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Influence of STEM Lessons on Critical Thinking

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INFLUENCE OF STEM LESSONS ON CRITICAL THINKING

by

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ABSTRACT

INFLUENCE OF STEM LESSONS ON CRITICAL THINKING

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The study of science, technology, engineering, and math (STEM) is leading educators into a new world of teaching. The classroom roles have been reversed and students are now in charge of their own learning. Students are learning how to engineer and solve real-world problems through critical thinking. Integrated STEM lessons are teaching students to use their prior knowledge across subject areas to prepare themselves for the workforce needed in the 21st century. This study was conducted in a rural second grade classroom with the number of students ranging from 16 to 21. Throughout this study qualitative data was collected. The students participated in integrated STEM lessons where qualitative data was collected through student work samples, student surveys, student interviews, and a teacher journal. In addition, students were asked to answer a student survey on their feelings toward science after each experiment.

Keywords: *STEM, 21st century skills, elementary, rural, integrated lessons, real-world problems, critical thinking*

DEDICATION

This work is dedicated to my family, friends, and to all the past and future students I will teach.

GRANT INFORMATION

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CHAPTER 1: INTRODUCTION

Problem Statement

STEM is the integrated study of two or more subjects from science, technology, engineering, and math. STEM lessons teach rigorous science, engineering, and math concepts through a real-world problem using a form of technology. STEM education can be defined as:

> STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Tsupros, Kohler & Hallinen, 2009).

Students are asked to use their prior knowledge and critical thinking skills to creatively solve the problem at hand. Gerlach from the National Science Teachers Association (2012) wrote, "Educationally, we imagine STEM instruction as creating the next innovators, the superstars. We look for highly proficient students and try to increase their interest in these fields so that we develop the innovators of the future" (p. 12).

Traditionally, subjects are taught in isolation without making cross-curricular connections. STEM lessons are integrated lessons that are designed to combine skills and standards across science and math. These lessons should include design-based tasks to encourage students to work collaboratively and promote critical thinking. "When you have children using their prior knowledge, their imagination, and trial and error to see

how the world works, those strategies transfer over into everything they do" (Linder et al., 2016, p.89). STEM lessons are extremely crucial in the primary grades. Young children often are asking the "why" questions and possess curiosity of how the world works.

Students need to be given the opportunity to experience failure, redesign, and success in the classroom within a guided activity. "STEM is important because it helps students become problem solvers. They become more willing to try new things as they learn to embrace and encounter new things" (Linder et al., 2016, p. 88). Critical thinking skills are something that cannot be directly taught in isolation. Critical thinking skills must be integrated into other lessons across varying subjects. One way this can be accomplished is through STEM lessons.

Purpose and Research Questions

Global jobs are requiring students to be educated in STEM. Educator's jobs are to create a workforce that will meet those demands in the technology and science sectors. Murphy from U.S. News & World Report (2011) states, "By 2018, 8 million jobs in the U.S. economy will require a college degree in STEM" (p. 1). Integrated STEM lessons encourage students to creatively solve real-world problems. The Next Generation Science Standards (NGSS) want students to use cross cutting concepts to apply critical thinking skills to their designs, questions, analysis, and solutions to real world problems. According to the NGSS website "When these concepts, such as "cause and effect," are made explicit for students, they can help students develop a coherent and scientifically-based view of the world around them" (www.nextgenscience.org, 2018).

The purpose of this study is to investigate improvements in student's critical thinking through group-based STEM activities. By preparing students to use their critical thinking skills, educators are making them literate for the 21st century. Students must possess "a blend of cognitive, interpersonal, intrapersonal characteristics that may support deeper learning and knowledge transfer" (Honey, Pearson, & Schweingruber, 2014, p. 35). This deep understanding must start in the primary grades. Clements and Sarama (2016) say, "Preschool and kindergarten children's knowledge of and interest in math and science predicts later success in STEM" (p. 75). The specific research question being asked in this qualitative research study is; What happens to student's critical thinking abilities when the teacher introduces integrated STEM lessons designed to enhance such critical thinking?

Methods Overview

This action research study took place in a rural school with emphasis on a second-grade classroom. This research design focused on four students with varying academic levels. Qualitative data were collected and analyzed by the second-grade classroom teacher. The data collected were: student surveys, teacher notes, classwork, and student interviews.

Definition of Key Terms

STEM: acronym for Science, Technology, Engineering, and Math

21st century skills: technology, interpersonal, and intrapersonal skills needed to be a productive member of a 21st century society

Elementary: grades kindergarten through sixth

Rural: small town with less than 2,000 people situated in a remote area

Integrated lessons: lessons that combine more than one subject area

Real-world problems: issues or problems that need to be solved to make the world a better place

Critical thinking: applying prior learned knowledge using logical thinking and creativity to advance problem solving skills

CHAPTER 2: LITERATURE REVIEW

Overview

Literature demonstrates the importance of critical thinking in students and also the importance of STEM in the classroom. “STEM approach in learning is expected to give a meaningful learning to students through systematic integration of knowledge, concept, and skills” (Afriana, Permanasari & Fitriani, 2016, p. 262). STEM instruction removes the barriers between the four subjects and uses an interdisciplinary approach to instruct students. Within these STEM lessons students are asked to use critical thinking skills to solve proposed real-world problems. STEM lessons benefit student’s problem-solving skills, logical thinking, and independency. This literature review will focus on three different topics that support this action research: STEM development, workforce and STEM, and critical thinking and STEM.

STEM Development

STEM education not only occurs in the classroom, the learnings start at home. “STEM learning begins at birth” (Moomaw, 2016, p. 237). From the time we are born our brains possess natural curiosity. Babies learn how the world works by watching parents and exploring. Toddlers start to ask the “what” and “why” questions over everything they see. Our brains want to naturally learn how the world works. “Research has shown that extensive neurological development occurs during the first five years of life, when neural wiring develops rapidly” (Moomaw, 2016, p. 237). Early STEM education needs to start in preschool and continue throughout childhood. All students need to be involved in STEM lessons K-12. All students have opinions as to how the world works and possess the natural curiosity to seek answers. Exposing students to

integrated STEM lessons will increase students' awareness of the world around them. These students are the future problem solvers of the world's problems. "Children are natural scientists, engineers, and problem solvers" (Murphy, 2011).

Allowing students to explore the world around them, through guided open-ended questions, will aid in students' development of academic, social, and personal skills. "Children who do not have opportunities to maximize brain development in STEM-related areas during these crucial early years are already at a disadvantage when they enter school" (Moomaw, 2016, p. 237). Research has found that elementary school is the critical time to instill the love for science into students. "Elementary school is the most appropriate time to engage students in integrated STEM education and spark the interest of elementary-aged students" (Daugherty, Carter & Swagerty, 2014, p. 46-47). Formal STEM education starts in the primary grades when high-quality teachers develop lessons that spark students' interest in STEM while promoting students' curiosity and problem-solving skills. These early grades lay the foundation for future learning in STEM.

STEM education looks different in many schools. Each school has its own challenges, curriculum, student demographics, and teacher preparedness. STEM education isn't a one size fits all model for each school. Teacher preparedness is one of the largest battles when it comes to implementing STEM education into schools. Teachers often avoid teaching content areas they feel unprepared in. Teachers need to be trained in the STEM areas and feel comfortable teaching these in their classroom. "Teachers must be provided with the proper professional development opportunities preparing them to guide all their students towards acquiring STEM literacy" (Kennedy & Odell, 2014, p. 246). Having teachers who are passionate about the areas in STEM will

instill positive attitudes into students, who in turn will care about solving real-world problems. This will also help improve students' attitudes towards science and math. "STEM approach reported more positive attitudes toward science than those studying science through a conventional approach" (Greca & Toma, 2018, p. 1390). Teachers must have time to collaborate and build lessons around each's specialized areas. "Teacher collaboration is a step toward the integration of disciplines, better mirroring what actually happens outside the classroom" (Chiu, Price & Ovrahim, 2015, p. 7). By allowing collaboration time within the school day, educators can implement STEM instructional practice school wide. Chui, Price, and Ovrahim (2015) describe the essential nature of collaboration time for "systematic, sustained, and positive changes to occur."

Workforce and STEM

There is a strong correlation between early STEM academic success and the chance for success in a STEM major or career. "A true commitment to increasing the number of American STEM graduates begins with producing students who have basic skills in writing, mathematics, and critical thinking as well as an ethical commitment of duty to achieving long-term goals" (Ramsey & Baethe, p. 32). To help curb the large number of job openings in STEM fields, teachers must do a better job of preparing students to be 21st century learners and skilled laborers. "Just as children of past generations had to gradually be taught labor skills, today's children need early instruction on the most basic of technological skills" (Lazaros, 2014, p. 26).

Elementary, middle, and high schools as well as universities and institutions, are publishing the need for students to be educated in STEM. Murphy from U.S. News & World Report states, "This is a key issue for K-12 education and it's a requirement to

create the kind of workforce our country needs" (2011, p. 1). The United States has job openings that are not being filled because we do not possess the workforce in order to fulfill those vacancies. "If the United States is to maintain its economic power, then we will need a STEM-educated workforce that can meet the demands of business in an increasingly complex and technology-driven economy" (Murphy, 2011, p. 1). The United States needs students who are capable of working in technical fields to solve real-world problems. President's Council of Advisors on Science and Technology (PCAST) concur, "The success of the United States in the 21st century – its wealth and welfare – will depend on the ideas and skills of its population. These have always been the Nation's most important assets" (2010, p. 1).

Researchers and educators seem to agree that we have a problem with our educational system preparing students to be contributing STEM workforce members. A goal is to expand the number of students who pursue bachelor and graduate level degrees in science and engineering. Thus, educators at all levels should be placing emphasis on preparing students to pursue degrees in STEM areas. Successful STEM programs have connections between businesses, colleges, and are trying to solve real world problems that their communities face. "STEM education becomes the priority in solving global issues and current real life's problem, such as: global warming, air and water pollution, fresh drinking water, as well as food safety (Afriana, Permanasari & Fitriani, 2016, p. 262).

Critical Thinking and STEM

Critical thinking is an essential component of STEM lessons. "STEM is very important because it helps students become problem solvers" (Linder et al., 2016, p. 88).

The National Science Standards and Technology Standards have critical thinking skills embedded within the standards. Most educators would agree that critical thinking is an area that student's struggle with and it is something that cannot be taught in isolation. "Critical thinking skills are not commonly recognized as a necessary part of the basic curriculum, whereas they are in fact the glue that connects knowledge of facts with any application of knowledge" (Walsh & Paul, 1986, p. 25).

Critical thinking skills in the elementary are enhanced through collaborating with peers and using prior knowledge. Rehmat (2015) states, "Integrated STEM activities in schools that foster social interaction and exploration can assist in developing students' critical thinking, communication, and problem-solving skills" (p. 62). Teachers can start promoting and encouraging critical thinking skills in their classrooms by showing and modeling their thinking processes aloud for students. "Critical thinking dispositions and attitudes need to be encouraged, modeled and reinforced in every aspect of classroom life" (Walsh & Paul, 1986, p. 29). The design of a STEM lesson also leads to foster student's critical thinking skills. "Experiences that are interdisciplinary and supported by collaborative problem-based, design-based, and/or inquiry learning strategies can have a significant impact on students' critical thinking skills" (Rehman, 2015, p. 63).

Educators are using children's prior knowledge and interest in the world to educate them in the subject areas of STEM. Murphy (2011) has found that students need to be able to touch, explore, build, and create objects with their hands in order to learn. These explorations can occur with integrated STEM lessons in the classroom. Integrated STEM lessons work best when students are given a real-world problem to solve through a design-based task. Students enhance their critical thinking skills through collaborating

with their peers. “Teachers can strengthen this by implementing tasks related to the lives of the children in your class” (Linder et al., 2016, p. 89).

Summary

There are many benefits to teaching STEM lessons in the classroom. Research has shown that teachers should focus on the integrated process throughout the STEM lesson. By incorporating all four subject areas into one lesson students gain language skills, practice the engineering and science process, and collaborate with their peers. STEM lessons promote critical thinking skills, enable students to be a worker in the 21st century, and also improve test scores. “Some benefits of STEM approach are improving students’ problem-solving skill, innovators, inventors, independent, logic thinker, and technological literacy” (Afriana, Fitriani & Permanasari, 2016, p. 262).

CHAPTER 3: METHODS

Overview

This action research study collected qualitative data from a rural second grade classroom. The research was gathered from four specific students with varying academic backgrounds. Data were collected to determine how the students' critical thinking abilities changed when the teacher introduces integrated STEM lessons. This chapter will focus on the school were the research was conducted, the participants of the study, and the types of data that were collected from February until May of the 2018-2019 school year.

Context of the Study

This study took place in a rural, mid-western Nebraska school. The school's population, preschool-twelfth grade is approximately 280 students. At this school, 69.7 % of the student population receives free and reduced lunches. The school has a high mobility rate. It is nothing for a classroom teacher to get 5 new students during the school year. The school has one teacher per grade level in Grades K-6 and is located all within one building. The school employs twenty-eight full time teachers. The school also has a large percentage of special education students, approximately 10% higher than the state percentage. We have one full-time special education teacher in preschool, two full-time special education teachers for grades K-5, one full-time special education teacher for grades 6-8, one full-time high school special education teacher, and also a life skills program for grades 6-12 that has a full-time special education teacher. Also employed are ten full time para professionals that work with special education and English language learning students.

The town is nestled off of highway 6 in northern Clay county with a population of 967 people. In the past this town held an ammunition depot where people were makers of bombs during World War Two. The military-built army barracks north of town close to the airbase. During this time, it was a bustling small town that had many shops and was thriving. Fast forward to current times and many of those shops are closed with windows boarded up. The remaining businesses are a bank and insurance company, a small grocery store, the nursing home, a bar and grill, coop elevator, a small community center building, community pool, and the school.

The second-grade classroom is in the elementary hallway. The classroom is in the middle of the hallway surrounded by other classrooms and across the hallway is the media center. The classroom is colorful and full of lively cheer from the students. Students' work is hung on the classroom walls and in the hallway. The classroom has six student computers that are used daily for several subjects. The teacher has access to a cart of thirty iPads that can be checked out for student use.

The student and teacher data for this research study was collected from five different STEM activities that were conducted in the second-grade classroom. The first STEM activity was designing your own planet. This activity occurred between February 28th and March 4th. Students were asked to pretend they worked for NASA as an astronaut or scientist. Students got to draw and design a new planet that they discovered in the solar system. Students were required write on the border of the picture how many moons their planet had, if it was a solid or gas planet, if it had rings, and any other interesting facts they deemed necessary. Research data were gathered from a leprechaun trap activity that students worked on from March 12th to March 14th. The objective for

students was to build a trap to catch the paper leprechaun. The leprechaun had to fit inside the trap and not be able to escape. As part of the building process students had to draw and design their trap using a variety of building materials. The third activity that data were gathered was from a holiday Easter peep experiment. Students conducted three different experiments with Easter Peep candy. Students placed a peep into warm water, pop, and vinegar. Students had to document the state of their peep in the three solutions at different time intervals. Additional data were gathered from an animal habitat activity between April 23rd and April 25th. The zoo was coming to town and enlisted the students to help build habitats to keep the animals and spectators safe. Students had to have a water source, protection, and food for the animals. The final activity where data were gathered was from a pollution experiment that was conducted from May 13th and May 14th. Students got to pollute the clean water with various pollutants then try to clean the water. Students realized that polluted water is very difficult to clean and that we need to take care of the water we have.

Participants

The participants in this study were in the second-grade classroom for the 2018-2019 school year. The age range of these students were seven to eight years old. The total students in the classroom ranged from sixteen to twenty-one students at any given time. This action research study focuses on four specific individual students whose families consented to participate in this study, two female students and two male students with varying academic backgrounds. These four students were selected based on their varying academic backgrounds and also their dependency to the town. Throughout this paper, pseudonyms are used to protect students' identity.

The first male student that was involved is Karl. Karl is of Hispanic ethnicity and comes from a traditional home. The main language spoken in Karl's home is Spanish. Karl's father works for a construction company out of town and is gone Mondays through Fridays. His mother is a stay-at-home mom that cleans houses a few days a week. Karl has one older brother in third grade and one younger brother in kindergarten. Throughout the school day Karl receives special education support and also English language learner support. Karl is functioning below grade level and was placed in the approaching reading group. His Accelerated Reading level throughout the second semester went from 1.7 (first grade, seventh month) to 2.9 (second grade, ninth month). Karl's second grade DIBELS assessment was 85 words per minute in December and 83 words per minutes in May.

The second male that was involved in this study is Donovan. Donovan is Caucasian and is an only child that comes from a traditional household. He also is an option enroll student that rides the school bus from another larger town. His parents wanted him attending a smaller school, the same school from which both of them graduated. Both of his parents work in the larger town. His mother is a receptionist at a nursing home and is father is employed by a local coop. Based on test scores, Donovan was placed in the on-level group, but quickly showed great improvement and was moved to the beyond grade level group. His Accelerated Reader level during the second semester went from a 2.9 (second grade ninth month) to 3.2 (third grade second month). His second grade DIBELS assessment in December was 97 words per minute and in May it was 114 words per minute.

The first female in this study is Lindsey. Lindsey is Caucasian and is being raised by her mother. She has one older sister that is in high school. Her mother is a receptionist

at a factory in a larger nearby town. According to test scores Lindsey was placed in the approaching reading group at the beginning of the school year. Lindsey received a daily reading and phonetic intervention that boosted her reading skills. During the second semester Lindsey was moved to the on-level group. Her Accelerated Reader level during the second semester went from a 2.9 (second grade ninth month) to 3.2 (third grade second month). Her second grade DIBELS assessment in December was 78 words per minute and 94 words per minute in May.

The second female, and last student participant in this study is Nikki. Nikki is Caucasian and comes from a traditional family. She is one of 4 siblings. Nikki has an older brother in fifth grade, a sister in kindergarten, and a baby sister at home. Her mother is a registered nurse at a clinic in a nearby larger town. Her father is the owner and operator of a family junkyard. Nikki was in the beyond reading group for the entire 2018-2019 school year. Her Accelerated Reader levels were consistently above the second-grade level and she was reading books between 3.0 and 4.0 (third grade through fourth grade). Her second grade DIBELS assessment in December was 105 words per minute and 125 words per minute in May.

The teacher-researcher was also a participant in this action research study. The teacher is 30 years old and has been employed by the school for seven years. All seven years of employment have been in the second-grade classroom. The teacher received a bachelor's degree from the University of Nebraska-Lincoln in elementary education and special education k-6 mild/moderate disabilities. She also attended Concordia University and received a master's of education with an emphasis on curriculum and instruction. The teacher has gone to numerous trainings and is currently enrolled in the Noyce STEM

graduate program at the University of Nebraska-Lincoln obtaining a masters of arts in teaching.

Data Collection

This action-research study collected qualitative research focused on four students. The data was collected over a four-month time period. Starting in February, parental consent was gained in person at parent-teacher conferences and research began. At the time of parental consent there were 19 students in the classroom. All parents gave consent for their children to participate in this study. During the four-month time period several STEM lessons were conducted in the classroom, aiming for complete documentation on five STEM activities.

Student Interview

The student survey is used as a primary data source. The student interview consisted of five questions that we asked pre and post STEM activity. The student interviews were conducted for all 5 STEM activities with the four target students. The pre-and post-interview asked similar but distinct questions. The pre-STEM interview asked the following five questions:

1. What building materials will you use? Why will these work?
2. How does this fit in with the real world?
3. How do you feel about this STEM experiment?
4. Do you have a design thought up in your head? Explain it to me.
5. What do you already know about this?

The post-STEM interview asked the following five questions:

1. Were those building materials successful? Were the building materials a good choice?
2. Did you solve the real-world problems?
3. How do you feel about this STEM experiment now?
4. Was your design successful?
5. What did you learn?

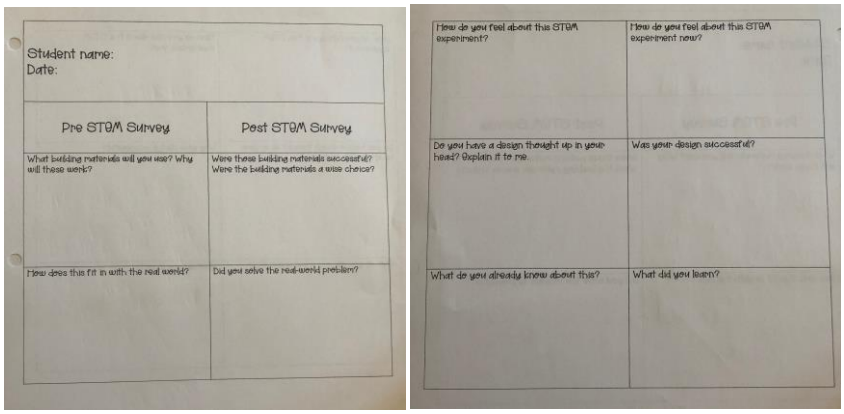


Figure 1. Pre-and Post- student activity interview.

The target students were interviewed one at a time in a separate quiet location before the STEM activity begun, then in the same location once the STEM activity was complete. Students' answers varied in length depending on their interest in the STEM activity and whether or not it was personally relatable to them. Some STEM activities would take several days to complete so the student interviews were spaced apart between one and three days. Recall bias was a primary concern of the data collected. The varying time between the pre and post interviews led to the target students sometimes forgetting what they liked about the activity and what materials they used. The teacher minimized this by never letting a STEM activity go more than three days.

Student Survey

The student survey is used as an additional primary data source. A student survey was given to every student in the classroom upon the completion of the STEM activity. Only the four targeted student's surveys were collected and analyzed for this research study. The student survey was comprised of seven student-friendly questions. The questions were asked in a yes and no manner. Students circled their answer for each question. The student survey asked the following questions:

1. Do you like science experiments?
2. Did you help your group?
3. Did your idea work?
4. Did you use the correct materials?
5. Would you like to do more science experiments?
6. Do you like science?
7. Do you want a job that has to do with science?

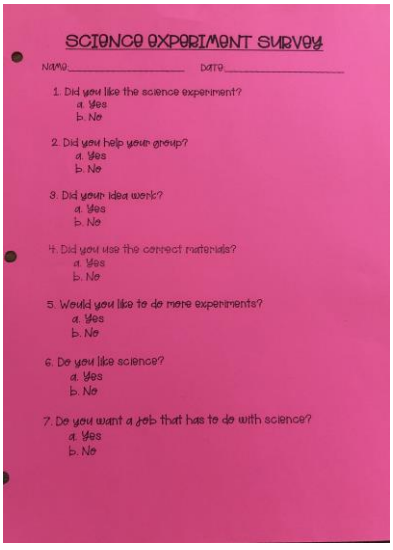
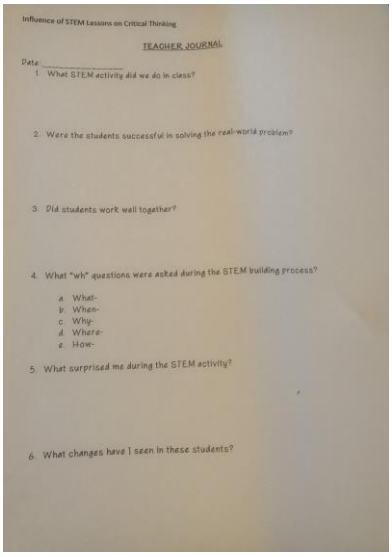


Figure 2. Student-friendly STEM survey.2

Recall bias was once again impacted with the student survey due to the varying time of STEM activities. The survey was completed between one and three days. This led to some discrimination among participants on whether or not they remembered the entire STEM activity.

Teacher Journal

The teacher/researcher journal was updated twice per week with notes about what was happening during science class. The teacher notes were detailed about how well the students worked together, if the students were successful, and what questions they asked the teacher. The teacher specifically targeted the what, when, why, where, and how questions (WH) that students asked during the activity. The teacher also took notes about what surprised her during the STEM activity and what changes were seen in the target students.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TEACHER JOURNAL

Date:_____

1. What STEM activity did we do in class?

2. Were the students successful in solving the real-world problem?

3. Did students work well together?

4. What "wh" questions were asked during the STEM building process?

a. What-
b. When-
c. Why-
d. Where-
e. How-

5. What surprised me during the STEM activity?

6. What changes have I seen in these students?

Figure 3. Teacher/researcher journal.

The flaws with the secondary data source are the inability to collect the data weekly due to weather days, district testing, and early dismissals. Also, there was not a STEM

activity conducted every week. The teacher had to continue with her normal science routine and curriculum and find creative ways to add STEM activities within the existing curriculum.

Data Analysis

Data were gathered in the second-grade classroom from February through May in 2019. The data came from five different STEM activities varying across the second-grade curriculum and standards. The five STEM activities were on pollution, animal habitats, planets, leprechauns, and Easter peeps. Collected data were organized by experiment then student interviews, student surveys, and teacher journal entries.

A primary source of data were student interviews. The student interviews were on a single sheet of paper for each student for every experiment. The student data was then organized into experiments. For each experiment there were four interview sheets. The interviews were then separated into pre and post interviews. The researcher wrote down the student's interviews into shorthand onto two different columns on notebook paper; pre and post interview. The researcher underlined common key words that were found among the pre and post interviews. The key words from the pre and post interviews were formed into a word cloud to find common themes. The data were analyzed to compare students critical thinking skills and science knowledge between pre and post student interviews across the research period.

An additional primary source of data, student surveys, were analyzed to see a change in student's perception of science. For every experiment, the target students completed a student survey. The student surveys were organized by experiment. On notebook paper the researcher organized the yes and no answers for all seven questions

using tally marks. By organizing the survey data by experiments, the researcher could see the changes in students answers across the research period. Once data was marked for the five experiments, all the data was compiled into a chart on notebook paper. The students' responses were once again coded with tally marks for yes and no for all five experiments on one sheet of paper. By compiling all the survey responses into one document, the researcher could see the overall trends for the survey answers. This data was displayed in a bar graph to show the target students' survey answers throughout the research time period.

The secondary source of data was the teacher journal entries. On the teacher journal entries special attention was given to the following questions:

- What WH questions were asked during the STEM building process?
- What surprised me during the STEM activity?
- What changes have I seen in these students?

The data from these specific questions were written in shorthand on notebook paper. The student questions were broken down into specific WH categories on the notebook paper. This allowed the researcher to see what type of questions were being asked most frequently by the students. Answers to what surprised me during the STEM activity were written in shorthand on notebook paper. Common themes between the weekly notes were color coded with highlighter. The changes that the researcher saw in the students were also written in shorthand on notebook paper. Common themes were highlighted and put into a word cloud. Furthermore, the teacher journal was analyzed to confirm the findings from the student interviews and surveys. Student quotes were taken from the teacher journal. The teacher journal also highlighted the critical thinking changes that were seen

in the targeted students. These critical thinking changes will be discussed in the findings chapter.

Summary

This action research study was conducted in a second-grade classroom. The research was gathered from four students with varying academic backgrounds. The research collected aims to determine how integrated STEM activities impacted student's critical thinking abilities. The data were collected from three different sources; two student sources and one teacher source. The data were analyzed and formed into word clouds with common themes highlighted. This helped to aid the researcher to confirm the purpose and address the research question of this study.

CHAPTER 4: FINDINGS

Overview

Data were collected from five STEM activities that occurred between February and May of the 2018-2019 school year. The data displayed in the graphs are in chronological order as to when the activity/experiment occurred in the classroom. Three different types of data were collected. Two types of student data and one type of teacher data. The data were analyzed to find common themes using word clouds and highlighting common themes. Key student findings that emerged were building with hands, wanting to do more experiments, and liking science. Key teacher findings that were noticed were students using resources, cooperating in groups, applying prior learned knowledge and skills, creativity and general thinking ability increased.

Student Insight-Hands On

Throughout this action research study, the researcher witnessed how students enjoy hands on activities. One of the questions on the pre-student interview was, “How do you feel about this STEM experiment?” The target students reported that seventy percent of the time they will like this experiment because they get to build or do things with their hands.

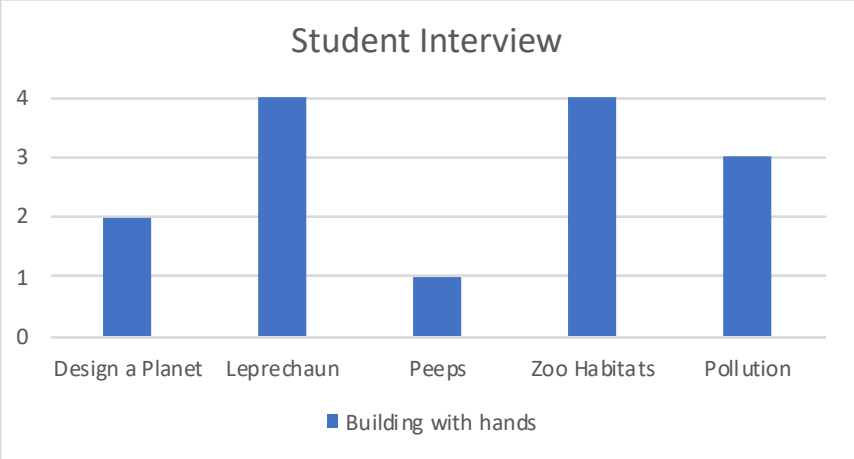

Figure 4. Student interview responses for Building with Hands.

In the pre-interview for the leprechaun activity Karl said, "I am going to love this because I get to build and play with my hands." For the animal habitat activity, Nikki stated, "I like things where I get to build and use my hands." This showed the teacher that students enjoy and are engaged by doing hands-on activities. This is a constant struggle with the outdated science curriculum that is being used. The teacher has to create or find hands-on activities for each lesson. But based on this data, the teacher's activities she has chosen were very beneficial for the students and target the different modalities of learners in the classroom.

Student Insight-Activities

An underlying purpose of this study was to foster engagement of science learning in second grade students. Students would look forward to experiments in science, often asking multiple times a day if they get to do an experiment today. After every STEM experiment/activity, the students would complete a survey. A student survey question was, "Would you like to do more experiments?" Nineteen out of twenty of the target

student surveys across five lessons stated they would like to do more science activities/experiments.

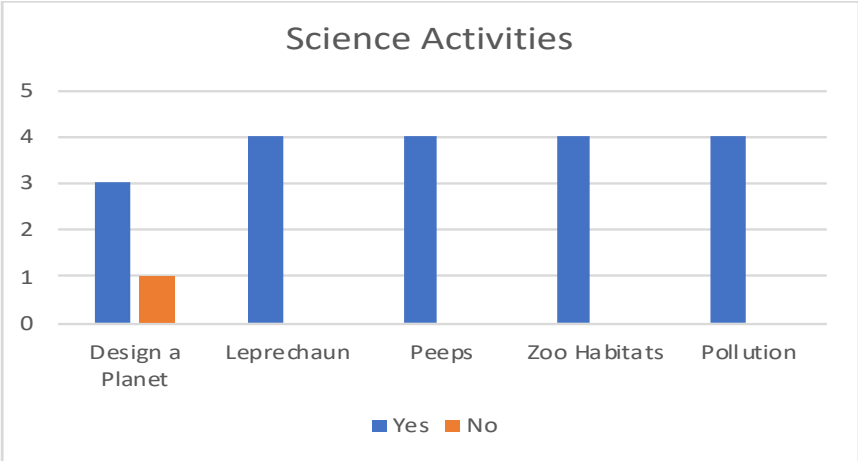

Figure 5. Student responses to survey question, "Would you like to do more experiments?"

It is important that students enjoy what they are learning and look forward to school. Students wanting to do more activities/experiments shows the teacher that she needs to keep doing these in her classroom. There was only one no answer to this survey question by Donovan. He didn't really like the art component of designing a new planet. He struggles with fine motor skills and doesn't care for drawing, coloring, or painting. This theme ties well into students enjoying hands-on activities. Data suggests that if students like to build with their hands, then the majority of them will like to do more experiments in the classroom. Also, providing primary grade students with tangible items enhances their retention and learning.

Student Insight-Science Perceptions

There were two questions on the student survey that had to do with students' perception of science. The answers to these questions were analyzed separately but fit under the same theme. The first question analyzed is "Do you like science?" Fifteen of

the twenty total target students' surveys said they like science. Five times, the target students said no.

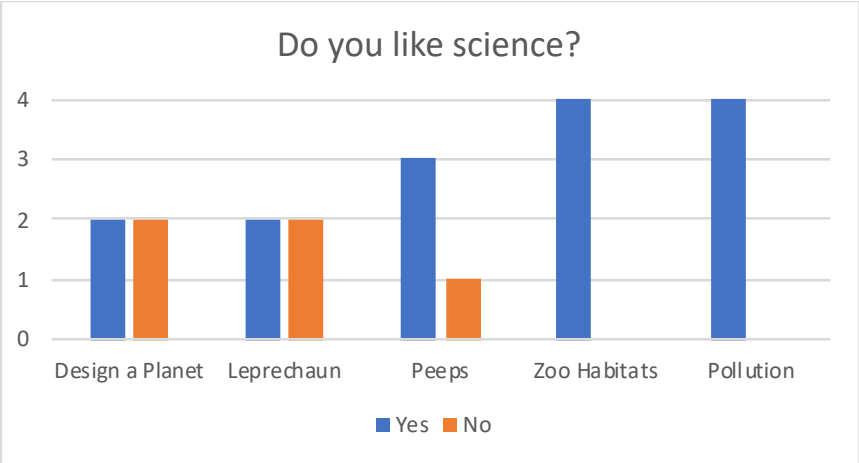

Figure 6. Student responses to survey question, "Do you like science?"

The data suggest that students started to like science more throughout the research period. When reviewing the data for students liking science, several reasons came up for the students that said no. Karl and Lindsey both said they did not like science on the student survey for the STEM activity, design a planet. They both said it didn't have anything to do with building and they like to build. On the peeps STEM activity survey, Donovan said he did not like science. Donovan didn't like the activity because he didn't like the peep candy and thought the peeps didn't melt quick enough. Nikki and Donovan circled that they didn't like science on the survey for the leprechaun activity. Both students were in the same small group for this activity. They said they didn't like science this day simply because their trap didn't work how they wanted it to. The data suggest that students liked science more when the STEM activity had more hands-on materials versus text book as shown in figure 4. The students were required to build an animal habitat for the zoo and also clean polluted water, both of these required students to be

hands on and both had all four of the target students liking science. The trendline for increasing the students' liking of science went up during the research period.

The second survey question that connects to science perceptions is, "Do you want a job that has to do with science?" Thirteen out of twenty of the target students surveys said they would like a job that has to do with science. Seven times, the target students said no.

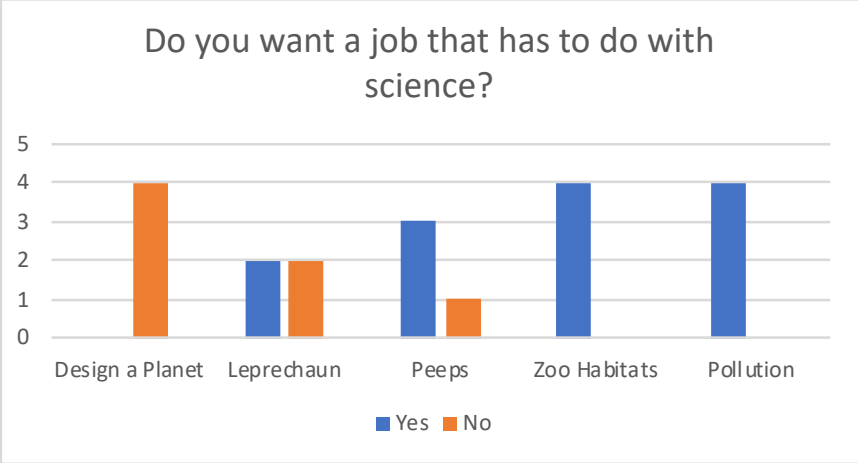

Figure 7. Student responses to survey question, "Do you want a job that has to do with science?"

The data suggest that students' perceptions of science careers changed throughout the research period. In the first STEM activity, none of the target students wanted a career in a science field. They didn't like the design a planet activity and that may have skewed their view on careers in science. But as the research period went on, students' perceptions changed. By the second STEM activity, leprechaun trap, the target students were starting to change their minds. Two students said no, simply because they were upset that their leprechaun trap didn't work. For the final three STEM activities, data suggest that students' perceptions about science careers started to change. Students were exposed to a variety of different types science activities/experiments and got to use

hands-on materials to test their knowledge and confirm their beliefs. Towards the end of the research period all four target students wanted a job in a science field.

Teacher Insight-Students Using Prior Knowledge and Skills

The teacher made several notes about the changes that were seen in the target students. While analyzing this data, the first theme that emerged was students using their prior knowledge and previously-learned skills. The teacher would provide explicit instruction over the chapter in the student's text book and then the students would apply their knowledge by completing a STEM activity. While the students were completing the activity, the teacher would take notes about what she was observing from the students. The teacher made a specific note about students using prior knowledge and previously learned skills on twelve out of nineteen journal entries.

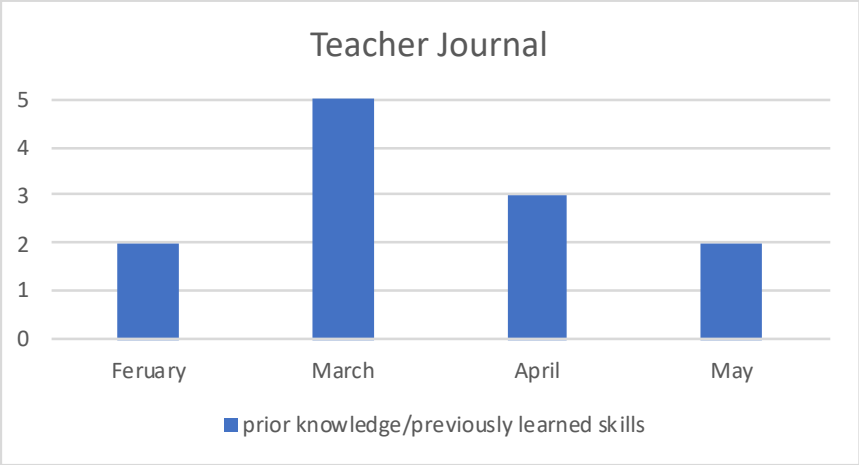

Figure 8. Number of teacher journal entries noting prior knowledge and previously-learned skills among target students.

The teacher wrote, "Great to see them making connections to the material." Students were able to use what they had learned from the text book and teacher instruction and apply it directly to the STEM activity. The teacher could often hear students say, we learned about this in our book or we already know this. The data

suggests that students were using their prior knowledge the most during the month of March. For the month of March, the student activities were to design a new planet, leprechaun traps, animal classification sort, and creating animal food chains. All of these activities were directly tied to the students' text books.

Teacher Insight-Group Cooperation

The teacher also made additional notes about student cooperation during STEM activities. Primary grade students tend to struggle with working in small groups and using their social skills appropriately. The STEM activities were set up with rules that the teacher went over with the students. Each group had a paper copy of these rules.

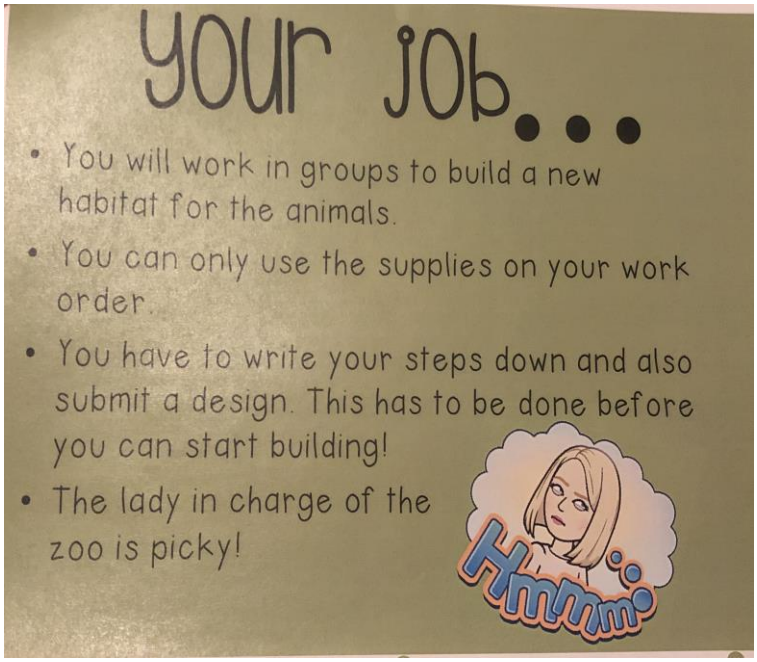

Figure 9. Students' rules for animal habitat activity.

These rules were reviewed daily while the activity was being conducted. The teacher made specific notes about student cooperation among groups on seven out of nineteen journal entries.

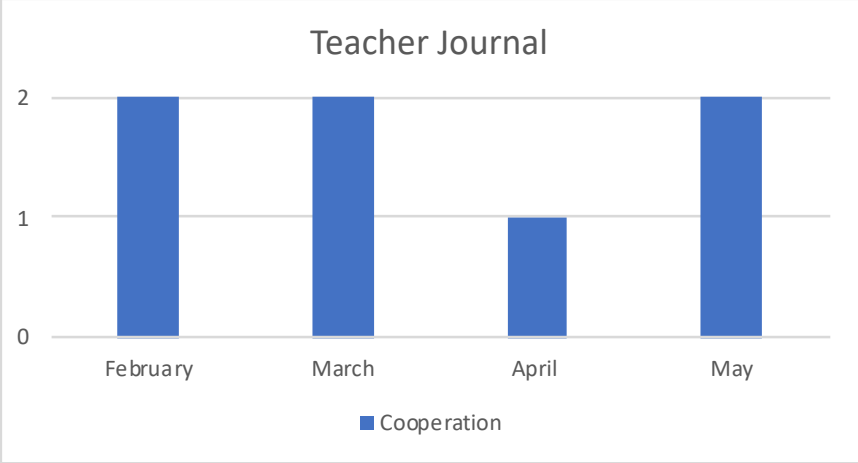

Figure 10. Number of teacher journal entries that noted cooperation among target students.

Student cooperation is a skill that many students struggle with. Often, there would be one student taking charge in the experiment and telling others what to do. To help combat this issue, the teacher would ask each group member what their role was and what they were helping do for the STEM activity. Although the data would suggest that student cooperation was low overall, the teacher did see a general improvement compared to cooperation between students before the research period. The data suggest that there was very little cooperation among students in the month of April. During the month of April, there were very few group assignments for the students to complete. The majority of the work completed in science during April was independent. For the months February, March, and May there were more group-based STEM activities for the students.

Teacher Insight-Creativity and Thinking Ability

The final theme that emerged from the teacher journal was students' creativity and general thinking ability. The class that was studied for this research struggled with

logical reasoning and critical thinking. The main purpose of this research was to determine if STEM lessons improved students' critical thinking abilities. The teacher made notes in the teacher journal regarding logical reasoning and creativity in eleven of nineteen journal entries.

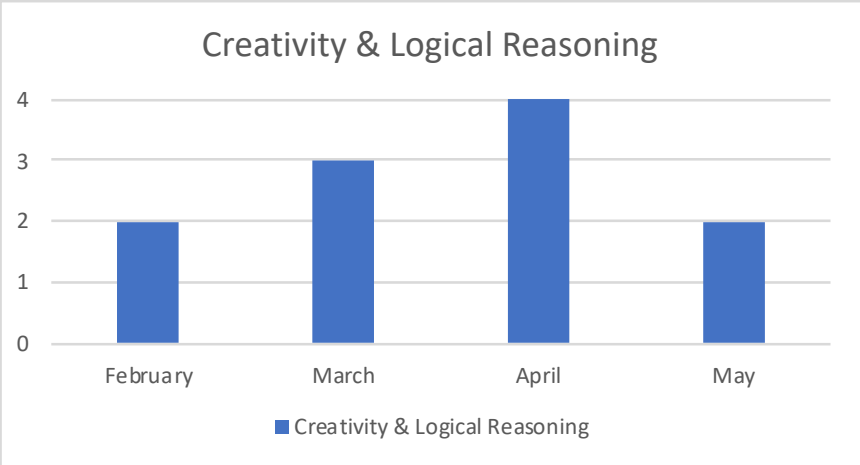

Figure 11. Number of teacher journal entries that noted creativity and logical reasoning among target students.

The data suggest that students' creativity and logical reasoning peaked during the month of April. There was a steady increase across the data collected from February through April. The data dropped down for the month of May, most likely due to field trips, track meets, and a shorter school schedule before summer break.

Summary

The data collected overall, tends to suggest that STEM lessons promote students' liking science, perceptions of careers in science, cooperation, using prior learned knowledge, being creative, and using thinking ability. The data collected show that students were engaged and liked the STEM activities. By keeping students engaged with hands-on activities, they used their prior knowledge and applied it to the activities.

CHAPTER 5: DISCUSSION AND CONCLUSIONS

Overview

It is important that STEM education begins at an early age and continues throughout school. This will allow people to be prepared for the 21st century workforce. The data collected in this study suggest that STEM activities enhance students' prior knowledge, perceptions of science, cooperation, creativity, and thinking ability. The data that was collected supports the literature that was used in conjunction with this research. Limitations of this study include small sample size and bias of the student surveys and interviews.

Discussion

The literature review to support this action research study focused on three research aspects; STEM development, workforce and STEM, critical thinking and STEM. These three research aspects tied directly into the research that was collected through this action research study. Research has shown that students develop critical thinking skills best when STEM is taught in an interdisciplinary manner in elementary classrooms. By completing STEM activities, primary grade students are exposed to a variety of different types of scientists and career options in science. The student data collected from this action research study suggested that STEM activities/experiments encourage students to seek careers in a science field, as shown in figure 7. All schools need to see the data that STEM activities drive science career options. There is a growing number of career options in STEM fields that are not being filled due to the lack of qualified candidates. As stated in chapter 2, "If the United States is to maintain its economic power, then we will need a STEM-educated workforce that can meet the

demands of business in an increasingly complex and technology-driven economy" (Murphy, 2011, p. 1).

STEM instruction needs to begin at an early age. All students have the right to a STEM education and need to be involved in STEM activities in the classroom. This is something that needs to occur more in classrooms. Students in the primary grades are impressionable and like science, as shown in findings summarized in figure 6. Research has found that elementary school is the critical time to instill the love for science into students, and findings from this study support this idea. "Elementary school is the most appropriate time to engage students in integrated STEM education and spark the interest of elementary-aged students" (Daugherty, Carter & Swagerty, 2014, p. 46-47). Students possess natural curiosity about how the world works and want to learn. It is the teacher's job to foster that love for learning. To enable teachers to be successful STEM educators, teachers need proper training and adequate collaboration time.

Allowing students to use their creativity towards academic challenges has shown to be successful in this research study. The findings summarized in figure 11 show that students use their creativity and logical reasoning during STEM activities. "STEM is very important because it helps students become problem solvers" (Linder et al., 2016, p. 88). During the research period, the researcher specifically noted students using creativity and logical thinking 57 percent of journal entries. Most educators would agree that critical thinking is an area that students' struggle with, and it is something that cannot be taught in isolation. "Critical thinking skills are not commonly recognized as a necessary part of the basic curriculum, whereas they are in fact the glue that connects knowledge of facts with any application of knowledge" (Walsh & Paul, 1986, p. 25).

Conclusions

The major take-away from this action research study is that STEM activities promote creativity, cooperation, and students' using their prior knowledge. The data collected in this action research study suggested that hands-on STEM activities students tend to like science and want to do more activities as shown in figures 4, 5, and 6. STEM activities foster students' creativity which leads into promoting critical thinking skills in young children. Critical thinking skills lead to adults that are prepared for the 21st century workforce. "Our nation's STEM innovators are dependent on our educational system to cultivate, excite, and promote their STEM learning to influence their future career decisions" (Cotabish, Dailey, Robinson & Hughes, p. 215).

Limitations

There are several limitations that were involved in this action research study. The first limitation is the researcher was also the classroom teacher. Many students just want to please their teacher and will do what he/she wants them to do. On the student survey students could have possible circled yes to answers simply to please their teacher. During the student interviews the researcher could have displayed unintended bias towards their answers because she knows what they have been taught in the classroom.

An additional limitation is the small sample size of only four students. Even though the four students had varying academic backgrounds, the data collected on them is limited compared to other research studies that involve larger samples. While this study yields insights that may be valuable for others, the results of this study are not generalizable. The four students who were chosen to be the participants in this study were reliable students that the researcher knew wouldn't be moving during the school

semester. The researcher would have gotten more data if all the students in the classroom were involved in this research study. It would have given the researcher a more accurate picture of whether STEM activities really improved all students' critical thinking skills.

Future Research

The students in this study enjoyed hands on activities and the building process. If this study was conducted again I think more attention needs to be given to the hands on, engineering process and how that ties into critical thinking. Primary grade students learn best when they are given something tangible to enhance their learning and fulfill their curiosity.

Additional research needs to be completed on critical thinking in elementary-aged students, in general. Critical thinking is a difficult skill set to test and assess on students since there is no agreed upon definition of what those skills are. Researchers and educators have different versions of what critical skills are and how they are used and assessed in the classroom. There are no set boundaries to test critical thinking skills in the classroom. Also, there is limited research tying critical thinking skills to STEM activities. Future studies in this area would be valuable to educators and researchers. With STEM being a relatively new teaching approach, within time there will likely be studies completed on how STEM ties into critical thinking across all age levels.

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