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Detecting a Possible Correlation between Hands-On Experimentation and Scientific Data Analysis in Eighth Grade Students

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Abstract

This action research examined the impact of integrating hands-on experimentation on eighth-grade students' skills of scientific data analysis and interpretation in a science middle school class. The intervention given to the treatment group was tasking students with completing scientific experiments during their daily lessons, along with collecting and analyzing data from those experiments. Collected data through both control and treatment groups indicated that there was no significant difference in mean test scores between the two groups. Discussions and suggestions for future studies were included.

Introduction

According to Edwards et al. (2014), the philosophy behind the middle school sector in education is one that sets out to prepare students for the rigors of high school while also tailoring to their specific needs as adolescents. A principal component of this philosophy is that middle school students will be learning in the classroom through hands-on experiences and working with their peers to solve problems. A middle school science curriculum that requires students to complete scientific experiments would meet the needs for students' social, physical, and intellectual growth. Additionally, such activities would promote interdisciplinary curriculum between different content areas such as math and English when components such as data analysis and formulation of conclusions from said data are included.

The Nebraska Department of Education (NDE) updated the Science Education Standards for public schools in 2017 to include three main categories in the curriculum: Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts (NDE, 2017). Of the eight Science and Engineering Practices that are used to develop the numerous standards, one of these practices is defined as Analyzing and Interpreting Data (NDE). Nebraska students expected to apply this Science and Engineering Practice to interpret and analyze data begins as early as Kindergarten with the standard SC.K.1.1.B, "Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull" (NDE). Throughout their primary, middle, and secondary level educational journeys, Nebraska students will continue to be asked to analyze and interpret data within their science classes (NDE).

Although Nebraska students have been exposed to a curriculum in which they practice analyzing and interpreting scientific data since they entered the K-12 public school system, it is surprising to see that students are still struggling with this skill. Actually, many scholars and educators (Krell et al., 2015; Lewis-Lancaster & Reisener, 2013) have sounded alarms on middle school students' struggles with data analysis and interpreting. This lack of ability to analyze and interpret data will have a negative effect on student success when it comes time to take the ACT. According to U.S. News (2020), the science section of the ACT relies partly on students' abilities to analyze and interpret visual, mathematical, and linguistic data. In 2021, the average ACT score of Nebraska students was 20.0, with the highest state average being Massachusetts at 27.6 (Edwards, 2021). When looking at how well Nebraska students performed on the science section, we have seen a decrease, "And in science Nebraska students scored an average of 20.0 [in 2020] compared to 20.2 in 2019 and 20.6 nationally" (NDE, 2020).

Research into the improvement of scientific data interpretation and analyzation among students is crucial (Carr et al., 2012), as it will likely lead to the increase of students' scores on the science section and overall score on the ACT. School administrators can then use this data of students' ACT science section scores to determine whether intervention for individual students is necessary or what further action needs to be made in order to improve this skill

(Allen & Sconing, 2005). Additionally, the development of this skill will also likely lead to an increase in students' overall performance and grades in future science classes (Maltese et al., 2015). Lastly, the ability of students to analyze and interpret data will further supplement their critical thinking abilities which will aid them in their future careers and lives, as their capacity to deal with and solve problems will be enhanced.

Given the importance of scientific data analysis and interpretation skills for students, researchers and educators have explored different instructional approaches and teaching methods to help improve this type of skills for students. Integrating hands-on experimentation in science classes is among many teaching strategies that have attracted attention. However, the result has also yielded mixed outcomes. Many researchers (Dhanapal & Shan, 2014; Kontra et al., 2015) suggested that students in science classes learn more effectively and perform at higher rates when they are given the opportunity to complete experiments during the learning process. The act of working with their hands activates the sensorimotor portion of students' brains and allows them to access that part of their brain and the connections created there from experimentation when completing assessments that require critical thinking and problem solving.

Conversely, other research has suggested that the act of hands-on experimentation when developing understanding of a particular scientific concept can actually be a hindrance in the learning process (Smith & Puntambekar, 2010). According to Smith and Puntambekar, hands-on experimentation in the science classroom can have an unpredicted negative effect on student learning when it comes to students working through the details of the experiment, the critical thinking required during the design and development of the experiment, and when using scientific equipment. Therefore, the goal of this action research was to determine the presence or absence of a correlation between hands-on experimentation and scientific data analysis and interpretation among eighth grade students through an intervention.

Action Research and Intervention Description

According to Bennett and Vu (2022), action research is a form of practitioner research commonly used in the field of education. It involves the researcher, who is often a classroom teacher, engaging in an action or intervention with the aim of improving some aspect of their practice, and then observing and reflecting on the results. This type of research can be helpful in classrooms because it allows teachers to identify areas where they need improvement and then take steps to address these issues. Within the scope of this action research project, the classroom teacher, who is also the lead author of this paper, implemented an intervention of integrating hands-on experimentation in her class to examine whether it can help improve her eighth-grade students' skills of scientific data analysis and interpretation.

Thirty-seven students involved in this study were from an eighth-grade class at a Class C school in eastern Nebraska. At the time this study was conducted, students were between the ages of 13 and 14. Ninety-seven percent of the students who participated in this study are of Caucasian ethnicity while two percent are of African American ethnicity. This group of students was composed of 44% females and 56% males. Fifty-six percent of these students optioned-in to the school district.

The eighth-grade students that participated in this study were split up into three different sections. One section was composed of 15 students (Period 1), one of 6 (Period 2), and the final section was composed of 16 eighth grade students (Period 5). Those 15 students (63% females and 37% males) in Period 1 were considered the Control Group in this study. This group of students completed two units of study without performing any data collection and interpretation. Instead, the Control Group only analyzed and interpreted data that had already been previously collected and organized. This data was presented through the district-approved middle-level science curriculum, Elevate Science™ (Figure 1).

It may be argued that this method is not a true Control Group because the students still analyzed and interpreted data, although they themselves did not collect it. However, it is an integral component of Nebraska State Science Standards that students analyze and interpret scientific data within their science class. Therefore, researchers could not in good practice as educators restrict students from data interpretation during science class. This procedure correlated with the intent of the study by looking for a correlation between hands-on experimentation and data analysis and interpretation, not by looking at whether practicing this skill had a notable effect on students' scores when tested on this skill.

Figure 1.

Example Elevate Science™ Lab Procedure in 8th Grade Science Classroom

Part A: Modeling Mechanical Waves

- ☐ **3.** Put on your goggles. Attach a piece of tape to one point in the middle of the spring toy.
- ☐ **4.** Hold one end of the spring toy and have your partner hold the other end. Stand far apart so that the spring sags only a few centimeters.
- ☐ **5.** **Make Observations** Have one person move one end of the spring up and down several times. Observe the movement of the piece of tape. Record your observations in Data Table A.
- ☐ **6.** **Make Observations** Let the spring become still. Then have one person move one end of the spring forward and back several times in a push-pull motion. Observe the motion of the piece of tape. Record your observations in Data Table A.
- ☐ **7.** Place the small floating toy in the middle of the pan of water.
- ☐ **8.** **Make Observations** Drop the small stone into one end of the pan of water. Observe the motion of the small floating toy. Record your observations in Data Table A.

Twenty-two students (30% females and 70% males) in Periods 2 and 5 were considered to be the Treatment Group in this study. The intervention given to the Treatment Group in this study was tasking students with completing scientific experiments during their daily lessons, along with collecting and analyzing data from those experiments.

The experimentation processes that students completed in class were also taken from the curriculum, Elevate Science™ (Figure 1). This curriculum aligned with Nebraska State Standards and was appropriate for the eighth grade level (Miller et al., 2020). Once the experimentation processes were completed, students were then asked to analyze and interpret the resulting data by answering critical thinking questions (Figure 2).

Figure 2. *Example Elevate Science™ Post-Lab Questions in 8th Grade Science Classroom*

Analyze and Interpret Data

Part A: Modeling Mechanical Waves

1. **Analyze Systems** Waves were transmitted through what medium or media in your model?
2. **Use Patterns** How did the piece of tape move in Step 5? What kind of wave did you model? Based on your observations, develop a definition of this type of wave.
3. **Use Patterns** How did the piece of tape move in Step 6? What kind of wave did you model? Based on your observations, develop a definition of this type of wave.

Additionally, students in the Treatment Group analyzed and interpreted data that had already been previously collected and organized, like the Control Group, and was made available through Elevate Science™, referred to as Enrichment Activities (Figure 3). Like the post-lab procedure, students in the Treatment Group were asked to analyze and interpret the data presented to them in the Enrichment Activities by answering critical thinking questions (Figure 4).

Students in the treatment group regularly completed both the hands-on experimentation procedures with post-lab questions and the Enrichment Activities with critical thinking questions in the same lesson on the same day during the course of this study.

Figure 3. *Example Elevate Science™ Enrichment Activity with Questions in 8th Grade Science Classroom*

Enrichment: Measuring Ocean Waves

Read the passage below, then complete the table. Use a separate sheet of paper to answer the questions that follow.

Scientists have been studying the properties of waves for as long as people have been sailing the ocean. Ocean waves can be measured using the same properties as are used to measure other waves. Accurate measurements of ocean waves help scientists to understand and predict tides, currents, and changes in the weather. This information ensures that ocean vessels and their passengers remain safe. With modern weather forecasting, crews are warned long before storm waves arise to threaten oceangoing vessels.

One way scientists collect marine weather data is through stationary buoys that are located throughout the ocean. Buoys collect data such as wave period, frequency, wavelength, and speed. Wave speed is calculated by multiplying wavelength times frequency. The frequency represents the number of wavelengths that pass a fixed point per second and is measured in hertz (waves/time). The period is the amount of time it takes one wavelength to pass the same point. Therefore, frequency (F) is inversely proportional to a period (T), and is calculated as $F = 1/T$. The table below lists data collected from a deep ocean buoy station. The first entry shows a distance of 6.4 meters between wave crests. Waves splash into the buoy once every 2 seconds, and wave speed is calculated at 3.2 m/sec.

Period (sec)	Frequency (hertz)	Wavelength (m)	Speed (m/sec)
2	0.5	6.4	3.2
3	0.33	18.8	
4		28.4	7.1
7	0.14		13.0
	0.10	175.0	17.5
14	0.07		23.8
17	0.06	500.0	

Source: marine.rutgers.edu

Figure 4. *Analyze and Interpret the Data Presented to Them in the Enrichment Activities by Answering Critical Thinking Questions*

Analyze and Interpret Data

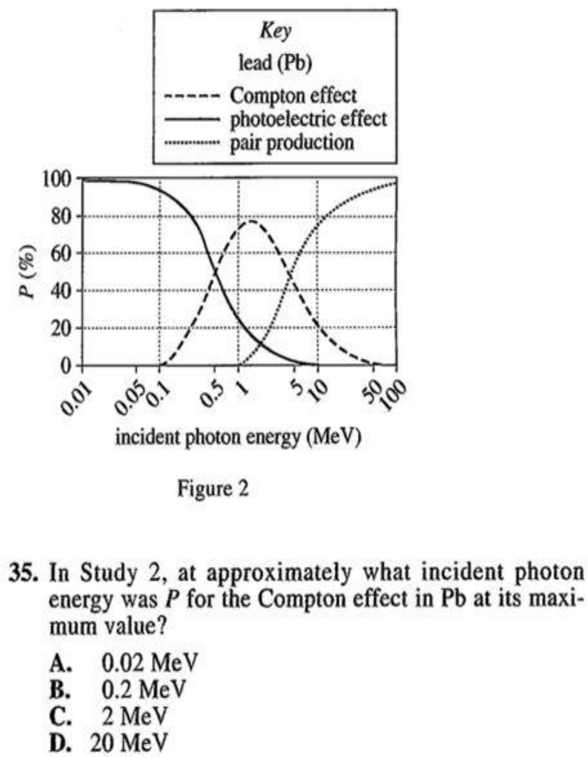
1. **Calculate** Complete the table by calculating the missing data values.
2. **Construct Graphs** On a sheet of graph paper, build a graph using data from the table. In the graph, show how wavelength is related to wave speed.
3. **Describe Patterns** What trend does your graph show?
4. **Cause and Effect** If the wave frequency increases, what happens to wave speed?
5. **Construct Explanations** If you were in a boat in the deep ocean, how could you tell whether the wave speed were getting faster?

The intervention was conducted over the course of approximately six weeks and was broken up into two units: Waves & Electromagnetic Radiation and Human Impact. In the Control Group, students analyzed and interpreted data over the course of eight lessons. In the Treatment Group, students also analyzed and interpreted data over the course of eight lessons, but they also interpreted and analyzed their own data that they collected through experimentation. These lessons were built around the Nebraska State Science Standards for the eighth-grade level and include the following example: “SC.8.2.2 Gather, analyze, and communicate evidence of waves and electromagnetic radiation” (NDE, 2017).

The lessons that were introduced to the two separate groups were given on the same days throughout the course of the two units. Of the eight lessons in the Treatment Group, five of the lessons included data collection through experimentation. The experimentation completed in the Treatment Group was conducted approximately once a week throughout the course of study. The data analysis and interpretation completed by both groups was also conducted approximately once a week throughout the course of study.

A summative assessment was given to both groups to determine the effects of the treatment on the students’ abilities to interpret and analyze scientific data. The summative assessment was composed of nine multiple choice questions that were similar in content and design to those found on ACT tests (Figure 5). The content on these questions was of general science and did not require extensive knowledge on a specific field of science (Albert, 2022).

Figure 5. *Example Formative Assessment Question Given to 8th Grade Students in Treatment and Control Groups*



Results

The scores of the summative assessment (out of 100%) were filed into an Excel spreadsheet and were analyzed through a two-sample t-test assuming unequal variances (Table 1). A two-sample t-test was used for data analysis in this study because it would allow users to determine whether there is a significant difference between the means of two different populations. Unequal variances between the two groups in this study was assumed because the standard deviations between the two groups was not calculated before running the test.

Using a p-value of 0.05, the significance in the difference between the average scores between the two groups was determined (Table 2). The t-test resulted in a two-tailed p-value greater than the alpha value of 0.05. The resulting two-tailed p-value was considered in this study in lieu-of the one-tailed p-value as the two-tailed value takes into consideration whether one group's mean was significantly greater or less than the other group's mean. Because the two-tailed p-value was greater than the alpha value of 0.05, the null hypothesis cannot be rejected; the data shows that there is no significant difference in mean test scores between the Control Group and the Treatment Group in this study (Table 2).

Table 1. Summative Assessment Scores of 8th Grade Students in Control or Treatment Group

Class Period	*Score*	*Group*
1	56	Control Group
	56	
	56	
	11	
	44	
	44	
	44	
	11	
	33	
	33	
	56	
	33	
	11	
	22	
	44	
2	67	Treatment Group
	67	
	44	
	33	
	44	
	67	
5	33	
	33	
	22	
	33	
	22	
	44	
	67	
	33	
	11	
	11	
	11	
	22	
	78	
	56	
	78	
	22	

Table 2. Results of Two-Sample t-Test Assuming Unequal Variances

	Control Group	*Treatment Group*
Mean	36.93333333	40.81818182
Variance	281.4952381	483.6796537
Observations	15	22
Hypothesized Mean Difference	0	
df	34	
t Stat	-0.608556284	
P(T<=t) one-tail	0.273431552	
t Critical one-tail	1.690924255	
P(T<=t) two-tail	0.546863103	
t Critical two-tail	2.032244509	

Evaluation

After plugging the resulting data of the summative assessment in this study into a two-sample t-test assuming unequal variances, the resulting p-value was larger than the alpha value of 0.05. This value suggests that there was no significant effect of the intervention on the Treatment Group in this study. Although the results of this study do not support the notion that students with hands-on experience in the classroom analyzing and interpreting scientific data have better skills when asked to perform this task compared to students who did not collect their own data, there are many factors that may have affected these results. For example, the Control Group in this study was smaller compared to the Treatment Group. The difference in size between these two groups may have had an effect on the results of this study.

Additionally, this study was performed over the course of six weeks. If students in the Treatment Group had been given more opportunities to practice analyzing and interpreting scientific data over a longer period of time, their scores on the summative assessment may have been higher. Lastly, we must consider the manner of testing in which the summative assessment was constructed and delivered and how it could have either correlated or clashed with individual students' specific learning styles. If students are naturally poor test-takers, then the summative assessment, which was written as a multiple-choice paper-pencil test, could have resulted in lower scores. These are just some of the sources of external factors that could have contributed to the results of this study and should be taken into consideration for future reproduction.

Discussion

If the resulting data of this study are a true representation of the lack of effect of hands-on collection of experimentation on students' ability to analyze and interpret data, a few questions could be raised: Did students not collect data through experimentation in a manner that was true to the Scientific Method? Are the experiences that students have when completing hands-on scientific experimentation worth the time, preparation work, and money if it has no effect on their ability to analyze and interpret scientific data? If the answer to the previous question is a "yes", then should we as a society focus less on standardized tests questioning students over their ability to interpret and analyze data that has been collected for them and in-lieu have students perform experimentation procedures to collect and interpret their own data? According to Brownell et al. (2015), students have reported that they believe analyzing and interpreting their own data from experimentation is highly useful in the development of scientific critical thinking skills.

Also, would this study have been more useful if it would have been able to be performed over years of a group of students' educational journeys to show whether there is growth or decline in their ability to interpret scientific data? This study looked at only one period of time in these students' lives; would the latter study provide more useful data to researchers? Lastly, in the lead author's personal experience as a classroom teacher, students in the middle level of education have shown declines in their reading comprehension abilities since the COVID-19 pandemic. Although students in this study were not on an IEP or 504 plan, she can attest that many do struggle in reading and comprehension. Therefore, could this inability to comprehend what the questions on their summative assessment was asking of them affect their ability to effectively analyze and interpret the scientific data presented to them?

Lastly, we must ponder the question of whether the age group of students that was selected for this study was appropriate. Should this study have been completed with students in secondary education or students who are in primary education? At what age do educational professionals need to determine that additional intervention regarding science education and students' abilities to analyze and interpret scientific data is needed if the end goal is for them to achieve high scores on their ACT? Is intervention at the middle level too late, or is it too soon considering most students won't even see the ACT until their Junior year of high school?

Another question can be raised: Should educational professionals put more of their focus and efforts towards the improvement of state standardized tests or national college-entrance exams such as the ACT? Although colleges and universities tend to disregard a student's performance on state standardized tests that they take throughout their primary, middle, and secondary educational journeys, these tests heavily influence public schools and the pressure that is put on them by the state education department. However, should not schools focus more on adequately preparing their students to achieve high ACT scores so that they are more likely to be admitted into the college(s) of their choice? Does the score a student receives on the ACT even have any correlation with their success in college once they are finally accepted and begin their post-secondary journeys? So many questions can be asked regarding this subject and similar ones.

Limitations and Suggestions for Future Studies

One of the main limitations of this action research project is the generalization of findings. The study was conducted with a small sample size of only 37 students, which may not be representative of the larger population. Additionally, the Control Group consisted of only 15 students while the Treatment Group had 22 students, which may lead to imbalanced groups and limit the ability to make accurate comparisons. Furthermore, the study was conducted in a single eighth grade class at a Class C school in eastern Nebraska, which may limit the applicability of the findings to other settings or populations.

Considering the results and limitations of this study and the numerous factors that could have negatively affected the said results, this study should be conducted again with some revisions. First, the Control and Treatment Groups should be made of approximately equal number of students and equal number of male and female students. Additionally, pre-treatment data would need to be collected in the form of a pre-test. Students will complete the summative assessment that they will take at the end of the study at the beginning as well. Students' scores on the assessment will be evaluated, but they will not be reported to the students and students will not be able to see the correct answers on the assessment. After the treatment has been administered, students will take the assessment again and the resulting scores will be compared to the pre-test; the presence or lack of significant improvement (using an alpha value of 0.05) will be determined.

Additionally, the summative assessment in this study was designed to include previous questions from the Science section of the ACT. The students in this study are in the eighth grade and have never seen questions designed like those on the ACT, even on their state standardized tests. Did the use of old ACT questions and their particular representation of scientific data hinder students' abilities to interpret and analyze the data presented to them effectively? To avoid such a negative effect on results, an additional revision to this study should include summative assessment questions in a format similar to what students have already seen in their science education journeys, such as those from their textbook and curriculum.

Lastly, we would still advise against completing a similar study with students who are in a special education program, such as those who are on an IEP or 504 plan; the students' specific learning disabilities could be a source of error in the results of the study. In order to include this group of students in a study of this manner, an additional study could be completed where researchers test the performance of scientific method by students as an aid to their specific learning disability in the classroom and how it can aid in their everyday learning within school. The results of this study could be of great use and benefit to researchers who are interested in studying special education students in the science classroom.

Conclusion

The results of this study suggest that there is no significant difference between the scores of the Control Group and Treatment Group. The data show that the Treatment Group did have a higher average score on the assessment than the Control Group, but not enough to be considered due to the treatment given (Table 2). The results of this study support previous research that suggests that hands-on experimentation in the science classroom can actually hinder students' ability to analyze and interpret scientific data (Smith & Puntambekar, 2010). Although students in this study were in the eighth grade, it was evident that they had limited experience working with scientific laboratory tools which could have hindered the learning process and the development of their data analysis and interpretation skills.

However, looking back on the design and implementation of this study, it is clear that there were likely many outside factors that contributed to the results. Additionally, the design of this study has flaws that need to be addressed before school districts consider the possibility of pushing less for hands-on experimentation in the science classroom. Therefore, this study would need to be redesigned and completed again in order to make a concrete conclusion regarding the effectiveness of this particular treatment on students' abilities to interpret and analyze scientific data.

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