The Impact of Experiments on Students

Joshua Steele

Abstract: Experiments engage students and improve their academic performance. Studies support this claim through the use of qualitative and quantitative methods. Research also suggests that there is an emotional component to the benefits of experiments. Qualitative results showed an increase in student interest and engagement for students that participated in the experiment. Quantitative results showed an increase in academic achievement for students that participated in the experiment. Scientific discourse also showed to be a valuable component of experiments as the scientific discourse creates a stronger scientific discipline. New programs and research are also generating new ways to analyze the scientific discourse, turning qualitative data to quantitative data. Overall, experiments are useful tools to generate interest and increase academic success.

Introduction

Science educators look to engage students and help them to better understand theoretical concepts with the use of experiments. Experiments are a valuable method of engagement, as they incorporate hands-on components. The hands-on components reinforce theoretical concepts, providing students with an alternative understanding of the topic. State and national standards also drive the use of experiments.

Science educators in Ohio follow the Ohio Learning Standards and Model Curriculum for Science (2019). These standards incorporate experiments through the Five E Model. Each E stands for an independent form of instruction: Engage, Explore, Explain, Elaborate, and Evaluate. Of the five E's, three of them pertain to experiments. Explore, Explain, and Elaborate all directly tie to experiments. The state of Ohio describes Explore as, "Investigate the phenomenon." Experiments are the investigation of a phenomenon, fitting the state's description perfectly. The State of Ohio outlines Explain as "Justify explanations with evidence." Experiments often include a laboratory report in which students record their findings and explain why those findings are significant. The laboratory report section of experiments would fit this description. Elaborate is described as "Extend and refine conceptual understanding." This definition would fit well with any hands-on activity that builds upon the lessons already started. The three E's listed in The Five E Model directs science educators to experiments.

Science educators also follow the Next Generation Science Standards (Spiegel, 2012). These standards are the national standards for science education. The Next Generation Science Standards has three main categories with several subsections. Two of the subsections categorized within the main topic of "Cross Cutting Concepts," fits the description of an experiment. The two subsections are "Cause and Effect" and "System and Models." Cause and effect are a large portion of science education. This relationship can be found in topics in most sections of science: ecology, biology, anatomy, physics, and chemistry. A simple description of this would be a ball launched at a certain angle travels a certain distance. This physics topic relates the angle to distance traveled through cause and effect. System and models can be

shown through a chemistry experiment. A system in chemistry is the combination of products and reactants. As reactants are added together, there is a physical model that shows through the generation of products. These cross-cutting concepts drive science educators to use experiments in their lessons.

Science educators are motivated to incorporate experiments by the state and federal standards; however, many science educators may not fully understand the importance of these hands-on activities. Experiments provide students with enriching learning opportunities that improve their academic performance and generate interest in the field of science.

Effects of Experiments

Students' Emotions

Experiments often have an emotional implication for students. Classroom activities can be repetitive and can lead to students becoming bored with monotonous paperwork and note taking. Experiments offer hands-on activities that break up the spells of paperwork.

Itzek-Greulich and Vollmer (2017) performed a study to examine students' emotional response to experiments. The researchers were able to gather a large sample size with 50 classes surveyed across 22 different secondary schools. The study used both qualitative and quantitative data to examine the emotional response of students. The researchers gathered qualitative data by recording students' phrases spoken throughout the experiment. These phrases were categorized by their connotation. A phrase of "This is interesting," would be considered positive while a phrase of "This does not make sense," would be considered negative. This qualitative data would be helpful to support the use of experiments. The study found that students phrases were more positive and showed higher interest than the control group. Itzek-Greulick and Vollmer (2017) states:

> The students in the lab-work conditions reported more positive emotional and motivational outcomes than their counterparts in the control condition. With one exception (anger, theoretical part), the lab work in the three experimental groups resulted in more favorable activity emotions, higher situational interest, and higher situational competence than the untreated control group. (p 24)

The results from this study support the use of experiments as a way to generate interest and engage students in the classroom. Science educators should look to utilize experiments, so students can partake in the engagement that experiments bring to the classroom.

Data on Effectiveness

Several studies have been performed in order to gather data on this topic. The studies used similar methods to obtain their data. Each study provided unique insight through their data collection. To operationalize Osborne's idea that argumentation has the potential to promote critical thinking, reflection, and the construction of conceptual knowledge, teachers need to encourage critique and argumentation in

science. However, to successfully argue, students need to ask questions. Therefore, it is the teacher's responsibility to provide opportunities for students to do so. Osborne (2014) states that teachers should "ask students to pose questions via a learning journal, establish a question corner in the classroom to supply 'questions of the week,' [and] include question-asking in evaluation" (p. 60). Allowing students to ask questions allows them to practice explaining what they observe and, in turn, forming ideas they can defend and argue. This research illustrates how science critique and argumentation can not only increase student learning in the classroom but also help them build skills that allow them to reason scientifically.

A study performed by Dhanapal and Shan (2014) looked to gather data on students' emotional and academic response to experiments. The researchers obtained information by surveying a class of international students ages seven to ten years old. The study used both qualitative and quantitative methods. Quantitative data was gathered through the test scores of the students. The test scores were provided by a pretest and posttest. Students showed a slight increase. The variance from pretest to posttest were slightly positive; however, the results were not statistically significant due to the small sample size and lack of conclusive increase. The increase overall was 4.32 percent. These results show some support; however, the qualitative results were more conclusive.

The study used a survey to gather qualitative information. The survey was given before and after the experiment was performed. Most of the students surveyed chose experiments as their preferred learning method in science. This indicates that the group already enjoyed experiments and could cause bias for the study; however, the other aspects of the survey showed improvement as well.

Researchers surveyed students to gauge the students' interest levels. Almost every category was positive with one area being neutral, interested in science, and one being negative, science is helpful to the future. The area of enjoying science lessons increased by twenty percent. This percentage increase supports the engagement of students. This increase of engagement will push students to do well academically as well. Another large increase was the area of extra reading. Students that participated in the experiment responded to be more likely to do extra reading. This is a strong step in the right direction for science educators. Reading about science in students' free time will create interest and generate background knowledge the students can utilize in the future. The qualitative results of the survey were statistically significant and suggest the students are more engaged with topics through experiments.

A study performed by Li and Wong (2018) used similar methods to examine the effect experiments have on students' learning. The study used several sections of a college class to increase their sample size. There were four total classes with one class acting as a control group. The students were ages 18 to 20 years old and attending an introductory college course. The experiment for this study was performed at the start of a lesson. Starting the lesson with an experiment was used as an introduction. The similarity to Dhanapal and Shan (2014) shows in their methods. Both qualitative and quantitative methods were used.

The qualitative methods involved a survey that was more broad, allowing students to pick from a selection of five answers. The five answers for each question were scaled one to five: 1: strongly disagree; 2: disagree; 3: neutral; 4: agree; 5: strongly agree. There were only six questions within the survey. The qualitative

methods resulted in statically insignificant results. The mean of the responses was 4.07 on the five-point scale. The results were statistically insignificant; however, most of the students responded in the four categories, showing students in favor of experiments in the lessons.

The quantitative method for this study involved pre and posttests. The large sample size and more conclusive data generated a statistically significant result. The groups that participated in the study had test scores increase by 23 to 65 percent more than the control group. Specifically, the groups had a 23 percent, 30 percent, 30 percent, and 65 percent increase than the control group. This is a statistically significant increase. This increase supports the use of experiments as students score better academically compared to the control group.

The studies by Dhanapal and Shan (2014) and Li and Wong (2018) presented support for experiments in science education. The Study by Dhanapal and Shan (2014) was able to obtain statistically significant qualitative data. This data supported the claims that experiments in classrooms are able to increase enthusiasm, engagement, and interest in science. The study by Li and Wong (2018) was able to obtain statistically significant quantitative results. These results support the claim that experiments increase students' academic performance. The studies are a good metric for science educators to examine and upon which to reflect.

Scientific Discourse

The data supports the value of experiments; scientific discourse is an important piece of experiments and the scientific community. Along with that, scientific discourse aligns with the standards mentioned in the Five E model and the Next Generation Science Standards. Experiments require students to obtain data, interpret that data, draw conclusions, and present their conclusions. The presentation often comes in the form of a laboratory report; however, there are times the presentation is given orally in front of peers. The presentation of conclusions directly involves scientific discourse. Because of this, scientific discourse is an important skill for students to develop.

A study by Bea et al. (2021) found that scientific discourse is increasing in intensity across American classrooms. The study amassed data from previous studies to generate comparisons. The data pool was collected from electronic and print articles. The amassed data was analyzed. Bea et al. (2021) found diversity in scientific discourse. Three forms of improvement for scientific discourse were observed: probe student ideas, recognize leadership roles, and use diverse strengths. Probing student ideas generates discussions and builds student confidence. A seemingly unrelated remark from a student may be the result of miscommunication. Probing the student's idea can allow the student to expand upon their idea. The student's idea may become more clear and related with further discussion. Leadership roles are a key component of scientific discussion and high school behavior. Students who can follow these roles show commitment. Many students contribute in other ways as well. This is why it is important to incorporate diverse strengths. Assigning roles for students to pick from can be a productive way to make sure each student plays a part in the discourse.

A study by Lee and Irving (2018) looked at the role of a teacher in scientific discourse. The study found that teachers play a vital role in scientific discourse. The researchers developed a code that analyzed dialog and class participation. The program was called CDAT. CDAT directly analyzed class activities, experiments, explanations, questions, and teacher feedback. The program tracked conversation length and key words. Lee & Irving (2018) collected data from two middle school classes and one high school class. The data collected is presented in Table 5 of the journal. The CDAT program was unique as the program turned qualitative data into quantitative data. Instead of taking a survey about the students' interest, researchers are able to calcualte and measure the amount of participation and diolog in a classroom. The program could also be used to compare the scientific discourse to the academic achievement in a classroom.

The devolpment of scientific discourse is increasing across American classrooms, and has shown to be a valuable resource when paired with experiments. Students can take a lot of value from the combination. With unique perspectives and programs, the measurement and growth of scientific discourse can continue.

Conclusion

Experiments are beneficial to students in terms of academics and engagement. Science educators can use this knowledge to incorporate experiments into their classrooms. Studies used qualitative and quantitative data to support the emotional benefits, academic benefits, and scientific discourse benefits provided by the use of experiments. The state and federal standards drive experiments for science educators with good support from the studies observed. As further research is performed science educators should be on the look out for benficial experiments to incorporate into their yearly lesson plans.

References

Bae, C., Mills, D., Zhang, F., Martinique, S., Cabrera, L., & Sea, M. (2021). A systematic review of science discourse in K–12 urban classrooms in the United States: Accounting for individual, collective, and contextual factors. *Review of Educational Research, 91*(6), 1-24. DOI:https://doi.org/10.3102/00346543211042415

Dhanapal, S., & Shan, E. (2014). A study on the effectiveness of hands-on experiments in learning science among year 4 students. *International Online Journal of Primary Education. 3*(1), 1-12. https://www.researchgate.net/publication/351985060

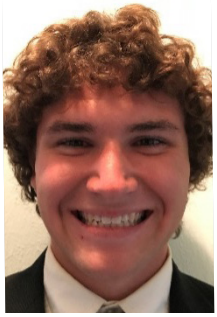
Itzek-Greulich, H., & Vollmer, C. (2017). Emotional and motivational outcomes of lab work in the secondary intermediate track: The contribution of a science center outreach lab. *Journal of Research in Science Teaching. 51*(1), 3-28. DOI: 10.1002/tea.21334

Lee, S., & Irving, K. (2018). Development of two-dimensional Classroom Discourse Analysis Tool (CDAT): scientific reasoning and dialog patterns in the secondary science classes. *International Journal of STEM Education. 5*(5), 1-17. DOI 10.1186/s40594-018-0100-0

Li, R., & Wong, T. (2018). Teaching them before we teach: The effectiveness of conducting classroom experiments before teaching the underlying theory. *LAFOR Journal of Education. 6*(3), 1-15. DOI: 10.22492/ije.6.3.05

Ohio Department of Education. (2019, May). *Ohio's learning standards*. Columbus. https://education.ohio.gov/getattachment/Topics/Learning-in-Ohio/Science/Ohios-Learning-Standards-and-MC/SciFinalStandardsMC060719.pdf.aspx?lang=en-US

Spiegel, J. (2012). *The three dimensions of the next generation science standards*. National Research Council. https://www.nextgenscience.org/



About the Author

Joshua Steele is a LAMP student at the University of Toledo. He is obtaining his master's degree in AYA Life Science/Chemistry. Josh's bachelor's degree was in Biology with a minor in Chemistry. His teaching passion is sharing the unique and fascinating sciences with students, especially ecology, genetics, and chemistry.