What Questions to Ask: Looking at how inquiry skills can impact achievement

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Abstract: Teaching students how to think and to question the world around them is in practice and theory part of the nature of science. The problem is that students are less likely to ask questions and be involved in the learning process, choosing instead to be passive in their education(Dragoş et al., 2015). In addressing the idea of getting students to engage in the learning process through questioning comes the idea about building questioning or inquiry skills. Through engaging students in meaningful creation of questions and the process of revising and editing their questions students can build their inquiry skills toolbox. The results of this study showed a marked increase in the number of questions that students asked and a change in the type of questions they asked. resulting in the findings that students can and do develop inquiry skills and critical thinking through practice and revision.Leading to the idea that the nature of science helps to build a community of thoughtful learners.

Introduction and Justification

Good questions build curious minds. Curious minds make new discoveries and have a deeper understanding, and appreciation, of the world around us. In science classrooms, many students struggle trying to absorb content, without understanding the mechanics of the scientific process. Students want the answer without being wholly involved in the learning process. Without the skills of inquiry, and settling for learning the wide overview of science, students are missing the importance of discovery. They fail to learn how to gather evidence and record data, to analyze their information and sources, and to make informed decisions (Dragoş et al., 2015). It is not just important for students to learn inquiry skills to understand scientific concepts, but to develop critical thinking skills that will help them be engaged participants in society (Anggraeni et al., 2017).

Inquiry in science is described as, the ways scientists describe what is going on in the world, based on evidence and data, in a particular field of study. Inquiry skills are then developed to allow scientists to move past the opening question and make discoveries (Akerson et al., 2007). Inquiry Skills include learning to make predictions and hypotheses through questioning, identifying dependent and independent variables, collecting data, and making observations of the natural world. Teaching students these methods provides them with a general framework that can be used in settings outside of the science classroom. Classrooms that are using next-generation science standards are working towards having students use this framework. However, enlarging students' inquiry skills has been difficult, as students unfamiliar or uncomfortable with the process are still struggling to ask questions in class. By assisting students in learning how to build their questioning skills, students will be able to perform better on assessments which assess content attainment.

In this study, I investigated how to introduce and build inquiry skills in students using the Question Formation Technique (QFT), which was developed by the right question institute, as a way to help students generate and improve questioning skills. The QFT has been adopted by Next Generation Science Standards as a tool used to introduce content within units so that students can base their learning on inquiry and make connections to information they already know (VanTassel-Baska & Stambaugh, 2007). The QFT introduces a scientific phenomenon which students can ask questions about, and build their inquiry skills by reviewing, revising, and editing their questions, so as to look deeper into the content. The QFT is also used as a way to engage students with the unit so they can build upon their comprehension in the topic.

In this study, I constructed lesson warm-ups around teaching students to use QFT, and the importance behind it, as it relates to scientific inquiry. Following the warm up instructions I evaluated students' performance both before and after the intervention, looking for growth in their inquiry skills, class participation and overall achievement. I did this through evaluating student work, and student self-reflections which were completed before and after the study.

Literature review

Inquiry Skills: Scientific Inquiry and the Inquiry Model.

Scientific inquiry is the process that researchers follow to make discoveries, conduct experiments, and expand their knowledge on the topics of their research. Scientific inquiry is oftentimes noted as being a part of the nature of science (Lederman et al., 2014). While scientific inquiry and the nature of science are certainly related there is an important distinction in teaching science. One is an overview which states what is science and the other is the process in how the science got there. This distinction is important in teaching science so that students can develop inquiry skills that assist them in understanding the fuller picture often left out in teaching. In the classroom teachers can assist students in developing their skills by using student-centered questioning teaching models.

Following the inquiry model, it's a teaching approach that is student-centered with a goal of instructing students how to acquire content knowledge rather than just teaching the content (Shanmugaveluet al., 2020). In a science classroom, teaching through the inquiry model revolves around using the same processes and skills that researchers use in their fields. Students are involved in activities and investigations that guide them toward learning about specific content. Teachers facilitate students' learning through guiding and encouraging questioning so that the students develop their own questions, which they then use as a guide in their learning process. (McBride et al., 2004). Most of the activities the inquiry model focuses on in science are lab-based activities. Students develop questions through creating hypotheses, finding patterns and relationships, and communicating their ideas (Ulfah et al., 2018). In my placement, the inquiry model is mostly used in lab activities and in Question Formulation Technique (QFT) which students do at the beginning of a unit. The QFT is a technique designed to help students develop inquiry skills through question formulation, evaluation, and revision (Rothstein & Santana, 2011).

What are Inquiry Skills?

The use of inquiry skills expands development through learning new things, making observations, experimenting, and problem-solving. These skills flow from a growing circular pattern, which follows creating questions about a phenomenon or real-world problem, researching that problem, revising questions, or creating more questions. From that, the student researches select answers, which they can then interpret or analyze. Inquiry skills build toward using critical thinking skills and higher-order questioning. Higher-order questioning is the idea of asking why something works, instead of a descriptive, what it is or where to find it (Nappi, J. S. 2017). Critical thinking skills include analysis, interpretation, inference, explanation, self-regulation, and open-mindedness of information (Gunawan et al., 2019). In many ways, critical thinking skills are similar to inquiry skills. Inquiry skills are important to developing students so they can become informed citizens of the world. These skills add another tool for them to make sense of the world around them, both in science, other academic areas, and life in general. (Harrison,2014).

Achievement in Science Classrooms:

What does achievement look like in relation to inquiry skills? How do we measure inquiry in the Classroom?

An important piece of teaching inquiry-based learning and inquiry skills is the emphasis on the need for multiple connections. These interactions include the curriculum that is presented, the students encounter with this new material, while encouraging the student to draw on their past learning and then move forward by developing connections between these points. Teachers are able to observe students' achievement in the content presented through formative assessments of the students developing skills (Harrison, 2014). It is important for teachers to keep factual information and direct instruction brisk, while asking guiding questions and providing students more class time to explore information. When looking at formative assessments, it is important to first have additional supporting materials readily available and designed for the students' learning needs, to facilitate their inquiries. At the academic level students have more places where they can access the materials first and then ask questions. For the more gifted students, a more effective strategy is to have them ask questions before and during, as well as have them revise some of the questions so they can delve deeper into their topic. (Cotton, K. 1988).

What is Higher-order questioning?

Inquiry skills, like questioning, can be assessed through several different methods which include; an analysis of the quantity of questions students are asking in class, and the type of questions they are asking. The type of questions follow two categories: open questions and closed questions. In addition to these types of questions, there is higher-order questioning which follows Bloom's taxonomy. These types of questions are aimed at having students think deeper about the content. It is important to note that

students should not be exclusively using higher-order questions, because all types of questions have a purpose.

Research Questions

1. How does learning guided inquiry skills lead to asking higher-order questions?
2. How does learning guided inquiry skills lead to achievement in content?

Methods

Participants and School Context

This study included 80 participants attending seventh and eighth grade at a rural charter school on the East coast. There were 43 seventh graders who participated and 37 eighth graders. The average class size was 21 students per class in seventh grade and 18 students per class in eighth grade. There were 41 male students and 39 female students. The majority of students were white, 6 students were African American and five students were Latino. Of the classes, 18 students had IEPs or a 504 plan and 15 students were classified as gifted and talented. Half of the students qualify for free and reduced meals. It should be noted that the number of students receiving free or reduced meals may be inaccurate as all meals at the school are free at this time, with no registry required, due to the Coronavirus Pandemic. Attendance at this school required admittance through an application and lottery system. This active school selection has revealed that families want their students to attend this school which is demonstrated through their at home support of their student. Several of the participants were children of staff at the school or have a parent who is a current or former educator.

Intervention

The study's goal was to address building students inquiry skills through using scientific phenomena and questioning strategies in daily warm ups with the hope of building students' inquiry skills. The study additionally contemplated if the students' inquiry skills increased would their understanding of scientific concepts also increase (as evidenced by individual achievement at the end of unit assessments). The study lasted for three weeks. The warm-ups in each class period took five to ten minutes. Each week, the QFT the students completed focused on the topic of the learning segment including the overarching unit topic. Additionally, students watched several videos and had small group and class discussions surrounding the week's focus. In the first week, classes completed a formal QFT, an example of which is in Appendix A. During this initial week, the focus was on what is scientific literacy, what inquiry means and the purpose of asking questions. In the second week, the focus of the class warm up's was on addressing the kinds of questions that students were asking, specifically if the questions were open or closed, and if the questions were aligned with the topic. During this week students created a collaborative board where they wrote questions they had about the learning segment or unit they were studying. The collaborative board also served as a way to review the kind of questions which were being asked as well as serving as a guide to answering some of the questions

and teaching how to find reliable sources of information. In the third and final week, the focus was for students to edit and revise their questions to focus on the unit topic and get comfortable asking more questions in class.

Additionally in the third week, students completed a second QFT. An overview of the data collection tools is given in Table 1. The QFT worksheet served as a measurement tool of students' inquiry skills. This study particularly focused on three things, the number of questions the students asked, the types, open or closed, of questions and if the questions aligned to the class discussion and the scientific phenomenon. Participants turned in their QFT worksheets and were assigned a random number, for the purpose of this study, to maintain students' anonymity. This data was reported as quantitative data. The scale used to determine the types of questions asked can be found in Appendix B. In addressing the studies second focus of achievement scores, from students' unit assessments, both before and after the intervention, were recorded from Schoology and no identifying information was given on the students. At the conclusion of the study, students participated in an overview survey regarding the study itself, as well as their feelings toward using inquiry in science.

QFT worksheet content:

During the intervention of the study, there were two formal QFT worksheets which students completed. For the two formal QFT worksheets, there were two versions created to address the two specific different grades participating in this study. Each QFT addresses a particular scientific phenomenon; students either watched a video showing the phenomenon or looked at a still image of the phenomenon. Students then were given a set amount of time to ask as many questions as they could about the phenomenon. Students were tasked with not stopping to judge, or answer but to simply write as many questions as they could. After the set time was up, students identified the type of question they asked and then revised them, as needed from open or closed types. Students were each given a number and that number was recorded on the worksheet. Students' worksheets were collected from the classroom teacher. The number was used in recording the QFT data for the study. Once quantitative data was collected the researcher and teacher gave feedback to students on their worksheets.

Addressing Accessibility in the Study:

To address students learning needs some modifications were made for both individual students as well as the study group. Modifications made for the study groups were; to give directions in both verbal and written form. Directions were posted in a slide show that walked students through the assignment. Directions were also written out on the worksheet for each student. The study groups read through the directions aloud together. When presenting the phenomenon the video or image was presented on the screen so everyone in the class could see it. Students were encouraged to move if they needed a better place to view. During small group or class discussions, one member of each table group took on the role of recorder and took notes for that group. Students were also encouraged to take their own notes. On the QFT worksheet, extended space was given for students to write more questions than expected. Specific modifications provided to

students during the study included; giving extended time for asking questions with the QFT, verbalizing their questions, and preferential seating for access to the board and the teacher.

Type of Methods

This study was conducted in four classes with two different grade levels. All work for the study was conducted during the 50-minute class block and materials were collected and stayed in the classroom. Students were familiar with the QFT process through its use in the classroom prior to the intervention. This study looked at student work and quantified their understanding of the content. It also asked the students to respond to how they felt about inquiry skills. This study can be classified as both quantitative and observational. The survey questions students responded to at the end of the study can be found in Appendix C.

Data sources

Table 1. Research Questions and Data Sources

Research question	Data source 1	Data source 2.	Data Source 3.
Does learning guided inquiry skills lead to asking more questions in class and asking questions aligned with the topic of the class?	Pre/Post QFT worksheets		Student Survey
Does learning guided inquiry skills lead to achievement in content?		Student's academic performance in Pre-intervention unit assessment and post-intervention unit assessment	Student Survey

Data Collection

Participants completed a paper QFT worksheet and submitted it during class time. Responses were recorded in excel for both the pre and post-intervention. Participants unit assessment scores were submitted to Schoology and reviewed by the researcher and the cooperating mentor teacher for their short answer responses. Lastly, the survey was collected and reviewed by the cooperating mentor teacher and researcher to identify trends and themes in students' responses.

Data Analysis

The quantitative measure was analyzed using three paired t-tests for two of the subscales of the QFT: the number of questions asked, the type of questions asked, and the pre and post-test scores. The qualitative measure of the study was reviewed by the cooperating mentor teacher and the researcher to look for themes and ideas.

Validity and Reliability

The QFT worksheet has been validated in multiple studies. In this study, the QFT was expanded to include a column identifying if the questions were aligned with the unit topic. The overall structure and format of the QFT remained the same. Both the researcher and cooperating mentor teacher reviewed the qualitative data for common themes and ideas. The quantitative data was reviewed by the researcher as well as a reviewer who went over a randomized list of students' worksheets and did an independent analysis of their work.

Results

To guide the investigation on how inquiry skills can impact achievement, I aimed to explore two research questions.

1. How does learning guided inquiry skills lead to asking higher order questioning?
2. How does learning guided inquiry skills lead to achievement in content?

Quantitative and qualitative data were collected in order to explore how increasing students' inquiry might increase their achievement.

How does learning guided inquiry skills lead to asking higher order questioning?

QFT worksheet results:

In the pre and post, QFT worksheet inquiry skills were measured, specifically in the number of questions students asked and the types of questions students were asking. A paired sample t-test showed that there was a significant increase in the number of questions students asked from the pre-intervention QFT (M= 4.70, SD =1.59) to the post-intervention QFT (M=5.50, SD= 2.089), t(test)=0.00001, $p<0.01$, Cohen's D= 0.4, Bayes factor= 5.14. There was also a significant increase in the types of questions students asked from pre-intervention (M=1.60, SD=1.49) to the post-intervention(M= 3.5, SD=2.011), t(test)= 0, $p<0.01$, Cohen's D =1.09, Bayes factor=12.42. The findings are displayed in tables 2 and 3.

As supported by the data, participants during the intervention, increased the number of questions they asked, not only on the QFT but also in class overall. I predicted that by having discussions and creating a classroom environment where the goal was centered around questioning, and inquiry, that students could become more open to the idea of asking questions in class and build their inquiry skills. By giving students the opportunity to ask questions, and then work toward solving them through learning the content, the students participated themselves in the scientific process, and not simply memorizing content. . To support the significant p-value a Cohen's D analysis was done for both tests to determine the effect size. For the number of questions asked the effect size was determined to be between a small and medium. This correlates to a small to medium change in the number of questions the participants asked. For the types of questions asked, Cohen's D

number indicated there was a large effect size. This meant that all the participants saw a large change in the types of questions they were asking.

Table 2:

Paired sample t-test comparing pre and post QFT for Number of questions asked

	N	M	SD	p	Cohen's D	Bayes Factor
Pre-test	80	4.701	1.593	0.000019	0.4	5.14
Post test	80	5.506	2.089			

Table 3:

Paired sample t-test comparing pre and post QFT for the type of question asked

	N	M	SD	p	Cohen's D	Bayes Factor
Pre-test	80	1.604	1.495	0	1.096	12.4
Post test	80	3.548	2.012			

Student Survey Results:

The qualitative data recorded in the study explored students' experiences with the intervention, what they learned and what their main takeaways were. In the survey responses, there were several themes that stood out. The first part of the survey was a series of Likert scale questions, with the majority of students in both seventh and eighth grade, answering that they strongly agree with the statement *I understand what is going on in the unit* and how it relates to our phenomenon. In the next two responses the students in seventh-grade answers were split between agree and strongly agree. In eight grade the students answered *strongly agree* on the same two questions. Almost all participants answered *strongly agree* for the final Likert scale question.

The survey included two short response questions. The first short answer question pertained to what was taught in the class discussions throughout the intervention; specifically relating to scientific literacy and asking questions. The questions asked students to reflect on the drawbacks and benefits of being scientifically literate, and what the drawbacks and benefits may be of asking questions. The responses from students ranged from being specific to themselves as well as being more in-general. Students brought up topics of motivation with achievement in the class. Some students talked about

how they might be perceived by other students or the teacher. A sample of student responses to Survey short answer questions can be found in table 4.

Table 4:

Short answer responses from survey questions

Student	Response
A	" I feel that the benefit to asking questions is that it helps when you are confused. One of the drawbacks is that others may think your dumb."
B	" The benefits to asking questions is that it helps you learn and being scientifically literate is important to understand the world."
C	" Scientific literacy benefits us cause it helps us look at the world… I don't know what its drawbacks would be."
D	"I think the benefits to asking questions is that it can help you when you are confused, its drawbacks are that other people know you don't get it."
E	" I ask questions so the teacher knows I like the topic and I don't ask questions when I am not interested."
F	"Asking questions is important because it helps us learn, not asking questions means that we will not know the information"

How does learning guided inquiry skills lead to achievement in content?

The pre and post-unit assessments measured students understanding of the content through multiple choice and short answer responses. A paired-sample t-test showed that there was not a significant difference between the pre-intervention assessment ($M=0.89$, $SD=0.135$) and the post-intervention assessment ($M= 0.86$, $SD= 0.193$), $t(test)=0.06$, $p>0.05$. The findings of the unit assessment are displayed in Table 5.

Despite there not being a statistical increase between the pre and post-assessments, students did increase their inquiry skills. In class, students demonstrated a change in the number of questions asked, as well as, more students were willing to speak up when they were confused about the topic. I predicted that given the effect size of the inquiry skills development that there should, with time, be an increase in the achievement of students in the class. It would be beneficial to the study to also look at pre and post-assessment data

for the same unit instead of comparing the unit prior to the intervention and the unit covered during the intervention.

Table 5:

Paired sample t-test comparing pre and post-assessment score

	N	M	SD	p
Pretest	80	0.89	0.135	0.0578
Post-test	80	0.86	0.193	

Discussion of Results

The results of this study echo the ideas and practices of the inquiry model. Specifically, by engaging students in the scientific process of asking questions about engaging with scientific phenomena in the unit of study. Participants in the study engaged in asking questions and making predictions based on their understanding. The inquiry model typically engages students in the scientific process through lab-based science. However, that is not always possible in a science classroom; though through developing inquiry skills students are able to make it possible by asking questions, making predictions on their questions, and making observations.

In the study, the goal was to increase inquiry skills. Through this increase, it was predicted that students would make more connections to the content and would be able to show their understanding. While there was no statistical difference in the achievement of students measured in a unit assessment. This assessment did have its flaws. It was not an assessment of a pre and post unit; it was an assessment measured of the unit prior and the unit after the intervention. While related topics were not the same and students may not perform the same way. Students in the study did show achievement in other ways. Through asking more questions and changing the types of questions students asked, students showed their understanding of the content through higher-order thinking. In Bloom's taxonomy with the type of questions, they are asking, they have shown that they are analyzing and evaluating the content instead of remembering specific terms and understandings.

Conclusions and implications

The goal of this study was to look at how science education helps to build an informed community of learners. Scientific literacy and achievement in science education are connected to students asking questions and developing inquiry skills as part of critical thinking. While scientific literacy and inquiry cannot be measured in a classroom study looking at the questions students ask and their achievement with their content can be

measured. In the first research question of the study *Does learning guided inquiry skills lead to asking more questions in class and asking questions aligned with the topic of the class?* The findings of this study found that yes practices around questioning scientific phenomena in a topic of study with a specific focus on inquiry skill development do lead to students asking more questions and better questions. This question can be extended to look at in future research how do students feel about asking better questions. and can revising questions help them think deeper about the topic of study. In addressing student achievement with the second question *Does learning guided inquiry skills lead to achievement in content?* this study's findings did not show any increase or decrease in students' achievement.

Limitations

One of the limitations of this study was the timing of the study. This study only lasted for three weeks covering one Unit of learning. If the study had been longer more data could have been collected looking at and potentially identifying themes and trends of students' growth of inquiry skills and achievement in one unit and over the course of the study. Additionally, the timing of the study was in the middle of the school year when the student's classroom procedures had already been developed. Students work on QFTs and investigate scientific phenomena prior to this study. If the study had taken place at the beginning of the year more observations could have been made as well as routines surrounding the warm-ups would become commonplace in the classroom setting and could have been less disruptive.

Another limitation this study faced was how achievement was measured in the intervention. The Study compared students' assessment scores for a prior unit to the study as the baseline data instead of having a unit pre-test being given to students. Potentially a more accurate depiction of students' achievement and growth could have been measured if there had been a true pre and post-test.

Implications

For teachers this study can be a tool to understand and implement the QFTas a tool for students to use in developing their own inquiry skills. This study also can be used in developing methods of inquiry for students allowing them to create their own questions and revise them to make them better and dive deeper into the content. Critical thinking and inquiry go hand in hand with one another but so does incorporating students' feelings toward asking questions. Writing questions down to look deeper into a topic is one faction of inquiry; another is to ask questions when the topic is not clear. Future research could potentially look into how verbalizing questions when confused can impact students' learning. Inquiry in science can lead to critical thinking and better questions can bridge the gap between thinking about science to being scientifically literate learners and members of a global community.

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Appendix A.

Name: Date: Period:

Content: _____

Unit ____: _____

Phenomenon Introduction

A phenomenon is an event that occurs or exists in nature that can be explained scientifically.

1. (*Insert directions for accessing the phenomenon here*)
2. You will now produce questions about the ***phenomenon*** you observed. Before you write down your questions, here are some rules to follow:

> **1. Ask as many questions as you can.**
>
> **2. Do not stop to answer, judge, or discuss the questions.**
>
> **3. Write down every question exactly as you think of them.**
>
> **4. Change any statements you write down into questions.**

3. **DIRECTIONS:** In the table below:
   a. Write your questions about the phenomenon.
      i. Write as many questions as you can.
   b. Read the following information:
      - Closed-ended questions can be answered with a "yes" or "no" or with a **one-word** answer.
      - Open-ended questions require an **explanation.**
   c. Mark the questions that are **closed-ended** with a C, and mark the questions that are **open-ended** with an O.
   d. Revise any **closed-ended question** and make it into an **open-ended question**. Write your reworded questions in the *Revised Closed/Open-Ended Questions* column.
   e. Review your list of questions.
      i. Choose **ONE (1) open-ended** question that will *best* help us understand or study this ***phenomenon***.
      ii. Write the question down on a post-it given to you by your teacher.
   f. Add your one (1) priority question to the Driving Question Board.

Questions (Don't judge, just write exactly what you think of, but remember, questions end with a "?".)	**Closed/ Open-**	**Revised Closed/Open-Ended Questions** (Turn any closed questions into open questions)	**Identify If your question is**

		Ended (*mark C or O*)		**aligned with the Unit** *(mark Y or N)*
1				
2				
3				
4				
5				
6				
7				
8				

9				
10				

Write Your Priority Question Here… (This is the question you are most interested in investigating in this unit it can be either open or closed)

Appendix B.

Score	Type of question
1	Closed-ended questions, Not aligned with the unit or topics in class discussion
2	Open-ended questions, Not aligned with the unit or topics of class discussion
3	Closed-ended questions, Thought out and aligned with the unit, or class discussions
4	Open-ended questions, aligned with the unit or topics of class discussion. well thought out

Appendix B.

Student Survey

	Strongly Disagree	Disagree	Agree	Strongly Agree
I understand what is going on in the unit and how it relates to our phenomenon.	□	□	□	□
I ask questions during class.	□	□	□	□
Whenever I am confused in class I ask questions to help me understand.	□	□	□	□
I feel asking questions Helps me understand what we are talking about/ doing in class.	□	□	□	□

What are the benefits or drawbacks of asking questions?

What are the benefits and drawbacks of being scientifically literate?

Do you think the warm-ups we did should continue (specifically the video warm-ups) why or why not?