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Are individuals' views on inquiry-based learning related to the level of inquiry they have experienced?

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Abstract

Inquiry based learning is an active learning process that engages students in data analysis, critical thinking and questioning. Many educators mistakenly think that science inquiry is either an all or nothing teaching method where they either guide the students through the process or leave it completely up to them. In truth, it can be divided into four different levels depending on the amount of information students are given at the beginning. The higher the inquiry level of an instructional activity the more student centered the activity. The purpose of this research was to determine if there is a relationship between the level of the instructional activities students were exposed to and students' feelings and reactions toward inquiry. It was found that students reacted similarly regardless oft he level of inquiry. Most responses were in a positive light and were varied as compared to the negative comments which were centered on time and effort. Defining

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ARE INDIVIDUALS' VIEWS ON INQUIRY-BASED LEARNING RELATED TO THE LEVEL OF INQUIRY THEY HAVE EXPERIENCED?

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Contents

Abstract:

Inquiry based learning is an active learning process that engages students in data analysis, critical thinking and questioning. Many educators mistakenly think that science inquiry is either an all or nothing teaching method where they either guide the students through the process or leave it completely up to them. In truth, it can be divided into four different levels depending on the amount of information students are given at the beginning. The higher the inquiry level of an instructional activity the more student-centered the activity. The purpose of this research was to determine if there is a relationship between the level of the instructional activities students were exposed to and students' feelings and reactions toward inquiry. It was found that students reacted similarly regardless of the level of inquiry. Most responses were in a positive light and were varied as compared to the negative comments which were centered on time and effort.

Defining Inquiry-based Learning and the Nature of Science

Science knowledge is constantly changing and expanding. A fundamental part of scientific literacy is realizing that all of the different laws, theories, hypothesis, and predictions are based on data gathered through the use of experiments. All of this comes together to generate our current understanding of natural phenomena. The Nature of Science touches on the fact that scientific knowledge is not set in stone, but is fundamentally based on evidence. Scientific knowledge changes as new evidence becomes available (McComas and Almazroa 1998). Unfortunately, the way that science is traditionally taught does not necessarily support this idea. Many instructors teach their students through a series of lectures where the students take notes. The students are left with a feeling that science is a bunch of facts rather than explanations of how things work. Even the laboratory activities seldom change students' minds on the matter since they often follow the procedure of "do this" and find the "result." These experiences may be part of why it is common for college students originally in the science field to change their major (Luckie et al. 2004).

Since science knowledge is comprised of explanations of phenomena that were gained through the use of experiments, it gives the impression to students that science is all hard facts that they should simply learn. This misconception led some instructors to believe that a different pedagogy, called inquiry, should be used to help students see the truth about science. Inquiry based learning is an active learning process that engages students in data analysis, critical thinking and questioning (Bell et al. 2005). Inquiry-based learning includes collecting and analyzing data and using it to make conclusions, closely mimicking the scientific process. The experience of the inquiry process allows them to put the information into their own context and know that science has a purpose and place in their lives (National Science Teachers Association 2009).

During the late 1980's and early 1990's there was a perceived need for standard learning goals across the United States. The reform was made by science educators coming together and discussing what an adult should know about science to make informed decisions about science related issues. With these goals in mind, they generated a set of scientific phenomena that a student should know at a particular grade level (National Research Council 1996). Teachers would then have guidelines to based their curriculum on. The end result of the movement was the production of different sets of requirements for students. Two notable ones are the National Science Education Standards (National Research Council 1996) and the Benchmarks for Science Literacy (American Association for the Advancement of Science 2009).

To enhance science literacy, the reforms suggested that adding more inquiry activities in the form of laboratory experiments would give students a more accurate feel of what science is like. Their influence has resulted in the reform of how science is taught in certain schools. The changes ranged from the addition of several labs to the designing a new curriculum focusing on allowing the students to have more independence in their studies. An estimated 80% of university science laboratory courses use some form of inquiry (Brickman et al. 2009). Many of the reforms have been met with positive reviews from both the staff and students (Holfstein et al. 2004). In comparison, the traditional science classes' reviews were mostly negative with students saying that the labs were long and not reflective of what they thought science should be (Luckie et al. 2004). Students who participated in science inquiry labs scored higher science literacy than their peers in traditional classes and showed more improvement throughout the course (Brickman et al. 2009).

However, not all educators are in agreement that inquiry-based instruction results in better understanding of science concepts. Some say that it puts more focus on the actual process of science instead of the core information so that students learn how to conduct experiments, but not necessarily what they mean (Kirschner et al. 2006). There are others who also argue that implementing inquiry strategies in a normal classroom setting is unrealistic due to it being more time consuming and requiring more preparatory work on the teacher's end (Eick et al. 2005). There is also the element of subjectivity where the instructors may not fully appreciate the work that was put into such experiments and the knowledge that was gained from them.

Other misconceptions are that the addition of hands-on-activities that engage students are all that is required for inquiry. Without the application of actual science concepts and learning through the use of the activities, they are nothing more than enjoyable time fillers. The flip side of this argument is that the only true inquiry-based learning activities are the ones where students develop and pursue their own specific questions. Teacher involvement and instruction is always needed during the learning process and guiding students through it is not necessarily taking away from their learning (National Science Teacher Association 2009). Many researchers have looked at whether inquiry-based instructional results in higher scientific literacy, the implications on science education and the public's reaction toward it. However, there has not been a direct connection between the different levels of inquiry and the responses to it.

Defining Inquiry Levels

Although all inquiry involves posing a question, analyzing data and developing explanations based on the data, the level of inquiry activities depends on how student-centered the activity is. There are three essential parts of inquiry: the testable question, the method to figuring out the question and the answer to the question. Inquiry activities are assigned a level depending on how much information was given to the students at the beginning (Bell et al. 2005). They range from 1-4, with one having all the information given and four having very little. The first level is where the teacher allows the students to conduct the experiment, but supplies all of the essential parts during certain points of the activity. This level is often used to introduce students to inquiry. Many of the classic "cook book" lab experiments fall into this category.

The second level is missing one of the essential parts of inquiry requiring the students to come up with the missing piece through the experiment. It gives the students more freedom to decide how they want to go about the experiment, but it also leaves more room for them to become confused or unsure of what they need to do. The third level is missing an additional part while the fourth level, also called open inquiry, is where the students decide on the question, methods, and answer through data (Bell et al. 2005). Although level 4 is the hardest of the levels, in reality it is the most common in the scientific world. Scientists are always looking for ways to answer different questions about the world which often involves conducting their own experiments based on what information is already available to them. Despite this, level 4 inquiry is the least commonly used in science education. For higher level students, intermediate levels are often used, instead, even though the students may be capable of doing the highest level inquiry. This is due to the time and effort that is required to complete level 4.

Comments on how teachers affect learning activities

Usually, instructors have considerable knowledge about the subject that they teach compared to the knowledge base of their students. Their experience allows them to use questions to gauge whether or not the students understand what they are presenting. It also gives them the ability to direct the lesson's flow and direction, giving them a sense of control over the students and their classroom (Roth 1996). This is commonly referred to as teacher-based-learning. However, the addition of inquiry can upset the accepted teacher role by allowing the students to direct their own learning a process known as student-based learning. The teacher then takes on a role of guiding the students as opposed to being the source of their knowledge.

Throughout the process of guiding the students, the teacher must refrain from telling them what exactly they are dealing with and what they should see or do, which undermines the inquiry process. If the teacher has previous experience in inquiry, the transition can be smooth and greatly benefit the students. Teachers should also keep in mind that student-based learning takes more time since the students do not necessarily have an idea of where they are going or how they are going to get there. Sometimes gentle prodding is needed along with some reassurance that the activity and its benefits are worthwhile.

Another concern of teachers is when students go off onto either a "wrong" topic or something that they cannot possibly test. The teacher is then put into a position where correcting the students may lead to the teacher giving them the "right" response undermining the inquiry process. The students also may see the teacher as, once again, the source of scientific information. One way around this is to praise the students on coming up with the idea and helping them to refine it (Van Zee et al. 2005). The students may then realize that something is not altogether right and find their way back to the original idea. The teacher also can provide assistance in the form of resources for the students along with personal experiences that could be shared giving the students more information to go on. Holding class discussions also has been beneficial for students in helping students to communicate their ideas as well as adjusting them.

Student reactions to inquiry

Elementary School

In a study done by Huann and colleagues (Huann et al. 2009), a classroom of fifth grade students was given two level 2 inquiry activities. In the first, they were asked to come up with a method to find out how to make the longest-lasting bubbles, while in the second they were to come up with testable questions for an activity involving making miniature parachutes. At the end of the year, students were given the "What is Happening in the Classroom" (WIHIC) test which looks at students' perceptions of their learning environment. The test was given at the beginning and end of the school year. Their scores were compared with two other classes of the same grade in the same school with similar teachers who did not implement inquiry. Students in the experimental group worked better together and were involved in the learning process, although they did feel that their teacher was less supportive of them than in the comparison groups.

Middle School

A study by Krajcik and his colleagues (Krajcik et al. 1998) of several seventh graders demonstrated that it is possible to have middle school students successfully conduct open-inquiry experiments. The students they observed were selected previously by the teachers and were not considered high achievers in science. The students designed and carried out their own inquiry experiments in line with what was being covered by the teacher resulting in a level four inquiry project. At the end of the experiments, students were asked how they felt about the experience. In general, they were more open to the inquiry activities because of the authenticity of the work. They were also very interested during the observable project phase of the work and enjoyed seeing their experiments and those of their peers develop as time went on. Unfortunately, there were also some downsides to the activities. Groups that did not share the work load between the members tended not to finish and complications arose when students needed to work on multiple projects at the same time.

Another group of researchers also found that middle school students were quite capable of making and running their own experiments. Gibson and Chase (Gibson and Chase 2002) ran a two-week summer camp focusing on students' attitudes toward science over a period of time when they were exposed to inquiry activities. The summer camp was made up of 7th and 8th graders lead by middle school science teachers. Students were allowed to make their own questions within the scope of biology/health, design their experiments and come up with their answer making it a level four inquiry activity.

Table 1: Students Reactions Toward Inquiry Activities

Study Researcher(s)	**Grade level(s)**	**Inquiry level(s)**	**Negative Comments**	**Positive Comments**
Huann et al.	5^{th}	2	Felt that the instructor was not as supportive	Worked well together, enjoyed learning process
Krajcik et al.	7^{th}	4	Did not finish on time, workload and teamwork issues	Authenticity, engagement in activities
Gibson and Chase	7^{th} - 8^{th}	4	None	Engaged in activities, teachers created a good environment to learn in
Tuan et al.	8^{th}	3	Experiments were too complicated, let others do their work and tell them what it meant	Increase in understanding of topics, real world usage
Holfstein et al.	11^{th}-12^{th}	2-3	Difficult work requiring much rethinking and many revisions	Authenticity, independence
Chang and Mao	9^{th}	3	Workload	Authenticity and working with classmates
Brickman et al.	College	4	Difficulty, workload, less confident than peers,	Authenticity, better understanding of concepts
Luckie et al.	College	4	Workload and group dynamics	Independence, seeing their own progress, future application of techniques learned
Kolkhorst et al.	College	3-4	Workload and time constraints	Independence, better understanding of concepts, future application of concepts
Myers and Burgess	College	3-4	None	Independence, facilitating their own learning, connecting concepts
Windshitl	College	4	Difficulty	Active learning

The following fall semester, a group of students was interviewed about their overall impression of the camp. The feedback that was received was very positive. Students mentioned that they found the hands-on activities to be engaging and interesting. There was also a good rapport between the students and their teachers. Students felt that the teachers created a positive environment and were open to discussion; they did not have to be afraid of saying a "wrong" answer. The aspect of authenticity of the experiments also made students more eager to learn.

Another study was done with the intention of comparing students attitudes toward science when given science inquiry instruction over traditional instruction. Tuan and his team (Tuan et al. 2005) conducted a 10-week experiment with about five hundred 8th graders; half of whom underwent a science inquiry curriculum. The students were given only the original testable questions, resulting in level 3 inquiry activities. Student interviews were done shortly after the completion of the activities. They appreciated that the activities were genuine and applicable to daily life. There was also pride in being able to understand concepts that the students would not have understood previously. In addition, students liked the feeling of being more involved in learning the concepts and figuring it out for themselves. The negative comments were from the point of view of students who did not understand the experiments. They said that the experiments were sometimes very complicated, which lead to them taking a back seat while their classmates did the activities and explained what it meant to them. Another student mentioned that he liked being able do and understand the experiment while his classmates could not, suggesting a possible division between students who "can" and "cannot" do science.

High School

In an effort to reform Israel's chemistry curriculum, Holfstein and his team (Holfstein et al. 2004) conducted an experiment with 11^{th} and 12^{th} grade students involving inquiry labs. The labs ranged from level 2-3. For the first experiments, students were to strictly follow the directions in their lab manuals. The second set of experiments gave them more freedom, allowing them to choose what question they wanted to pursue along with the methods for obtaining the results. At the end of the school year students were interviewed for their thoughts on the laboratories. Most of the comments were positive with many students citing that they liked the authentic learning along with the independence that it brought. They also found that they enjoyed working with their peers and felt supported by their instructors. The only negative comments were that at times the work was quite challenging, resulting in many revisions and rethinking of the experiment.

In Taiwan, another group of 9^{th} grade high school students studying earth science underwent science inquiry activities in an effort to see whether or not incorporating them into the curriculum would make a difference to students. The students worked in larger groups than the other studies (six members). Additionally, students were allowed to choose their groups. For the activity itself, students were asked to plot the path of the sun given specific conditions and analyze the shadows that it made. They were to research the phenomenon as a team and come up with an explanation. Given the requirements, the activity was classified at level 3.

Afterward, students' perceptions of the activity were positive. They enjoyed the hands on aspect of the activities along with working together, something that is not the norm in Taiwan. Their confidence in their skills increased as well as their interest in the class. In addition, authenticity of the work played a part in their involvement. The downsides to the activities were that students already had a great deal of work and stress related to a required exam they were to take so the extra time and work was not welcomed (Chang and Mao 1999). There was also another trial done with different students at the same time which yielded similar results (Mao and Chang 1999).

University and College Students

Brickman and her colleagues (Brickman et al. 2009) put together a very interesting study on how inquiry activities affect college students. They took a series of sections of introductory biology for non-majors with two-thirds of the sections were given the standard "cook book" laboratories. The remaining sections underwent inquiry experiments. They were given the original question, but had to determine the methods and the answer to the question, making it a level 3 inquiry. The questions were based on real situations and were often taken from newspaper articles or other current media. At the end of the semester, students were given a survey about how comfortable they felt with scientific techniques. Interviews were also done to determine students' reactions to the change in curriculum.

Overall, the feelings of the students involved in the inquiry experiments were mostly negative. Many were frustrated with having to come up with the different components of the lab. Since the class was for non-majors, students also felt that they were not as adept at knowing what they needed to do as compared to those majoring in the subject. There was also less motivation for them to learn the techniques since they would not be continuing on in the scientific field. The survey showed that students in the inquiry sections were less confident in their abilities in the lab work than those in the traditional setting, even though they showed a greater increase in scientific literacy.

One of the biggest complaints was the amount of work that the lab took compared to the more traditional lab. However, this feeling may be due to the fact that the lab sections were next door to each other, allowing the different sections to see each other. Students from the inquiry sections were able to view directly how their classmates had an easier time than they did as well as get out early. Both groups also attended the lecture portion of the class together allowing them to discuss the differences between the labs, leading to more dissatisfaction. Despite all of the negative feelings, students in the inquiry sections did express that they enjoyed the authenticity of the work and being able to apply it in real life. They also expressed that their understanding of science in general had increased. However, if they had the choice they would have picked the traditional instruction citing the comfort of an easier class.

Another college biology class had far more positive reviews. In an effort to reform their science curriculum, Luckie and his team (Luckie et al. 2009) experimented with an inquiry-based science lab instead of their original "cook book" formula. Students were divided into teams of four to work on a question of their choosing within the subject they were learning. They conducted procedural labs to gain experience with the techniques and equipment they would use for their inquiry-based projects. These procedural labs were not part of the grading process and students did not have to submit any work from these labs unless they were related to their project question. Students worked on several level 4 inquiry projects over the course of the semester. At the end they were interviewed about their opinions of the reforms. The negative comments centered on working in groups along with the higher workload of the projects. On the other hand, the students were quite happy with the progress that they had made from the beginning of the class to the end, as well as the freedom of choosing their own experiments to conduct. One student mentioned that the benefits learned from the experience far outweighed the amount of work.

A physiology class observed by Kolkhorst (Kolkhorst et al. 2001) also showed positive reactions. The students' final assignments were two level four inquiry research projects based on a topic of their choosing within the limits of the physiology lab and its equipment. To prepare them for this, the first weeks of lab were spent going through level 3 labs partly of their choosing and guided by an instructor. By the time the final projects came, students had an understanding of possible projects and how they would set up their experiments. Students also were required to write journal entries about their frustrations, concerns, and feelings about the labs. Overall, many of the students enjoyed the experience. They enjoyed the freedom to decide what they wanted to research and how to find it. They also stated that they understood the concepts better because they were focused more on the process of investigation rather than on obtaining a good grade. The knowledge they gained during this time could also be applied later in their careers. The few negative comments centered on the amount of work for the projects and the time constraints.

Another set of researchers also arrived at a similar conclusion with an organismal biology class course similar to Kolkhorst's. This experiment and the introductory ones were all level three with the final project being a level four. Students' comments about the course were positive, especially about the fact that they learned how to do and conduct their own experiments, something that they were not able to do in previous classes. They liked the deviation from the usual "cook book" labs. Bringing all the concepts together even from previous classes was also eye-opening for them. The fact that the laboratories were really, in essence, their own made the experience more enjoyable (Myers and Burgess 2003). In addition, students from a science teaching methods course completed similar inquiry projects. The projects were of their choice and were level four. The students kept journals of their thoughts and difficulties. Students were initially frustrated with the amount of thinking that they had to do, but in the end felt that the experience of testing their own ideas and learning how to problem-solve effectively more than made up for the additional work (Windshitl 2002).

Discussion and Results

In general, elementary and middle school students had similar reactions toward the inquiry activities. Their reactions were more related to how the teams worked together and the workload than to the actual process of inquiry. One of the studies focusing on college classes also reported similar student responses. For example, the elementary and middle school classrooms both had problems with teamwork even though the levels were quite different (2 as opposed to 4). Meanwhile the high school and majority of the college students' comments were more in line with the process. All of the high school/college classes which had level 3 or 4 projects displayed the same positive comments about authenticity and real learning along with the negative comments about time and level of difficulty. The reactions from all of the students did not seem to be affected by what level of inquiry the activity was. Therefore, there does not seem to be a connection between inquiry level and students reactions; the reactions are simply associated with the inquiry process itself. Scaffolding techniques were mentioned with the elementary students only, but probably would have improved secondary and college student responses to inquiry.

Despite the resistance to science inquiry in general, students' comments were mostly positive. Students exposed to more science inquiry tend to have more positive views on science (Gibson and Chase 2002). There was also an indication that they felt they understood the concepts better than they would have given more traditional means, supporting the use of inquiry in student learning. Their negative comments were about the amount of time and work that they had to put into the projects, which seems to be a common feeling among students. What was surprising was the fact that the level of inquiry for the activities did not seem to have much influence on the students. The students who underwent level 2 inquiry activities had similar reactions as those who did level 4 projects.

As for the quality and quantity of the different experiments, it would have been a great asset if there had been more information about inquiry activities at the elementary level. The only article found mentioning the responses of inquiry in that section was with 5th graders, the highest grade in elementary. Many elementary teachers prefer not to teach a lot of science inquiry because their students are getting used to the science in general (Tower 2000). At the lowest grades, students are still struggling with learning to read and write, which can make gathering and recording data hard, not to mention following directions, both verbal and written. Even a fourth grade teacher who was trying to introduce her students to inquiry was quite frustrated with their seeming lack of skills not only in developing their own questions, but in seeking out information. Many of them simply did not know how to research, so she had to teach them how before she could even think about teaching them the basics of inquiry. Perhaps doing some simple experiments with predictions and explanations of how the results were obtained would make a good introduction to inquiry activities.

Difficulties in conducting surveys

The process of inquiry is a continuum of questions, experiments, data and ultimately the answer to the original question if all goes well. Many would say that it is the scientific method in its splendor. The process of inquiry also entails collaboration between different individuals on how things are done and what the data actually says, often leading to disputes. There are very few circumstances where everyone completely agrees with how things are done. This can lead to dissent about the inquiry process itself, not because of what was accomplished, but because of personal preferences and concerns. Communication difficulties were also a factor in whether or not the groups worked well. Some of this was dependent on the size of the groups and how they were managed. Groups that were lead by a single individual received more negative criticism that those with co-leaders (Mebane 2000).

There is also the difficulty of getting answers that were reflective of how students feel as a whole. In many cases, the samples were small and the situations were circumstantial, leading to a question of reproducibility as well as reliability. Students' reactions were also affected by where the students were in their scientific studies. The undergraduate students who were taking the non-majors biology class had more negative comments than the students taking other science courses and who were majoring in the sciences. The difference seemed to be centered on whether or not the information would be useful to them in the future; something that the non-majors lacked (Lyons 2006).

Future studies

Despite there not being a connection between the level of science inquiry and students' reactions, their reactions toward inquiry are in general quite positive. Many of them have stated that it was more authentic than traditional learning. This comparison is linked to the fact that, in general, traditional teaching methods are used much more frequently than inquiry based ones. When students are faced with inquiry activities after being exposed to traditional techniques for so long they become understandably confused and frustrated, especially when the amount of work that they had to do for class has increased. If students had been more exposed to inquiry during their science education, then there might be less resistance to inquiry. It would be interesting to see whether or not students' reactions would be similar had they been exposed to inquiry over extended periods of time. There might also be a difference in how they related to the different levels because students would have a better understanding of the whole inquiry process.

Conclusion

The purpose of this review was to find whether or not students' feelings toward inquiry were related to the inquiry level of the activity. After reviewing the activities and reactions of students from elementary to higher education, a connection between the inquiry level and their reactions was not found. Negative comments focused mostly on time constraints, workload, difficulty and working with others. The positive statements were on the application and authenticity of the activities along with the independence of running their own experiments. The bottom line is that to make inquiry-based instruction effective students must feel that the activities are authentic, worthwhile, and will benefit them later in life.

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