Science Labs and Their Positive Impacts on Students' Understanding of Science Concepts

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Abstract: Laboratory experiments are an important aspect of science students' educational journeys. This paper demonstrates that when students perform labs in their science classes, they have an increased understanding of the associated science concepts, and they are better able to learn science as a result. Laboratory experiments give students the opportunity to enhance their discourse skills, work collaboratively with their peers, and connect science concepts to real life scenarios. Furthermore, laboratory experiments are learner-centered, and they are a tool science teachers can use that result in their students having increased understanding of abstract science concepts. All these aspects of laboratory experiments result in students having a better understanding of the content and an increased ability to learn science effectively.

Introduction

When science students are given the opportunity to perform laboratory experiments (labs) in their science classes, they get a better understanding of the science content, and they can learn abstract science concepts more easily. Accordingly, labs are directly correlated to student understanding of science concepts. Science laboratory experiments are beneficial to students because of the way they incorporate hands on and real-life applications as well as peer collaboration. Furthermore, these laboratory experiments create a learner-centered environment, and they enhance scientific discourse. These aspects of science labs help to demonstrate that participating in science labs is directly correlated to student success in science courses as supported by several research studies.

Hands On and Real-Life Applications of Labs

Science students who are exposed to laboratory settings can learn the content while also engaging in the process of constructing their knowledge by actively doing science. Science students can easily be given a list of facts to memorize, but reciting and recalling facts is not true evidence that learning has occurred. For learning to occur, students need to be able to use higher order thinking skills and apply their knowledge of the content. The highest domains of Bloom's Taxonomy are creating and evaluating. Students have learned something when they draw connections among ideas, justify a stand, and produce original work. In the case of science, labs allow students to create a hypothesis and a series of steps to test it. Labs also require students to analyze the data and evaluate conclusions based on the results. Students demonstrate learning in science when they are able to construct an experiment, collect the data, analyze and present the data, and draw conclusions based on the science content and abstract science topics. Science labs are directly correlated to an increase in student learning and understanding because students learn by doing.

One study states that "just as one cannot learn swimming by reading a book one cannot become a doctor without 'practicing' on the human body" (Ghoshal, 2011, p. 16). By that logic, students cannot become chemists without physically doing chemistry. The act of participating in a hands-on experiment helps the students interact with the content and connect the science topics to their real lives.

In addition, when students are more active in their learning, their sense of self-efficacy increases which leads to mastery. When a professional scientist sets out to execute a laboratory experiment, they make a list of daily goals, weekly goals, and/or overall goals. Dinther et al. (2011) states that if a science teacher has his or her students create a list of goals for an experiment, this will increase their sense of self-efficacy. In other words, this will help students believe that they can develop and achieve their personal goals when it comes to the lab. This not only helps students to learn science more effectively, but it also helps them to become lifelong learners (Dinther et al., 2011). This will help them with their future careers, no matter what subject they pursue in college and beyond. To continue, "Goal setting combined with self-reflection, another self-regulation component, can provide students the opportunity of perceptions of learning progress, which can lead to a mastery experience," (Dinther et al., 2011, p. 104). In other words, setting goals and working to achieve these goals, helps students to perform better at a specific task. In the field of science, setting goals for laboratory experiments helps students to perform better academically in the science classes where they participate in these labs.

Labs and Collaborative Learning

In the field of science, laboratory work is collaborative. This collaboration comes in many forms and results in more sound science. An example of this collaboration is peer review. Scientists read the work of others to determine if the experiment and data are replicable and if the conclusions are logical and based in sound findings. For students in science classes, this collaboration results in an increased understanding of the content that is being taught. A study by Raviv et al. (2019) was done to support this claim. In the study, students in a seventh-grade science class were asked to complete four different laboratory experiments. Two of those labs were to be done with a group of students, and the other two labs were to be done alone. For each of the labs, students were required to write a report consisting of the procedure, the data, and the conclusions/findings. The teacher assessed each lab report based on content, level of detail, textual richness, and the presentation of the findings. The teacher found that the group lab reports scored, on average, higher than the individual lab reports. Also, when asked their opinions, most of the students preferred the labs that were done in groups. The students said that they liked working with their classmates, and doing so, helped them to understand the purpose of the labs and the science behind the labs better (Raviv et al., 2019). Based on this study, it can be concluded that students who work in groups or pairs to complete a science laboratory experiment score better and have increased understanding of the science concepts.

Members of the scientific community work closely with peers to evaluate each other's data and its replicability, perform labs, and form hypotheses. By incorporating labs into the science classroom, students can collaborate with their peers and

gain valuable life skills relating to teamwork. This can benefit students outside of the classroom when applying for colleges and jobs in the future. Employers and prospective universities value teamwork and the ability to communicate effectively with others, and students who develop these skills in science labs will have a leg up over students who did not collaborate with peers in science labs.

Hofstein et al. (2012) studied labs and their role in the field of science education throughout a variety of years. He stated that labs provide a way for students to "reflect on findings, clarify understandings and misunderstandings with peers, and consult a range of resources," (Hofstein et al., 2012, p. 405). In addition, when students collaborate with their peers in a laboratory setting, the teacher can observe each group and inspect each students' actions and dialogues to create questions and come up with future activities that fit into the zones of proximal development of each student. This helps students to accomplish science at a higher level by allowing them to access tasks that they can complete with assistance and on their own. As a science teacher, incorporating labs into the classroom is a helpful tool that frees the teacher up from lecturing and leaves more time for formative assessments and planning for differentiation to help each student as an individual. Clearly, there are many benefits to labs due to the positive aspects of collaboration involved those results in a better understanding of the science topics for the students.

A Learner Centered Environment

Labs promote a learner-centered environment which contributes to a positive impact on student learning and understanding of science topics. A study by Trumper (2003) looked at the historical overview of the goals of physics laboratories. Based on the information collected, the paper sought to present perspectives for the future of physics education based on the approaches of constructivist and social constructivist concerns. These approaches assume "the existence of learners' conceptual schemata and the active application of these in responding to and making sense of new situations," (Trumper, 2003, p. 650). The paper by Trumper (2003) attempted to validate the belief that microcomputer-based laboratories, also known as MBLs, are extremely beneficial to physics education. The MBL software allows for faster data collection and results in more time for the students to focus on the underlying scientific principles. It was determined that successful physics labs were learner-centered, because they caused students to become participants in a scientific process where they could explore the physical world, analyze data, draw conclusions, and generalize their understanding of a phenomena as part of their everyday lives (Trumper, 2003). This type of lab would be beneficial in all science classes as a way of getting students to better learn scientific principles as they relate to their personal lives.

Labs Enhancing Scientific Discourse

There are several aspects to consider when teaching students to become literate in scientific communication. For a person to communicate effectively in the world of science, they must be able to read and write technical reports, work collaboratively with their peers, understand and give professional presentations, and create or

view models to help analyze data and make sense of conclusions. These skills come into play daily through reading or writing publications, presenting data to a superior, developing plans to test a hypothesis, peer reviewing the work of others, and more. All these skills are characteristics of scientific discourse that are enhanced when students are given the opportunity to participate in science labs. This enhancement of scientific discourse leads to an increased understanding of science content for the students.

One study that supports the value of labs based on the opportunities for scientific discourse that experiments provide students was conducted by splitting students into two groups. A control group did not perform any labs, but the experimental group was given an opportunity to learn and assume responsibility for their own learning by conducting an inquiry-type experiment. All students were then given a professional research paper and asked to accumulate a list of questions for the author as though they were doing a peer review of the article after either completing the lab or not completing the lab based on which group they were assigned to be in (Hofstein et al., 2005). As a result, "evidence was presented that shows that the students improved their ability to ask better and more relevant questions as a result of gaining experience with the inquiry-type experiments," (Hofstein et al., 2005, p. 800). This is representative of scientific discourse because effective scientists need to be able to communicate with their peers. Scientists also must possess the ability to read and review papers and confirm or deny the conclusions presented in said papers based on the methods and replicability of the experiment and its data. This study shows the importance of including labs to get students to think deeply about science concepts and ask relevant questions.

Additional aspects of scientific discourse that are implemented through labs include investigation and data analysis. One study looked to collect science teachers' interpretations of scientific investigation through a regional survey consisting of 101 eleventh grade science teachers from a range of science content areas. In the survey, teachers were asked what features make up a scientific investigation that would best support year eleven student learning (Moeed, 2013). Most teachers viewed scientific investigation as "children doing science to find out, seeing theory proven so they can believe it, learning skills and applying them in new contexts, and in students' everyday lives," (Moeed, 2013, p. 548). Furthermore, the teachers who participated in the study claimed that students gain the most from scientific investigation when they "discuss expectations, observations, conclusions, theories, and explanations," (Moeed, 2013, p. 540). The teachers stated that it is best when students do this before, during, and after completing an activity. It is important to note that the results of this study were only drawn from one section of the country, and deeper insights may have been collected if a national teacher survey with a larger pool of educators was carried out instead (Moeed, 2013). Despite the limitations of the study, findings suggest that "science investigation that best supported student learning was understood to include experiments," (Moeed, 2013, p. 537). When students are active participants in an experimental investigation where they can make a claim and support it though argumentation and data, they become more verse in scientific discourse, and student understanding improves as a result.

Labs provide an environment suitable for practicing all of these discourse skills and are therefore beneficial to student learning. Labs help students to think deeper

about work produced by others. This is important and can be applied to other subject matters as well. For example, social studies teachers work to get their students to analyze sources and determine their bias and validity so they can make their own informed choices about key issues in government and society. In science, professional work is often viewed with scrutiny by other scientists who are working to dispute or support a claim. Increasing scientific discourse through labs also improves students' scientific communication skills and makes them more confident in their ability to learn. Overall, performing labs teaches students to ask relevant questions about the world around them because they have a better overall understanding of the science topics and theories they are taught in the classroom.

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Conclusion

It is clear that having students participate in laboratory experiments results in the students having a better understanding of the science content because labs are learner centered. Performing experiments leads to an increase in the types of scientific discourse skills that are practiced in class. Performing laboratory experiments also produces more positive collaboration, and the presentation of real-life applications, all of which help students to better understand science concepts and topics. Performing physical labs helps students to use the science content they learn in class and incorporate higher order thinking skills as opposed to simply memorizing a series of facts. This, in turn, results in the students having a better understanding of the associated science concepts.

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About the Author

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