly	Observe and compare temperature change of different materials over time. Organize and communicate results of investigations. Relate the rate and amount of temperature changes to properties of materials	Students research shadow puppetry. Perform a shadow play based on Grandmother Steals The Sun." Students develop and improvise original Caveman's Story: A Debate About the Power of the Sun: Objective: communicate the results of investigations In skit form
3. Solar water heaters	The color of the collector in a solar water heater affects the change in temperature. Placing a clear cover on a solar water heater Affects the change in water temperature The surface area of the collector in a water heater affects the change in the water temperature	Observe and compare the effect of different colors and covers on solar water heaters of a collector to energy Science Processes Organize data and communicate results on graphs Relate the surface area of a collector to energy transfer	Body warm-up and movement accompanied by CD music and classroom keyboard

Table 7 continued

Investigations	Science content	Science processes	Creative drama activity
4. Solar houses	The change of energy from one form to another or the movement of energy is called energy transfer A heat sink is a material that can absorb a large amount of heat for its volume and release the energy slowly Insulation can be used in a solar house to maintain its inside temperature Solar energy is energy from the sun that comes to Earth in the form of light Space heating is the transfer of heat energy to air in an enclosed space	Observe and compare variables on solar house heating efficiency Use information to build an efficiently solar-heated model house Investigate insulation as a means of holding in heat in a space	Students will write, act, direct and produce a television commercial advertising the efficiency of solar heated homes

Appendix 2: TDSAS Survey of Science Attitude

See Table 8.

Table 8 The three-dimension elementary science attitude survey (TDSAS)

1. I think it is very important to learn science.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
2. I think learning science is fun.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
3. I always ask my parents science questions.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
4. I like to help others to solve the problems by using science knowledge I have learned.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
5. I think people pay too much attention on science.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
6. I do not think science will be very useful to me for my future job.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
7. I like to find out why something happens by doing experiments rather than by being told.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
8. Learning science will help me to learn other subjects.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
9. I do not think I will pursue a science related career in the future.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
10. Team work is often needed for solving hard science problems.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
11. I want to be a scientist when I grow up.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
12. I do not like to spend much time doing science.
5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree
Thank You For Your Time In Completing This Survey!

Read each sentence carefully. After reading the sentence, please circle the number below the sentence that tells to what extent you agree or disagree with the sentence about science. Use the following scale to rank the extent to which you agree or disagree

5 = Strongly Agree 4 = Agree 3 = Neutral 2 = Disagree 1 = Strongly Disagree

References

Alsop, S., & Watts, M. (2003). Science education and effect. *International Journal of Science Education, 25*(9), 1043–1047.

Ariel, B. (2007). The integration of creative drama into science teaching. Ph.D. dissertation, Kansas State University, United States-Kansas. Retrieved October 18, 2011, from dissertations & theses: A&l. (Publication No. AAT 3291364).

Aubusson, P., Fogwill, S., Barr, R., & Perkovic, L. (1997). What happens when students do simulation-role-play in science? *Research in Science Education, 27*(4), 565–579.

Baker, P. H. (2005). Managing student behavior: How ready are teachers to meet the challenge? *American Secondary Education, 33*(2), 51–64.
Bland, J. M., & Altman, D. G. (1997). Cronbach's alpha. *British Medical Journal, 314*, 572.
Braund, M. (1999). Electric drama to improve understanding in science. *School Science Review, 81*(294), 35–41.
Bray, J. N., Lee, J., Smith, L. L., & Yorks, L. (2000). *Collaborative inquiry in practice: Action, reflection, and making meaning*. Thousand Oaks, CA: Sage Publications, Inc.
Catteral, J., Iwanaga, J., & Chapleau, R. (1999). Champions of change: The impact of the arts on learning. In E. B. Fiske (Ed.), *Champions of change* (p. 130). Washington, DC: The President's Committee on the Arts and the Humanities.
Cole, M. (1978). *Mind in society: The development of higher psychological processes/L. S*. Cambridge, MA: Harvard University Press.
Craker, D. E. (2006). Attitudes toward science of students enrolled in introductory level science courses at UW-La cross. *UW-L Journal of Undergraduate Research, IX*, 1–6.
Davis, E. A. (2003). Prompting middle school science students for productive reflection: Generic and direct prompts. *The Journal of the Learning Sciences, 12*(1), 91–142.
Davis, J. H., & Belm, T. (1978). Terminology of drama/theatre with and for children: A redefinition. *Children's Theatre Review, 27*(1), 10–11.
DeCruz, H., & DeSmedt, J. (2010). Science as structured imagination. *Journal of Creative Behavior, 44*(1), 29–44.
Duveen, J., & Solomon, J. (1994). The great evolution trial: Use of role-play in the classroom. *Journal of Research in Science Teaching, 31*(5), 575–582.
Foley, B. J., & McPhee, C. (2008). *Students' attitudes towards science in classes using hands-on or textbook based curriculum*. Paper presented at the meeting of the American Educational Research Association, New York, NY.
Frederick, L. R., & Shaw, E. L. Jr. (1998). *Examining the effects of science manipulatives on achievement, attitudes, and journal writing of elementary science students.* Paper presented at the meeting of the Mid-South Educational Research Association, New Orleans, LA.
Frederick, L. R., & Shaw, E. L. Jr. (1999). *Effects of science manipulatives on achievement, attitudes, and journal writing of elementary science students revisited.* Paper presented at the meeting of the Mid-South Educational Research Association, Point Clear, AL.
Gallagher, J. J. (2007). *Teaching science for understanding: A practical guide for middle and high school teachers*. Columbus, OH: Pearson Merrill Prentice Hall.
Georghiades, P. (2000). Beyond conceptual change learning in science education: Focusing on transfer, durability and metacognition. *Educational Research, 42*(2), 119–139.
Glasson, G. (1993). Reinterpreting the learning cycle from a social constructivist perspective: A qualitative study of teachers' belief and practice. *Journal of Research in Science Teaching, 30*(2), 187–207.
Gullatt, D. E. (2007). Research links the arts with student academic gains. *The Educational Forum, 71*, 211.
Haladyna, T., Olsen, R., & Shaughnessy, J. (1982). Relationships of student, teacher, and learning environment variables to attitudes toward science. *Journal of Research in Science Teaching, 20*(4), 311–324.
Hewson, P. W., & Hewson, M. G. (1988). An appropriate conception of teaching science: A view from studies of science learning. *Science Education, 72*(5), 597–614.
Kamen, M. (1991). Use of creative drama to evaluate elementary school students. In G. Kulm & S. Malcom (Eds.), *Science assessment in the service of reform*. Washington, DC: AAAS.
Kim, B. (2001). Social constructivism. In M. Orey (Ed.), *Emerging perspectives on learning, teaching and technology*. Department of Educational Psychology and Instructional Technology, University of Georgia, Athens, Georgia. Retrieved from http://www.coe.uga.edu/epltt/SocialConstructivism.htm.
Koballa, T. (1989). *Changing and measuring attitudes in the science classroom*. (Research Matters—to the Science Teacher, Report No. 8901). Retrieved from National Association for Research in Science Teaching website: http://www.narst.org/publications/research/attitude.cfm.
Ladrousse, G. P. (1989). *Role play*. Oxford: Oxford University Press.
Leach, L. S. (1992). *Full-option science system: Effects on science attitudes and achievement of female fifth-grade students*. Master's thesis, Texas Tech University.
Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331–359.

Martin, L. (2010). Science and creativity: The importance of ontology for scientific understanding. *Gifted and Talented International, 25*(1), 69–73.

Metcalfe, R. J. A., Abbott, S., Bray, P., Exley, J., & Wisnia, D. (1984). Teaching science through drama: An empirical investigation. *Research in Science and Technological Education, 2*(1), 77–81.

Mills, G. E. (2000). *Action research*. Columbus, OH: Merrill.

National Research Council. (1996). *National science education standards*. National Committee for Science Education Standards and Assessment. Washington, DC: National Academy Press.

National Research Council (NRC). (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academies Press.

National Research Council (NRC). (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: National Academies Press.

Ornstein, A. (2006). The frequency of hands-on experimentation and student attitudes toward science: A statistically significant relation. *Journal of Science Education and Technology, 15*(3), 285–297.

Osmond, C. R. (2007). Drama education and the body: I am therefore I think. In L. Bresler (Ed.), *International handbook of research in arts education* (pp. 1109–1118). Dordrecht, Netherlands: Springer.

Pine, K., Messer, D., & St. John, K. (2001). Children's misconceptions in primary science: Survey of teacher's views. *Research in Science & Technological Education, 19*(1), 79–96.

Renzulli, J. (1977). *The enrichment triad model: A guide for developing defensible programs for the gifted*. Mansfield Center, CT: Creative Learning Press.

Ruby, A. (2006). Improving science achievement at high-poverty urban middle schools. *Science Education, 90*(6), 1005–1027.

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

Sternberg, R. J. (1988). *The nature of creativity: Contemporary psychological perspectives*. New York: Cambridge University Press.

Taber, K., De Trafford, T., & Quail, T. (2006). Conceptual resources for constructing the concepts of electricity: The role of models, analogies and imagination. *Physics Education, 41*(2), 155–160.

Tippett, C. (2009). Argumentation: The science of language. *Journal of Elementary Science Education, 21*(1), 17–25.

Tytler, R. (2002). Teaching for understanding in science: Constructivist/Conceptual change teaching approaches. *Australian Teachers' Journal, 48*(4), 30–35.

Walsh, E., & Edwards, R. (2009). Buns, scissors, and strawberry-laces—A model of science education? *Education in Science, 235*, 12–13.

Ward, W. (1957). *Playmaking with children from kindergarten through junior high school*. New York: Appleton-Century-Crofts Inc.

Wee, S. J. (2009). A case study of drama for young children in early childhood programs. *Journal of Research in Childhood Education, 23*(4), 489–501.

Young, B. J., & Lee, S. K. (2005). The effects of a kit-based science curriculum and intensive science professional development on elementary student science achievement. *Journal of Science Education and Technology, 14*(5/6), 471–481.

Zhang, D., & Campbell, T. (2010). The psychometric evaluation of a three-dimension elementary science attitude survey. *Journal of Science Teacher Education, 22*(7), 595–612.