Three- and Four-Year Olds Learn about Gears through Arts Incorporation

Dessy Stoycheva

University of Northern Iowa

and

Leann Perkins

University of Northern Iowa

Child Development Center

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Abstract

This research paper explores art integration into a science lesson unit that follows the Next Generation Science Standards (K-PS2-1) and focuses on the effects on memory retention of key concepts along with levels of enjoyment. An experiment was conducted with children ages 3 and 4 teaching scientific concepts about gears while incorporating student-made art products. The children were assigned to alternating experimental (art-integrated) or control (no art) conditions during the four stages of the lesson. The results did not show statistically significant differences at the alpha = 0.05 level between conditions in the amount of information retained based on the pretest, posttest, and distal posttest. However, there were overall knowledge gains for both conditions demonstrated by the gain scores. It appeared that incorporating arts into the curriculum can be beneficial for children, including those of diverse cultural backgrounds, as it provides a more enjoyable learning environment. Arts integration can also facilitate the construction of children's schema of gears which later may ease the learning of more complex concepts related to motion, stability, forces, and interaction.

Key Words

Arts-integration, STEM education, STEAM education, Next Generation Science Standards, schema theory

Introduction

Even though in the United States, education is considered primarily a state and local responsibility, historically the federal role in education has been to fill gaps in state and local support for education when critical national needs arise. The lack of interest in STEM (Science, Technology, Engineering, and Mathematics) related fields has resulted in only 4.4% of American undergraduates enrolled in such majors, whereas the STEM job market is increasing three times faster than the rest of the economy (Land, 2013). Thus federal and state legislation in recent years have imposed standards and assessments with direct curriculum implications (No Child Left Behind, 2001). The need for literacy and science preparation has dislocated the arts into occupying a fraction of the curricular units. Meanwhile, there has been a long-standing concern that American students are falling behind in science and are experiencing a decline in reading at grade level, especially around third grade (Gardner, Larsen, Baker, Campbell, & Crosby, 1983; Chall, Jacobs, Baldwin, & Chall, 2009). Solid foundations for learning need to be created during the primary years, including preschool and kindergarten.

An effective path to improved learning skills and science involvement is suggested to be through use of integrated curriculum that promotes learning across different domains (Poldberg, Trainin, & Andrzejczak, 2013). The arts can serve as a tool for cross-domain integration and can enhance both the teaching methodology and the learning process. According to Goldberg (1997), the arts can be incorporated in three ways: through learning *about* the arts, learning *with* the arts, and learning *through* the arts. This way, the STEM curricula can be transformed into STEAM (Science, Technology, Engineering, Arts, and Mathematics).

This study tests a STEAM lesson set with preschool-aged children through a pretest-posttest counterbalanced design aimed at investigating the effects of art integration on memory and attitude. The arts were incorporated in terms of "learning through the arts"- the arts facilitated the scientific learning while arts concepts were not explicitly taught. This teaching approach "constructs and demonstrates understanding through an art form in which students engage in a creative process which connects an art form and another subject area" (Silverstein & Layne, 2010).

Literature Review

To provide a foundation for the study, several topics from the professional literature are reviewed. These topics include the adoption of standards, positive attitudes, knowledge retention, and formation of schemata. Many advantages of integrating the arts into STEM education to produce STEAM education are elucidated. Specific examples of positive student affect when arts are incorporated into the curriculum are explored.

STEM or STEAM

Traditional STEM (Science, Technology, Engineering, and Mathematics) degrees center instruction on the development of convergent cognitive skills. These include the logical, objective, realistic, intellectual, planned, discriminative, systematic, and quantitative thought processes. On the other hand, art degrees are found to develop divergent cognitive skills. This type of reasoning includes the use of intuition, subjectivity, emotion, imagination, impulsivity, holistic approaches, free-wheeling, and qualitative thought (Land, 2013). In this regard, integrating arts into STEM would enrich education enabling students to combine the convergent and divergent approaches when faced with problem solving situations.

Different studies maintain that arts can bridge the interest in STEM as they entail processes similar with those in STEM fields. For example, the engineering design process involves the following aspects also found in some art forms: defining a problem, researching information and techniques, brainstorming solutions and approaches, creating prototypes, presenting to an audience, and refining the final solution (Bequette & Bequette, 2012).

Root-Bernstein and Root-Bernstein (2013) offered specific examples of famous scientists in support of the idea that science can benefit from skills fostered by arts and crafts. Such skills used in both science and the arts are: observation, pattern identification, visual thinking, and manipulative ability. Visual arts, music, and crafts are found to enhance manipulative abilities, fine motor skills, and visual-spatial thinking of scientists. In fact, visual imaging ability is suggested as a predictor of success in scientific subjects in grades K-16 (Newcombe, 2010).

Curriculum-integrated activities found to improve visual-spatial skills include mental rotation tasks, paper folding, Tetris games, use of maps and graphs, analogies, gestures, and vocabulary involving positional prepositions and use of spatial language (Newcombe, 2010). If STEM is transformed into STEAM, the curricula will take advantage of the divergent skills developed by arts and crafts and might even be able to narrow the achievement gaps.

Positive Attitude and Enjoyment

Complex emotional, cognitive, and creative processes take place in students' involvement with learning. Different researchers suggest that the arts encourage engagement leading to an improved attitude toward school (Catterall, Chapleau, & Iwanga, 1999; Deasey, 2002; Hetland & Winner, 2001; Winner & Cooper, 2000). When students enjoy the learning process, they naturally improve their behavior and achievement. Especially during the early grade levels when basic learning skills are formed and the conceptual foundations are laid, it is important to create a pleasant, joyful atmosphere that predisposes children to view school as a positive, desirable experience.

Investigators in Finland (Nevanen, Juvonen, & Ruismaki, 2014) recorded the effects of an arts education project on school readiness in terms of learning skills and attitudes. They incorporated a circus theme in the curriculum for students ages 3-9 that involved different projects related to dance, architecture, literature, drama, and visual arts. One of the main reported results was a positive effect on children's social-emotional development. The children's attitudes toward practicing and learning improved as a result of their ongoing success at the given tasks. Their self-confidence increased as well as their interest in problem-solving. Such art-centered projects can provide opportunities for children to express themselves in unique ways, thereby feeling engaged and motivated. Additionally, arts integration can promote listening skills, goal-oriented work, self-evaluation of progress, and desire to receive feedback, which are all factors in school readiness but also in science preparedness (Nevanen, et al., 2014).

Similar findings of the benefits of arts integration were reported with a US sample by Doyle, Hofstetter, Kendig, and Strick (2014). They described a three-year-long professional development program that prepared teachers to integrate the arts in everyday instruction to support student achievement. Not only did arts integration allow teachers to be more confident in the continuous use of arts in regular instruction, but significant improvements were observed with their students, too. The teachers noted that their students enjoyed being involved in the arts and hoped that this would lead to long-term learning success. The students also displayed increased social competence as a result of working together on collaborative arts projects. Some of the emergent themes from the teachers' journals described the students' excitement, enthusiasm, motivation, focus, and exhibition of pride in their creations. Some children were able to increase their listening skills and motivation; others were able to channel their emotions into the arts. Teachers observed that dramatization helped some students' comprehension of the material.

Knowledge Retention

Another benefit of arts integration has been identified as long-term retention of information. Mechanisms that naturally occur when the arts are involved increase learning. Rehearsal of content, elaboration, generation, enactment, oral production, effort after meaning, emotional arousal, and pictorial representation have been isolated as specific strategies for successful encoding and retrieval of information (Rinne, Gregory, Yarmolinskaya, & Hardiman, 2011).

The effects of these mechanisms for long-term content retention have been tested recently. A study divided elementary students into two groups: an arts-integrated instruction group and a control group without arts-integration. The immediate posttest showed that students in both groups learned the science content similarly; however, the distal posttest showed that students who learned through the arts retained the information better compared to the control group (Hardiman, Rinne, & Yarmolinskaya, 2014). The broad suggestion for education from this study is that arts integration may increase student involvement and deepen cognitive processing thus leading to less memory attrition in long-term recall of information.

Learning and Schemata Construction

The discussion of how arts integration may enhance STEM curricula is focused on benefits to students' learning. However, there is no consensus between education and psychology or an overarching grand theory explaining the nature of learning. In this respect, Alexander, Schallert, and Reynolds (2009) proposed a complex definition of learning which maintains that it is crucial for educators to consider the *what*, *who*, *where*, and *when* of the learning process because learning and teaching are interrelated. The *what* can encompass levels of learning ranging from forming of habits, through spontaneous concepts, to scientific concepts. The discussion of the *where* of learning considers the physical, social, and cultural environment. The *who* is determined by the learner's biological, cognitive, experiential, and affective characteristics. The *when* suggests that learning can happen during a short time period (days, weeks) or may be distributed over long periods (months, years) and can be determined by the history of the particular group of people.

The learner's background is a powerful factor in the learning process that has been analyzed by linguists, psychologists, and educational researchers through the concept of schema. Schema theory states that all knowledge is organized into conceptual units which represent generalized descriptions and serve as a system for comprehension. Each person's schemata are unique and reflect the experiences and prior structures of knowledge which shape the person's theories about the world. These theories affect the way information is interpreted, but they also continue to change as new information is received; they undergo either accommodation (adjusting the schema to incorporate new information) or assimilation (interpretation of new experiences in terms of existing schemata) (Kant, 1781; Bartlett, 1932; Piaget, 1953; Posner, Strike, Hewson, & Gertzog, 1982).

Many studies have explored the effects of schemata on learning in general and on text comprehension in particular. Anderson, Reynold, Schallert, and Goetz (1977) define these effects on three levels. One is that the person's perception of whether he or she comprehends a message depends on the connections the person makes back to his or her schemata. Another is that schemata enable filling in the gaps of information (inferencing) when the texts do not provide clarity. The third is that high-level schemata adjust people's perceptions to seeing messages in a certain way, i.e. they fine-tune what information one is open to. Anderson et al. (1977) conducted an experiment determining that people from different backgrounds "saw" different meanings in the same text passage. Some of the findings indicated that background did not influence the total amount of information learned and remembered; rather it influenced the type of information or the perceptions of meanings.

Another direction of exploring schema theory leads to the cultural specifics of a person's background or to cultural schemata. "Culture influences knowledge, beliefs, and values; and that knowledge, beliefs, and values influence comprehension processes" (Reynolds, Taylor, Steffensen, Shirey, & Anderson, 1982). Cultural schemata can be used in educational practice with minority children or children of diverse cultures who may not apply common schemata. With the growing diversity in education, there is a concern that significant differences in cultural schemata may interfere with the learning process among subcultures in the US despite cultural overlaps.

This identification of cultural schemata as an important factor in student learning begs the question if some of the achievement gaps and the lack of involvement in STEM related majors that students may experience can be attributed to the disconnect between their culture and the culture of the school, and the culture transmitted by the standard curriculum. Poldberg et al. (2013) reiterate the need for specific strategies when reaching out to diverse student populations. At risk students may benefit from linking images, language, and domain knowledge (science) through the arts. Non-linguistic representation has been found to assist English language learners in expressing their ideas which can promote engagement in the learning process. Thus, arts integration could be the missing component bridging cultural and socio-economic diversity in the science classroom.

The schema approach to learning can also be used to explain how young learners create their schema of gears and how that schema can be later activated in new learning situations. The inference-making process should be considered not only when analyzing comprehension of specific scientific concepts related to gears but also when investigating different interpretations and perceptions based on children's schemata.

The 5E Instructional Model

The format of this unit on gears follows the 5-E model of science instruction based on a purposeful succession of different instructional phases of the lesson: Engagement, Exploration, Explanation, Expansion, and Evaluation (Trowbridge & Bybee, 1990). The activities during the engagement stage are meant to stimulate thinking and connections to prior knowledge. During the exploration phase the teacher is a facilitator of the students' hands-on investigation of the topic and asks questions to direct the attention and thinking without giving away answers to questions that may arise. The lesson in this study used the pretest and the introductory arts activity as the engagement and exploration phase. The children were introduced to the gear toys and prompted to think about their functions as they expressed their prior knowledge. Also, they prepared the art work that was attached to the moving gears during later lessons. The artwork consisted of drawings of the children's favorite people or animals on both hanging cards and cards glued to Popsicle sticks.

Not until the next phase of the 5-E model does the teacher provide definitions and explanations, using the students' prior knowledge and experiences. The students were then encouraged to identify patterns and relationships in gear motion. The first three lessons in this study fulfilled the explanation phase as the teacher introduced the gear concepts and encouraged deeper understanding through hands-on tasks. The children in the experimental condition created narratives about their drawings (what their people or animals were doing on the gears). In this way, the children explained their understandings of the scientific concepts through dramatization.

During the expansion phase of the 5-E model, the students solidified their understandings of gears by applying their knowledge to new situations when making their own models of machines with gears. The fourth lesson facilitated expansion of the new knowledge by introducing real life pictures of machines that use gears. The children either organized them based on which gear belongs to which machine in the control group or used them as models to create their own machines with gears from cut outs in the experimental group. Students in the experimental condition assembled their own machines by selecting pre-cut paper gears of different shapes and sizes, coloring them, and attaching them to a big sheet of cardstock paper. This activity facilitated their self-directed creativity based on the newly acquired scientific information.

The last phase of the 5-E model requires evaluation by the teacher but also self-assessment and peer-assessment. The children's comparisons of their art work was a form of peer-assessment. The posttest and the distal posttest of their newly formed knowledge served as the major assessment of the unit's results. The gear-play structure allowed the students to use the processes of scientific inquiry to construct their own experiments and to connect ideas in a motivating environment.

The Topic of Gears

This topic promotes some of the core concepts in the NGSS related to forces, motion, and engineering. When gears are assembled they transmit motion and force within a machine. The force causes motion and moves the object (in this case, rotating the gears). To create a properly functioning machine, the gears need to be connected by meshing their teeth so the input of force results in sequential motion (Hsu, 2003). Smaller gears rotate faster because the input force travels a smaller distance while the edge of a larger gear travels a longer distance and results in greater force. Same size gears will rotate with the same speed and force. Two attached gears rotate in opposite directions (Hsu, 2003).

Previous studies have found these concepts to be challenging for students in second and even fifth grade. Not only did few students understand how gears fit together, they often confused mechanical advantage with speed. This created common misconceptions about the nature of the gear motion such as the belief that all gears turn in the same direction with the same speed (Lehrer & Schäuble, 1998; Smith, 2014).

Introduction of gear concepts to children may assist students in developing an understanding of the structure and function of machines through observation, investigation, and interaction. Another advantage of exposure to gears is enhancement of students' abilities to focus on complex concepts such as mechanical advantage and mathematics (Lehrer & Schäuble, 1998).

National Standards Addressed

National Science Standards

The lesson in this study developed the topic of gears by addressing science and engineering standards of the Next Generation Science Standards (NGSS Lead States, 2013). These standards have been recently implemented in the public schools of the State of Iowa and include new engineering components.

The NGSS include three components: (1) Science and engineering practices, (2) Disciplinary core ideas, and (3) Crosscutting concepts. Each lesson should include at least one example of each of the three components so that students can benefit from engaging in multiple domains of learning. These performance expectations are not meant to prescribe instruction, instead they offer teachers freedom and flexibility in the planning of a lesson. Their specific purpose is to describe the essential learning goals and how these goals will be assessed at each grade level (Workosky & Willard, 2015). The newly added “Engineering Design” standards aim at introducing real life applications of science and developing skills to enable those. For instance, students are expected to be able to define problems, to gather information based on which to generate possible solutions; to evaluate and test multiple options; and to build or improve tools. These practices have not been explicitly included in science standards until now and are believed to contribute to creative and innovative solutions to the problems of the future. The lesson designed for this study aligns with the following standards:

- K-PS2 Motion and Stability: Forces and Interactions;
- K-PS2-1: Students can plan and conduct an investigation to compare the effects of different strengths or directions of pushes and pulls on the motion of an object (gears);
- K-PS2-2: Analyze data to determine if a design solution works as intended to change the speed or direction of an object (gears) with a push or a pull; and
- K-2-ETS1 Engineering Design: Ask a question, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

These standards were included in the activities associated with all stages of the lesson, including the exploratory pretest. The students were allowed to investigate how the gear set could be assembled, what students could do with the gears, and to solve problems when the gears did not function correctly. They were prompted to observe where the issues originated (for example, not meshing the teeth of the gears) and to make adjustments accordingly. Their attention was also directed to changes of speed and direction and the effects of those changes.

National Core Arts Standards

The other standards addressed in the current lesson are related to the arts (National Coalition for Core Arts Standards, 2014). They are divided into four categories, each consisting of a few different Anchor Standards: Creating (three Anchor Standards); Performing/Presenting/Producing (three Anchor Standards), Responding (three Anchor Standards), and Connecting (two Anchor Standard). Their goal is to “guide educators in providing a unified quality arts education for students in Pre-K through high school” (National Coalition for Core Arts Standards, 2014). The specific standards utilized in this study are:

- Visual Arts- Creating; Anchor Standard 1: Pre-K: Engage in self-directed play with materials. Engage in self-directed, creative making. Share and talk about personal artwork.
- Theatre- Anchor Standard 1: Pre-K: With prompting and support, transition between imagination and reality in dramatic play or a guided drama experience (e.g., process drama, story drama, and creative drama).

The first standard was supported during the pretest when the children explored the gear toy set, as well as during all four stages of the lesson when they figured out its functions, asked questions, and drew their own pictures to decorate the gears. The second standard was addressed during the first, second, and third lesson when the experimental groups enacted stories they had created about the people or animals in their pictures.

Method

Overview and Research Questions

This study developed and tested an instructional unit with four lessons for pre-K children integrating the arts into the STEM (Science, Technology, Engineering, and Mathematics) curriculum, thus resulting in STEAM (Science, Technology, Engineering, Arts, and Mathematics) instruction. The creation of this unit was a response to the growing popularity of STEAM education due to its potential to motivate students through meaningful project work. Even though some specific benefits of STEAM curriculum have been identified, more research is needed to document and explore them. Moreover, early childhood education is often glossed over and there is an insufficient amount of research conducted to address the introduction to the STEM standards and specifically the infusion of arts into them. This study will contribute to the goal of accumulating more information regarding pre-K education by adapting the Kindergarten STEM standards and offering a possible model for an arts integrated lesson.

Therefore, the broad research question in the current study was: How do three and four-year-old children learn about gears through STEAM curriculum? The secondary research questions are: How does the incorporation of arts into the NGSS affect children's retention of gear concepts? How does arts integration affect students' enjoyment, motivation, and interest during the lesson?

Setting and Participants

The setting for this study was a child development center in the Midwestern United States. This setting was chosen because the educators use the STEM standards in their instruction and some of them are currently undergoing additional workshops familiarizing them with the NGSS specifically. The preschool group was recruited as the researcher is particularly interested in the 3 and 4 years age group and how the NGSS can be adapted for it. Thus a purposive sampling was selected as best suiting the goals of this study. According to Welman and Kruger (1999) this is the kind of non-probability sampling identifying as primary participants those who have experiences related to the phenomenon of interest, based on the researcher's judgment and goal.

The participants consisted of 16 children (7 girls, 9 boys; 10 European- American, 4 Middle Eastern, 1 Korean-American, and 1 Asian-American; 8 three-year-olds and 8 four-year-olds). The study was approved by the Institutional Review Board Human Subjects Committee of the overseeing university and by the preschool director. All participants and their parents provided signed informed consent to participate in the study.

Design and Procedure

This is a pretest-posttest counterbalanced design in which two randomly chosen groups of children from the same preschool class participated alternating between the experimental and control conditions: Group A and Group B. The groups had equal numbers of children (8 in each) and approximately the same number of boys and girls. A knowledge pretest was distributed to all children. During the knowledge test, the children were introduced to toy gears and were given the opportunity to show what they could do with them through play. A knowledge posttest was given one week after the end of the lesson. A distal posttest followed after an additional two weeks. The same questions and scoring chart were used in the pretest, posttest, and the distal posttest (see Table 1). The goal was to determine whether the arts integrated lessons helped the children retain the learned information longer than they would with non-arts-integrated lessons. The following open-ended questions were used for knowledge evaluation: *What can you do with these gears? Can you show me how they work? Show and tell me everything you know about gears.*

The instructional unit on gears was divided into four parts (four lessons) which were taught by the teacher to both groups; however, they alternated as to which one received the arts incorporated instruction and which did not (see Table 2). In each lesson both groups were familiarized with specific vocabulary related to the concepts about gears.

Instrumentation

After each lesson of the instructional unit, every child was given an attitude survey in the form of smiley faces pictures (see Table 3). They were asked to point to the face that best illustrated how they felt about the gear activity. Translation of word-based Likert-type scales to picture-based Likert-type scales for young children is appropriate because the inability to read is a barrier. Associating emotions with their visual, pictorial representation promotes a meaningful response and could be more accurate than verbal description (Reynolds-Keefer & Johnson, 2011). Children's answers were tallied for frequency; the children were also asked about the reason why they felt that way. These responses added qualitative data.

Table 1. *Pretest/Posttest/Distal Posttest Scoring Chart*

Part	Measure	Possible Points
General questions to show what gears generally teach	Can identify the word for gear or gears	1
	Can attach a gear on the platform block	1
	Can attach multiple gears but they are not connected	1
	Can mesh the teeth of two gears	1
	Can mesh teeth of more than two gears	1
	Can spin a gear with hand on gear	1
	Can spin gear with a handle	1
	Name things you can do with gears (to play, to spin, to build machines)	3
Questions used for the experiment	Lesson 1. Can the child show or tell that small gears spin faster?	2
	Lesson 1 Vocabulary: Rotate	1
	Lesson 2. Can the child show or tell that Gears next to each other turn in opposite directions?	2
	Lesson 2. Vocabulary: Opposite	1
	Lesson 3. Can the child show or tell that Gears have to touch to transfer motion?	2
	Lesson 3. Vocabulary: Teeth	1
	Lesson 4. Can the child show or tell that Gears are in machines?	2
	Lesson 4 Vocabulary: Machines	1

Materials

The children were provided Quercetti Gears set to explore and to use as learning through play. They were also given paper cards to draw on which were previously prepared by the researcher to fit the gear set. Some of the cards were attached to Popsicle sticks so that they can be stuck onto small handles that fit on top of the gears. Others had holes in the upper end so they can be hung from tall hangers fitting onto the gears. For the activities in the last lesson, there were pre-made cards with pictures of real-life gears and the machines they fit into. These materials provide opportunities for the children to create a story about what their pictures were doing on the gears. This way they integrated the narrative and the art of drawing into the scientific content.

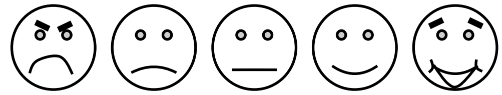
Table 2: *Lesson Plan Schedule*

Event	Group	Condition	Lesson Activity
Engagement and Exploration Phase of the Learning Cycle			
Pretest	Both		Knowledge test
Explanation Phase of the Learning Cycle: Learning Principles of How Gears Work			
Lesson 1: Small gears spin faster.	Group A	Control	Playing with toy gears. Vocabulary: "Rotate"
	Group B	Experimental= Arts-Integrated	Playing with toy gears and drawing figures to put on them. Vocabulary: "Rotate"
Attitude Test	Both		Smiley faces scale
Lesson 2: Gears next to each other turn in opposite directions	Group B	Control	Track the direction of the toy gears. Vocabulary: "Opposite"
	Group A	Experimental= Arts-Integrated	Making up a narrative about the figures on the toy gears moving in different directions. Vocabulary: "Opposite"
Attitude Test	Both		Smiley faces scale
Lesson 3: Gears have to touch to transfer force	Group A	Control	Connecting the teeth of different gears and explaining how force is transferred along touching gears. Vocabulary: "Teeth on the gear touch".
	Group B	Experimental= Arts-Integrated	Connecting the teeth of different gears and putting figures on the later gears. Vocabulary: "Teeth on the gear touch".
Attitude Test	Both		Smiley faces scale
Expansion Phase: How Gears Are Used in Real Life			
Lesson 4: Gears are in many machines	Group B	Control	Sorting pictures of machines with gears into two groups- the gear and the machine it is part of. Vocabulary: "Machines".
	Group A	Experimental= Arts-Integrated	Examining pictures of machines with gears. Using gear cut-outs to make own machine. Vocabulary: "Machines".
Attitude Test	Both		Smiley faces scale
Evaluation Phase of the Learning Cycle			
Post-test 1- 1 week later; Post-test 2- 2 weeks after Post-test 1	Both		Knowledge test; Distal posttest

Table 3: *Attitude Survey*

Point to a face to show how you feel about learning about gears.

Tell why you feel that way.



Results

Knowledge Pretest, Posttest, and Distal Posttest

The children in both groups had similar overall levels of knowledge about gears as demonstrated by their mean pretest scores. However, on the section with general questions about what gears experiences teach (see Table 1), Group A scored higher than Group B (x1=4.38 and x2=3.88) suggesting that some of the students may have had a previous experience with gears or a pre-existing general schema of gears.

At the posttest, there was no significant difference between the performance of students under the experimental and the control conditions, even though the experimental condition mean was slightly higher. Interestingly, the two conditions maintained their difference in scores related to the general questions about what gear experiences teach (x1=7.25 and x2=6.88). The most striking results on the posttest were the gain scores for all children as in Table 4.

It is shown that all children involved in the gear lessons, regardless of the condition, demonstrated significantly more knowledge on the posttest and distal posttest in comparison to the pretest. The scores for the experiment at the distal posttest were even higher than the posttest and slightly in favor of the experimental condition. The difference between the two conditions was not significant at α = 0.05 but if compared to α = 0.1 it was.

It should be noted that these results suggest that the children have gained comprehension about the scientific concepts as stated in the standards, as well as about the general learning experience with gears which helped them build their schema of gears.

Table 4. *Pretest, Posttest, and Distal Posttest Results**

		Mean Scores for Experiment				
Timing	Eight General Knowledge Questions Separate from Experiment (10 possible points)	Control Condition (12 possible points)	Experimental Condition (12 possible points)	t-Test p-value	Significant difference?	Mean Score for Sum of All Measures (22 possible points)
Pretest	4.13 (1.5)	0.44 (1.0)	0.06 (0.3)	0.08	No	4.63 (1.9)
Posttest	7.06 (0.6)	2.69 (1.9)	2.81 (1.6)	0.38	No	12.56 (3.2)
Pretest to Posttest Gain Score	2.94 (1.6)	2.25 (2.0)	2.75 (1.5)	0.12	No	7.94 (2.5)
Distal Posttest	6.38 (1.1)	3.13 (2.1)	3.56 (1.7)	0.21	No	13.06 (3.9)
Pretest to Distal Posttest Gain Score	2.25 (1.2)	2.69 (2.4)	3.50 (1.7)	0.10	Not at alpha = 0.05	8.44 (3.4)

* Standard deviations in parentheses

Attitude Survey Results

The attitude survey was based on five-point Likert-type scale presented after each of the four lessons of the instructional unit on gears (two lessons in the control condition and two lessons in the experimental condition). This design made the maximum possible score for each of the conditions 10. There was no difference found between the attitudes demonstrated during the experimental and control lessons (see Table 5). However, the scores were positive (a sum of 6 or greater per condition) in both conditions suggesting that all the students enjoyed the learning experience.

Table 5. Attitude Survey Quantitative Results

Mean Attitude Score for Sum of Two Lessons in Same Condition		*t*-Test	Statistically Significant?
Experimental Condition	Control Condition	*p*-Value	
6.81 (2.2)	7.00 (2.1)	0.41	No

The explanations that children provided when selecting a face from the Likert scale were summarized in Table 6. The most frequent response for both conditions was that they liked the gears and the gear activities. Generally, children from both conditions enjoyed watching the gears spin. The children in the experimental condition especially liked the last lesson when they made their own machines with the gear paper cut-outs provided. Their counterparts in the control condition also expressed that they liked the gear pictures, perhaps because it was a new activity and helped them visualize real life machines. However, even though children in the experimental condition also played with these pictures, only one child pointed out the pictures as a reason for choosing a happy face. The rest of them identified the gear cut-outs activity that followed the picture matching as the reason why they chose a happy face. This suggests that even if both groups enjoyed this part of the lesson, students under the experimental condition enjoyed making their own machines even more.

The next most frequent justification for the choice of a rating face was "Because I am happy." Because of their young age, the children sometimes seemed unable to differentiate their general mood at the time and the emotion related to the particular gear activity. This can be a possible explanation why there were more "I am happy" responses in the control condition. This inability to discriminate between situations can also be related to the answers "I like grumpy faces." These children enjoyed playing with the gears, yet chose a picture face based on unrelated to the activity reasons. Children in the control condition expressed five times that they didn't like the activities as much that time. This can also suggest that they might have lacked the stimulation that the arts provide to keep their interest and engagement. Only one time a child could not say why the he or she made a choice of a face.

Table 6.

Reason for Choice of Face on Attitude Scale	Frequency	
	Control Condition	Experimental Condition
I like gears and gear activities	9	10
I like the gear cut-outs art activity	0	7
I am happy	6	4
I like that gears spin	4	3
I like grumpy faces	0	3
I like the pictures of machines with gears	5	1
I didn't enjoy the activities as much today	5	0
I don't know	0	1

Observational Data of Student Performance

Pretest. At the pretest it became evident that some of the children were more verbal than others. They shared their initial observations and asked questions about the gears right away. Some noted that there were many parts that needed to be put together and that the gears were different sizes. Others had difficulties fitting the parts together and said that one needed “strong muscles” to “push super hard.” Most children intuitively started spinning individual gears with their fingers but some suggested that some kind of “tool” was needed and were interested in the art holders. Only three children were able to correctly attach two gears together so that their teeth meshed and one child attached more than two gears this way. Seven children said that they have seen gears before; however, not all of them were aware of their function or seemed experienced playing with them.

Lessons. The children quickly began to notice how the gears work as early as the first lesson. They were prompted by the teacher to focus on different aspects in each of the three lessons corresponding to the scientific concepts addressed by the standards- small gears spin faster; gears next to each other rotate in opposite directions; and gears need to touch to transfer motion.

During the first lesson most of the children in the experimental condition were able to notice that the smaller gears spin faster, while the children in the control condition had difficulties and said that they all spin the same. There was a similar pattern during the second lesson concerning the direction of the rotation. It is possible that placing the drawings on holders attached to the gears in the experimental condition made it easier to observe the speed and direction of the gears.

Nevertheless, teachers should be aware that these two concepts of direction and speed of the gears can present a challenge for students, especially in the early developmental stages when they learn through discovery and observation. Some of the students throughout this lesson kept incorrectly stating that the gears spin the same in terms of direction and speed. They would assume that the gear which spun the rest “gets more power” and spun the fastest. They would also point to the biggest and brightest colored gear as fast maybe because it attracted their attention more.

The children in the experimental condition were better able to describe their comprehension of the newly introduced concepts through their narratives and dramatizations. A girl said that her pictures on the gears were of a girl and her dad who were dancing and singing a song. The dad on the bigger gear was dancing slowly and the girl on the small one was moving fast. A boy’s story was that a giraffe and an elephant were spinning on the merry-go-round and one of them jumped on the fast wheel (the small one) to find the way to the park. Another boy was moving his pictures between the big and the small gear because they were “flying the drones to the other gear.”

During the second experimental lesson regarding the direction of the gears, one of the boys told the story of a dinosaur roaring at the people hanging on the art holder so the people started spinning in the opposite direction. During the third lesson another boy said that an ant eater and a girl are eating popcorn and holding hands because the gears “need to touch so the one rotates the other.” Overall, the concept of touching the teeth of the gears was easier to comprehend in both conditions. The last section of the lesson introducing real life machines with gears encouraged the children to imagine what machines their gears could be. Two children compared them to racing cars, another two compared them to trains, one boy called them a “cruncher grinder,” and a couple of girls recognized the gears as being in bikes and clocks.

All of the children showed interest in the picture matching game of real gears and machines. The children in the experimental condition who made their own machines with paper cut-outs of gears had different approaches to their art. Some attached only a couple of gears to the big paper sheet and drew the rest of the machine. Others tried to attach as many gears on the paper as they could, while at the same time, making the teeth mesh.

Figure 1a shows a boy in the control condition of lesson 3. He was very skilled at attaching and rotating multiple gears while learning the scientific concepts in the lessons. In Figure 1b, the children participate in the experimental condition of lesson 3. They have laid out their drawings and are looking for ways to attach them to the gears so they can make up a story about them. They are comfortable with connecting multiple gears; however, their focus is not primarily on the number of gears attached (as in Figure 1a) but on the art. Figure 1c illustrates the control condition for lesson 4 when the children were playing the picture matching game. After the first couple of pictures were matched, the children became more skilled at figuring out quickly which of the rest of the gears were part of the internal workings of which machine. The last picture in Figure 1d captures the resulting art from the experimental condition in lesson 4. These four children created a train (top left), a bike (top right), a clock (bottom left), and a truck (bottom right) by attaching gear cut outs and by drawing.

Posttest. The difference in the children's skills and experience with gears between the pretest and posttest was striking. All of them played with multiple correctly-attached gears of different sizes, sometimes up to eight different sizes attached in clusters or a T-shaped sequence. However, they would not always explain the gear functions and concepts verbally. Those who did verbalize used the lesson vocabulary "opposite directions" and "teeth of the gear" more often than "rotate." None of the children used the word "machine," yet most of them were able to give an example of a machine or where they have seen real gears ("in the truck," "train," "bike," "ferris wheel"). There were some interesting suggestions as to how the teeth are called by those who forgot the word "teeth": "the grips," "the flowers," "the spikes." All of those alternative words evoked vivid images and associations with the actual function of the gear teeth which suggested that they were filling in the gap in their schema of gears.

One of the girls asked about her art at the posttest. Even though she drew her pictures ten days prior, she remembered what they were and wanted to attach them to the gears again just like we had done during the lessons. This suggests that she associated her art and the stories about the pictures with the gears concepts. The art might have helped her learn about the gears or might have made the learning process more enjoyable for her. The art might have also become integrated in her schema of gears. She was one of the English language learners so the verbalization of her schema was lacking but she demonstrated improved skills.

Distal Posttest. Even though the researcher did not conduct an attitude evaluation at the distal posttest, most of the children expected the Likert type scale with faces. They asked about them or went to the researcher looking for them. They may have remembered them because they are naturally drawn to pictorial representations.

All children were more comfortable and more confident during the distal posttest. This was manifested by the ease with which they answered the questions and the fact that even the English language learners were able to use some of the new vocabulary. The gears were assembled in more complex patterns including different sizes and colors. One of the girls who was an English language learner seemed to be more interested in sorting gears by colors and sizes rather than focusing on their function. She was also looking for the pictures she drew to put them on the gear holders. It is possible that children from diverse backgrounds may have more difficulties learning scientific concepts because of the language and cultural barriers (Goldberg, 1997). However, it appeared in this case that the arts can bridge their learning by using personally meaningful experiences as means of introduction to science.

Most of the vocabulary that was targeted during lessons was used by the children on the distal posttest. Similar to the posttest, the word "machines" was used only by a couple of children but most of them gave real life examples of machines that use gears. The direction and speed of gear rotation was again challenging for some students; yet there were less errors than at the posttest. Another interesting observation was that most children exhibited problem solving skills. When the gears did not connect properly, they knew how to move the holders, base blocks, or change gear sizes to create a functioning machine. Some children even explained that process: "The teeth are not going in; I need to move the gears." This experience justifies the NGSS requirements to encourage applied science and problem solving.

Discussion

Possible Benefits

One of the biggest benefits of this gears lesson was the amount of new knowledge constructed by the children, as indicated by the gain scores between the pretest, posttest, and distal posttest. This knowledge must have developed richer schemata about the function of gears and a better understanding about real life applications of gears. At the pretest some children demonstrated some familiarity with the gears which speaks to initialization of a schema for gears. However, at the posttest and distal posttest they were much more proficient in manipulating the gears and sometimes explaining about them which, in turn, alludes to greater development of that initial schema. Following the proposition of schema theory, it is expected here that children will make associations with gears in future situations when rotation, or machines, for example, are mentioned. These terms may act as a cue which triggers the schema of gears. Alternatively, when they hear the word gears, their schema may bring about the specific characteristics of gears. Enriching children's schemata can foster their future learning of scientific concepts. Figure 2 illustrates the structure of the possible gear schema that was created during the lessons

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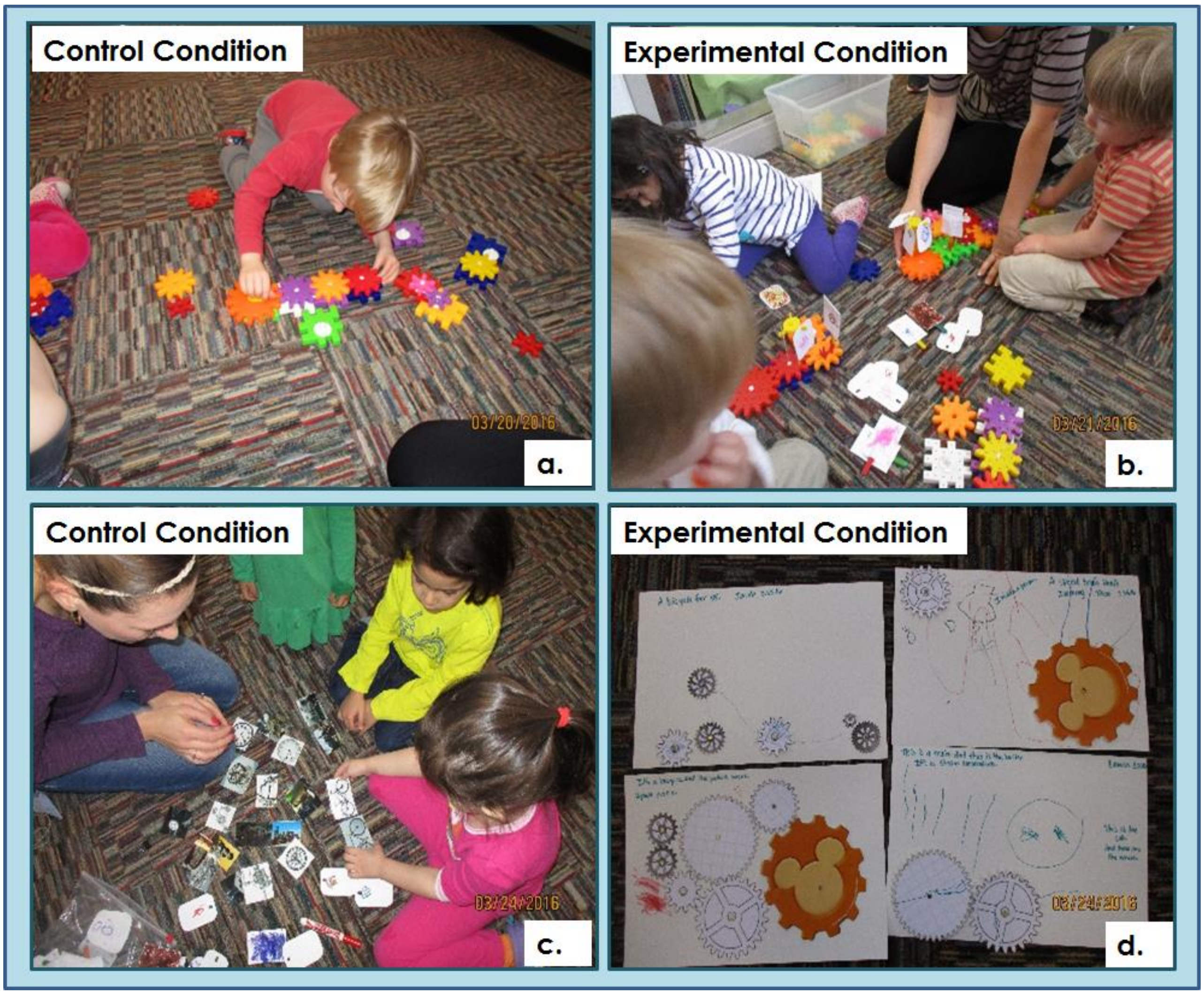

Figure 1. Activities during the experimental and control conditions.

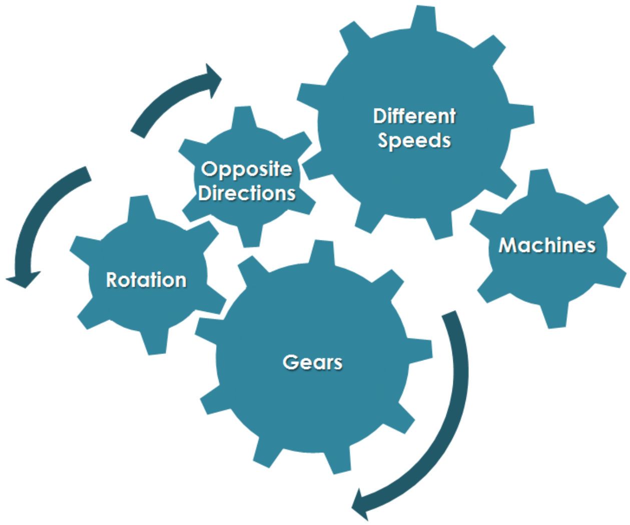

Figure 2. Novel gear schema

Another advantage of this lesson was that *what*, *who*, *where*, and *when* of the learning process was considered as emphasized by Alexander, et.al (2009). The *what* was the gears which encompassed the different levels of learning- it started with forming skills and habits of assembling gears, then encouraged spontaneous concepts, and in the end introduced scientific concepts. The *where* of learning was the children's natural environment at the child development center to which they were accustomed. The social environment was also kept within their comfort zone by having their teacher teach the lesson designed by the researcher and by interacting with their friends during the lessons.

The cultural environment in that group of children was diverse which means that each child may have had already formed different cultural schemata. These schemata were bridged by the arts and exploratory play which eased them into the lessons. This idea of cultural schemata is also related to the *who* in the learning process- not only were the learner's biological, cognitive, and experiential characteristics considered, but also their cultural background. The *when* suggests that learning can happen during a short or long period of time.

The lessons were conducted during the short period of one week but the assumption was that they would prepare the students for continuous long-term learning in science. The posttest and the distal posttest supported this assumption as they suggested higher confidence levels, less mistakes made, and continuous growth in learning. Most children showed interest in the lessons by eagerly waiting their turn and asking when the next time would be to play again. The children who developed a little more advanced schema of gears initiated problem solving situations. They would look for more complicated ways to attach as many gears and levers as they could and if it did not work, they were able to adjust or change parts. These observations are similar to the findings of Nevanen et al. (2014) and Hofstetter et al. (2014) and align with the engineering goals of the NGSS.

Limitations

One possible explanation why there were no statistically significant results between the art-integrated experimental condition and the control condition can be that at preschool, children are involved in some type of artistic creation or representation on a daily basis. It is not until they enter school that their time for arts becomes limited. More significant effects may surface with a sample of students in later grade levels.

Another reason can be the limitations of the study design. The sample was small and three students were absent during different sections of the lesson. A future direction would be to recreate the study with a vast sample in a better-controlled setting. The instrumentation needs to be improved, too. The smiley faces Likert-type scale was not always reliable without further probing for the reason of the choice. Often children in this age group may pick a face that is visually more attractive or the face that describes them that day which is not a direct reference to the activity that took place. There were instances in this study when the child said that he or she liked the gears but selected the sad face because the child missed his or her mom or because the child did not feel well. Three children chose the angry face because they liked angry faces while the researcher observation suggested that they enjoyed the interactions in the lesson. Therefore, other researchers need to be cautious when developing Likert scale-based evaluation or simply verbal evaluation for children in early childhood.

Another factor that played a role was the age of the children. There could be a big difference developmentally between a three-year-old and a four-year-old, especially in terms of verbalizing their experiences. This poses challenges to experimental research with a sample of such an early age and maybe that is why not many studies are available. There are too many factors to be controlled in such a setting- distractions, the children's affective state that day unrelated to the lessons, influences amongst the children, etc. The four-year-olds would have more pre-existing knowledge than the three-year-olds and they already have foundations of their schemata. However, this lesson can be valuable for practitioners who experience these real life classroom situations and need an example of instructional practices.

Conclusion

This study adapted the NGSS and the National Core Arts Standards to develop an art-integrated lesson unit about gears with three and four-year-old preschool children. The researcher's interest in the topic was provoked by the new requirements to implement science standards and the upcoming adjustment of those for preschoolers. These developments have caused some difficulties for practitioners and examples of successful implementations of lessons are needed. Moreover, there is lack of research supporting the effectiveness of the standards and of arts integration into them, especially for early childhood. This study added to the existing knowledge by supporting some of the previous findings in the literature even though it did not prove with statistical significance the difference in performance between the experimental and control conditions. However, it suggests what considerations future research should have and what the real life classroom situations could be where the teacher is not always in full control of the different factors but still need to facilitate learning.

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