Argumentation in The Science Classroom

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Abstract: Proper argumentation in the science classroom promotes conceptual understanding of complex phenomena, while also giving learners the ability to participate in authentic scientific reasoning. This methodical process that is often skipped in science classrooms gives students a chance to practice testing claims, refining their positions, and effectively communicating evidenced-based ideas to their peers. These methods of investigation teach proper scientific reasoning and communication skills that will simultaneously promote higher-order student thinking. The current studies suggest an increasing need for teachers to support their students in creating and enriching concept schemas through modeling questions/proper arguments, providing prompts, eliciting prior knowledge, guiding investigation, and encouraging reflective discussions.

Introduction

To promote optimal student learning and improve the educational experience for students, teachers need to design lesson plans that offer students the opportunity to explore and strengthen scientific skills, such as argumentation: the ability to evaluate and use evidence to construct an explanation (Developing scientific arguments and discussions, 2019). This skill allows students to ask questions and engage in critical evaluation of evidence and ideas. Doing so not only promotes conceptual understanding of complex phenomena, but also equips learners with the ability to participate in authentic scientific reasoning that will help them interpret the natural systems of the world around them. Lambert and Bleicher (2017) suggested that argumentation can lead to more integration of higher order thinking and reasoning into many peoples' lives. Allowing students to reflect on these fundamental skills that science is built on promotes problem-solving skills that will translate to other subject areas, as well as life outside of school.

Proper Argumentation

Proper scientific argumentation involves the ability to present evidence-based scientific ideas that support claims. Evidence for an idea being presented could be in support or against a certain explanation that has been formed through observation, experimentation, and/or investigation. Being able to effectively argue requires the ability to properly communicate and reason to establish and prove why the gathered evidence confirms the claim being made. Clear reasoning in science involves the use of scientific ideas, theories, or principles to make logical connections to show evidence in support of a claim. This fundamental process is used every day to uncover truth and solve conflict. Without these fundamental skills, researchers would not be able to share their discoveries with their peers or with the public; thus, individuals would not be able to benefit from their scientific findings and advancements.

Students would benefit greatly if teachers taught them how to defend their way of thinking with evidence and reasoning while also staying open-minded to other ideas. Doing so would teach them how to converse and interact as a professional in science. Having the ability to participate in a conversation about the critique of scientific ideas, discoveries, phenomena, etc. allows the opportunity for both students to reflect on their true understanding of the ideas while also helping them find gaps in their own reasoning/argument. Accepting claims, ideas, or points blindly ignores the opportunity to practice critiquing ideas, creating claims, gathering evidence and linking that evidence to make an argument. This methodical process that is often skipped in science classrooms gives students a chance to practice testing claims, refining their positions, and effectively communicating evidenced-based ideas to their peers. These methods of investigation teach proper scientific reasoning and communication skills that will simultaneously promote higher-order student thinking – a critical mental process that is essential for true learning.

Effects of Argumentation in The Classroom

Questioning and Critiquing Concepts

To address the importance of incorporating argumentation and the ability to engage in critique within the science curriculum, Osborne (2014) discusses the significance of giving students the opportunity to engage in argumentation and questioning to "not only help build students' understanding of science but also develop their ability to reason scientifically" (p. 53). The need to influence students to ask questions, critique others, gather evidence, and build arguments is important because it forces the individual to cognitively engage in defending their own position. By doing this they are engaging in a practice that real scientists do every day. Osborne (2014) mentions that these scientific skills and processes are the core of scientific practice itself and without them, there would not be the construction of reliable knowledge. Knowledge and facts that we know and accept today, such as "the fact that we live at the bottom of a deep gravity well, on the surface of a gas-covered planet going around a nuclear fireball 90 million miles away," (Osborne, 2014, p. 61) has been questioned by scientists for a very long time. And it is statements like these that seem difficult to believe but are often accepted without question by a lot of people today, including students. Osborne (2014) mentions that ideas and theories like these are worthy of discussion.

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.

Conceptual Understanding

To see how this concept holds up in a practical setting, there were many research studies done in classrooms around the world. One study was conducted in a public high school in the province of Çankırı, Turkey (Gültepe, 2021). The researchers wanted to see the effectiveness of an argumentation-based teaching approach in developing students' conceptual understanding of scientific material (Gültepe, 2021). Chemistry teacher, Eskişehir Osmangaz, performed this study with 52 of his 12th-grade students. The study involved the conceptual understanding of hydrogen bonding. To establish how much each of the students knew about the topic before the argumentative instruction was put in place, there was a pre-test given. The same concept test was also administered as a post-test. The student answers were evaluated by a rubric created by the researcher to compare the differences (Gültepe, 2021). The chemistry teacher "focused on scaffolding by argumentation to increase the comprehension of the students and their ability to employ and communicate with representations about hydrogen bonding in chemistry" (Gültepe, 2021, p. 199). There were both quantitative and qualitative analyses conducted. For example, the students were tested on whether or not they knew the definition of hydrogen bonding, as well as if they understood how to draw and explain what a hydrogen bond looked like. The quantitative data consisted of the mean, median, and standard deviations of the students' scores based on their answers before and after instruction. The qualitative data was discussed and scored by both the chemistry teacher and researcher (Gültepe, 2021). The data revealed that there were improvements observed in students' understanding of the material after the argumentation-based teaching. This showed that scientific argumentation contributed to a higher understanding and comprehension of "concept schemas" (Gültepe, 2021, p. 206) related to hydrogen bonding.

Science Process Skills

Another study was done in support of the claim that states, by "developing argumentation skills one could also develop science process skills together with science content learning" (Ping et al., 2020, p. 277). The authors argued that it is not only imperative for students to possess science process skills such as scientific argumentation because it is a crucial process of scientific inquiry, but also because it will help students become scientifically literate in a country where being able to "critically evaluate scientific findings would become a valuable asset to the country" (Ping et al., 2020, p. 277). The focus of this research study was on the formation of argumentative skills such as the ability to critique, reason, provide evidence-based claims, and ultimately communicate these ideas through practical-based inquiry activities. The researchers were specifically testing three different teaching approaches that involved varying levels of argumentative discourse-based intervention, and the resulting scores of students' argumentation skills, science process skills, and conceptual understanding of the material.

The study involved an 8-week intervention of 112 10th-grade biology students who were learning about diffusion and osmosis (Ping et al., 2020). The research aimed to examine the effect that teaching and learning activities in the LAB-MADI module have on students in different groups: the Modified Argument-Driven Inquiry (MADI) group, the Inquiry Without Argumentation (IWA) group, and the Conventional (CON) group (Ping et al., 2020). The teachers who were in charge of the students in the MADI group performed strategies such as, eliciting prior knowledge, helping find research questions, guiding investigation and data collection, helping analyze data and producing arguments, and encouraging reflective discussions. The teachers in charge of the students in the IWA group performed all of the same inquiry-based strategies, however, they did not implement any guidance regarding argumentative-based discussions. They focused strictly on guiding the students in analyzing data and reflecting on experimental results. The teachers in charge of the students in the CON group were only allowed to go as far as introducing the problem statement and providing the procedure for data analysis (Ping et al., 2020). The data was evaluated through a pre-test and post-test that were given during the course of the study. The type of data that was evaluated was based on an "argumentative essay the students wrote which was set under the Argumentation Skills Test (UKH), a written practical test set under the Science Process Skills Test (UKPS) [and a] multiple-choice test under Understanding of Diffusion and Osmosis Concept Test (UKRO)" (Ping et al., 2020, p. 279).

After the course of eight weeks, the researchers analyzed the students' pre-test and post-test scores. They established the three dependent variables as argumentative skills, science process skills, and the understanding of diffusion and osmosis concepts (Ping et al., 2020). Based on these points of evaluation, it was found that the post-test score of the MADI group was higher than the IWA group and the CON group regarding argumentation skills and science process skills. However, the post-test mean score for conceptual learning was a little higher in the IWA group compared to the MADI group, but significantly higher than the CON group (Ping, 2020). Based on the data of the intervention, it was found that the 10th-grade biology students in the Modified Argument-Driven Inquiry group outperformed the other two groups regarding argumentation and science process skills. They were able to create higher-quality arguments compared to the students exposed to the traditional approach. It was also found that the students in the MADI group were able to create clear explanations for claims that included evidence to back them up (Ping, 2020). The data collected from this study shows the level of impact teaching argumentation and inquiry-based strategies have on students' reasoning abilities. The results also show how important it is for teachers to give students the opportunity to work in groups and investigate scientific phenomena by discussing various ideas/claims through evidence-based argumentation. This study emphasizes the need for guided communication and interaction between students and their peers, like in the MADI group, to increase conceptual learning by simultaneously improving their argumentation and science process skills.

A similar study was done to test the effectiveness of the MADI approach. The authors, Antonio and Prudente (2021), introduces the meaning behind the study as an increasing need for individuals to demonstrate proper scientific knowledge in order to participate and understand real-world scientific advances. To read and understand research studies or actively participate in scientific discussions, students are expected to demonstrate skills in explaining scientific phenomena, interpreting data and evidence, and communicating/defending their claims with reason. Students can acquire these skills in science classrooms when they are given "meaningful opportunities for the cultivation of scientific understanding and argumentation skills" (Antonio & Prudente, 2021, p. 193). Through these opportunities, they can then acquire higher-order thinking skills that not only help them comprehend complex scientific material but also help enable "students to make informed decisions about personal and relevant issues" (Antonio & Prudente, 2021, p. 193).

To dive deeper into this concept, Antonio and Prudente (2021), conducted a research study that required students to conduct an investigation and generate a scientific argument. The approach required the teacher to follow a 7E Instructional Model: "elicitation, engagement, exploration, explanation, elaboration, evaluation, and extension" (Antonio & Prudente, 2021, p. 199). This approach was created to allow students to practice real-life scientific processes by allowing them to participate in argumentative sessions facilitated by the instructor. The teacher would guide the students in the activities by introducing a question to investigate, encouraging them to monitor their discussions/progress, asking students to reflect on their discussions, and providing "metacognitive prompts" such as "Have we reached our goal? What worked? What didn't work? and How should we do things differently next time?" (Antonio & Prudente, 2021, p. 199).

Two tests were created to evaluate the student's conceptual and argumentative skills before and after the intervention. One of the exams consisted of 30 multiple-choice questions testing their content knowledge and the other asked the students to create an argument based on a given question. Students were evaluated on whether or not they provided reasoning that linked evidence to the claim, if they included proper scientific concepts, how well they included evidence to support their argument, and if they made a complete and accurate claim (Antonio & Prudente, 2021).

It was found that after the students were exposed to the MADI approach there was a significant change in the student's conceptual understanding as well as their ability to properly argue. Students in both the MADI and Conventional groups acquired an increase in conceptual knowledge, however, only the students exposed to the Argumentative-Driven Inquiry approach made "significant gains concerning their scientific writing abilities and understanding of the development and nature of scientific knowledge" (Antonio & Prudente, 2021, p. 194). They were able to create higher-quality arguments compared to the students exposed to the traditional approach. The significant data collected from this study shows the level of impact teaching argumentation and inquiry-based strategies have on students' reasoning abilities.

Conclusion

The professional community of science educators collectively encourages teachers to give students the space and opportunity to create, innovate and experiment with argumentation in the construction of scientific knowledge. All of the research studies that tested and implemented argumentative-based strategies in the classroom discovered that students can develop and improve their argumentation skills, science process skills, and understanding of the concepts by being involved in the production of spoken and written arguments. These significant findings went hand in hand with the main ideas mentioned in Osborne's (2014) theory essay in which he encourages teachers to guide students in asking questions, thinking critically, providing evidence, and critiquing others. Taken as a whole, it appears that teacher guidance and training play a critical role in ensuring students' active participation in class discussions. When students are guided and taught how to properly argue in the science classroom, they ultimately understand complex science concepts and phenomena better. It was found that simply putting students in discussion groups does not do enough to promote effective verbal and/or written scientific conversation. It is agreed that students need to be given the opportunity to construct and develop evidence-based explanations or arguments through inquiry-based practical work.

Accordingly, these research findings highlight the need for teachers to provide students opportunities to discuss and critique content, provide evidence for their claims, and challenge other students' evidence or claims. The current studies suggest an increasing need for teachers to support their students in creating and enriching concept schemas through modeling questions/proper arguments, providing prompts, eliciting prior knowledge, guiding investigation, and encouraging reflective discussions. However, according to Gültepe (2021), additional research must be done with more extensive and long-term studies that include a higher population count. Future research should replicate these findings in settings with a larger sample size to better understand the impact that scientific argumentation has in the classroom.

References

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