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CONTENTS

Assessing and Overcoming the Barriers Impeding Inquiry Based Education

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Abstract:

This case study aims to 1) assess the relationship between teachers' conceptions of inquiry and the number of perceived inquiry barriers and 2) provide solutions to overcome the inquiry barriers perceived by teachers in the case study. Though no relationship was discovered there were important trends in the concepts and barriers analyzed. Perceived inquiry barriers can prevent teachers from implementing inquiry using the barriers as evidence for why the methodology is not effective. It is essential that teachers are provided professional development opportunities to overcome the barriers of inquiry in order to provide students with authentic learning experiences.

INTRODUCTION

The drive for an educational revolution stems from Paulo Freire's call for students to have a voice in their education, rather than the typical teacher-directed education which deposits recall knowledge into the "bank" known as students' brains (Freire, 1970). Morrison (2014) states that throughout the United States, high school teachers are expected to move away from just depositing information and instead implement inquiry into the science curriculum as required by the National Science Education Standards and the Ohio Department of Education.

Inquiry instructional standards can help ensure that teachers provide students with an opportunity to experience and explain phenomena that occur naturally around them (Rascoe, 2010). The result of inquiry teaching allows students to ask questions about the real word, develop experiments, and analyze different explanations for the data they gather (Mumba, Mejia, Chabalengula, & Mbewe, 2010).

Morrison (2014) states it is essential for inquiry to be authentic to students. This means students' questions and investigations should be derived from their own personal experiences while their teachers are merely acting as a facilitator (Myers, Myers, & Hudson, 2009). The scientific processing skills (Ergul et al., 2011) and problem solving skills students develop when immersed in authentic inquiry are beneficial to their lives (Burton & Frazier, 2012). These skills aid in the development of becoming participatory citizens by making personal and politically-based decisions (Hart, 1997); further preparing students for life outside of high school and life in the real word.

Levels of Inquiry

There are four different levels of inquiry which can be embedded into science investigations ranging from closed to open inquiry such as: confirmation, structured, guided, and open-ended (Mumba et al., 2010). Confirmation inquiry is the lowest level of inquiry as it is a teacher centered approach in which students follow cookbook procedures to complete a science investigation (Gengarelly & Abrams, 2008). Open-ended inquiry is the highest level of inquiry as it is a student centered approach in which students develop the investigation, methods and form conclusions based on data analysis with the teacher as a facilitator (Gengarelly & Abrams, 2008). Hart (1997) illustrates that the highest level of student participation is achieved when students initiate their own research and share the responsibility of decisions in learning with the teacher in the classroom consistent with open-ended inquiry.

Issues with Inquiry Education

Freire (1970) suggests that in order to cease student oppression the solution is to transform the structure of education through inquiry, such that students can be free from the marginalization of traditional teaching. The goal of education reform in America is to progress from passive to active learning through inquiry based teaching as describe in the NSES and ODE standards. Despite inquiry being a science education standard by ODE and NSES, many teachers do not implement it for multiple reasons (Ohio Department of Education, 2011; Lotter, Rushton, & Singer, 2013; Morrison, 2014; Gengarelly & Abrams, 2008) even though teachers recognize the effectiveness of inquiry as a teaching approach (Gengarelly & Abrams, 2008). Koballa, Dias, and Atkinson (2009) concur by stating that numerous barriers exist that thwart teachers from implementing inquiry in the

classroom. Barriers such as: standardized testing, availability of resources, lack of time, student incapability, loss of classroom management, and lack of professional or personal inquiry experiences.

These inquiry barriers can alter a teacher's conception of inquiry resulting in the abandonment of inquiry based teaching in high school classrooms. Ozel & Luft (2013) suggest that a direct correlation exists between teachers' conceptualization of inquiry and its implementation in the classroom. Evidence from Ozel and Luft (2013) year long study showed that science teachers with closed inquiry conceptions also practice closed inquiry instruction in the classroom with little growth during the school year. This paper aims to review the barriers of inquiry that impede its implementation by describing a case study I conducted in 2015 assessing conceptions of inquiry based teaching.

Methods

In order to investigate the impact of teachers' inquiry conceptions and inquiry implementation in secondary science education, quantitative data was collected in the form of questionnaires. This case study aims to determine whether a relationship exists between teachers' conceptions of inquiry and the number of inquiry barriers perceived in the classroom. It is expected that the more negative the conceptions of inquiry the more inquiry barriers will be perceived and the more positive the conceptions of inquiry the fewer inquiry barriers will be perceived.

Population and Sampling

The investigation was conducted in a school district located in southeast Cincinnati, Ohio in collaboration with two suburban public high schools, with a population consisting of secondary educators. A total of 120 teachers provide services to students while 17 teach science as a core subject. The grade levels and subject taught by each science teacher are dependent on certification and course content availability.

Participants

Of the total population of science teachers, seven volunteered to participate creating the sample of this investigation. There was both a quantitative and qualitative part of the investigation, which included the survey based questionnaire and the classroom observations respectively. Seven

teachers participated in the quantitative portion of the investigation through completion of an online survey while zero teachers volunteered to participate in the qualitative portion of the investigation, classroom observations; therefore the classroom observation methods was omitted from the paper and no qualitative data was gathered.

Data Collection

The first objective of the investigation was to measure teachers' conceptions of inquiry by dispersing a survey based questionnaire to collect quantitative data. The science teachers were given the survey electronically through Google forms. The survey consists of 29 items, in which 20 used a 5-point Likert scale with the following options: 1) Strongly Agree, 2) Agree, 3) Neutral, 4) Disagree, and 5) Strongly Disagree. The key features of inquiry were reworded to form the 20 likert questions in the survey distributed to the science teachers. These questions were created from and used to measure participants' conceptions of inquiry using the "essential features of classroom inquiry and their variations" rubric adapted from the National Research Council (NRC) (2000) (Appendix A). One question allows survey participants to quantify the barriers that impede inquiry-based education, which was used to assess possible explanations for negative inquiry conceptions (Koballa, Dias, & Atkinson, 2009). Of the remaining questions, one question identifies consent for participation, six questions gather demographic information, and one is open ended for comments regarding inquiry.

Analysis

The "essential features of classroom inquiry and their variations" rubric (NRC, 2000, p. 29) was utilized to assess survey responses to identify each teacher's conceptions of inquiry. Each block from the "essential features of classroom inquiry and their variations" rubric (NRC, 2000) represented the key features of inquiry. To analyze the survey responses, each answer to the 20 Likert questions was compared to the "essential features of classroom inquiry and their variations" rubric aligned with each key feature (NRC, 2000). A circle on the "essential features of classroom inquiry and their variations" (NRC, 2000) rubric indicated their acceptance of a key feature of inquiry. Each key feature of inquiry had responses for each variation of inquiry such as: variation A indicated open inquiry, variation B indicated guided inquiry, variation C indicated structured inquiry, and variation D indicated verification inquiry. From variation A to variation D student centeredness decreases as teacher directedness increases (Appendix A).

Science teachers with a positive conception of inquiry would agree with the statements under variation A and variation B of the "essential features of classroom inquiry and their variations" rubric (NRC, 2000) while disagreeing with more statements under variation C and variation D. Science teachers with a negative conception of inquiry would agree with the statements under variation C and variation D of the "essential features of classroom inquiry and their variations" rubric (NRC, 2000) while disagreeing with more statements under variation A and variation B.

Results

Conceptions of Inquiry. Seven teachers responded to the survey administered to the 17 teachers in the science department. Four of the seven were females while the remaining three were males. Due to the zero participants for classroom observations, only the survey was used to evaluate the conceptions of inquiry.

During the analysis of each Likert question, some of the teachers agreed with multiple statements for each key feature of inquiry indicating support of multiple variations of inquiry. In this case, any statement in which a teacher strongly agreed negated all other agreed upon statements. A teacher's conception of inquiry was determined based upon how many strongly agreed or agreed upon statements there were per each variation of the "essential features of classroom inquiry and their variations" rubric (NRC, 2000). According to this analysis method, there were: five teachers with conceptions aligning with variation A, open inquiry; one teacher with conceptions aligning with variation C, structured inquiry; and one teacher in which the results were inconclusive because all responses were in agreement with each statement of the "essential features of classroom inquiry and their variations" rubric (NRC, 2000).

Table 1: The Variations of Inquiry and Teachers' Conceptions

Variations of Inquiry	Teacher 1	Teacher 2	Teacher 3	Teacher 4	Teacher 5	Teacher 6	Teacher 7
A (Open)	x	x		x		x	x
B (Guided)							
C (Structured)			x				
D (Verification)							

Three teachers offered comments when asked if there are other thoughts or feelings regarding inquiry that was not targeted in the survey. Teacher 1 stated, "[inquiry is] a time consuming technique and we need to spend lots of time to teach the students this strategy from the grade school all the way to high school." Teacher 3 discussed the implementation of inquiry as independent subject dependent stating, "In chemistry, it is much more difficult to allow the students' to pose his/her own questions to test and give them the freedom to work with chemicals. Through guided experiments, they still have freedom to collect and process data. [Students] still need to be able to analyze the data and draw conclusions based on scientific evidence."

Teacher 4 identified the same concern as Teacher 1 in which students lack the practice needed to understand and complete inquiry activities. Teacher 4 states,

> *"I find that students do not have enough "practice" learning through inquiry to fully implement this style of teaching in my classroom. While I frequently use POGIL (Process Oriented Guided Inquiry Learning) assignments to begin units, as far as laboratory activities go, inquiry-based learning can be a challenge. Students do not know where to begin or how to continue when presented with a true inquiry lab. It is my experience that most students even have great difficulty following a "cookie-cutter" laboratory activity where procedures are fully communicated in the lab procedure. My honors students, though, seem to do better when asked to manipulate a lab variable or create their own experiment. Consequently, I think the biggest barrier to inquiry implementation is low-performing students (and lack of experience)."*

The reflections from Teachers 1, 3, and 4 indicate that despite the analysis of each survey using the "essential features of classroom inquiry and their variations" rubric (NRC, 2000) negative conceptions of inquiry are still present in two of the five teachers considered to have conceptions that align with variation A, the most student centered variation. Teacher 7, one of the three remaining teachers in variation A, holds a more positive conception of inquiry stating, "Inquiry-based teaching is a wonderful approach to student-centered learning." However, teacher 7 recognizes that there are barriers in place that can prevent a teacher from always using inquiry stating, "a teacher must cover a specific amount in content in a given amount of time, it becomes difficult to devote the time to the process."

Barriers of Inquiry

In this case study of only seven teachers, there was no correlation between the number of inquiry barriers and conceptions of inquiry although trends were noted. A large sample size may

results in a correlation between the number of inquiry barriers and conceptions of inquiry. Table 2 illustrates each teacher's perceived barriers to inquiry. It is evident from the data table that all seven teachers perceive time constraints as a barrier to the implementation of inquiry and all seven teachers do not perceive that the reason inquiry is not implemented in science classroom is due to the teachers inability to understand how to implement inquiry or the lack of professional development regarding inquiry based teaching. It is also important to note that Teacher 7, who provided the most positive and open conception of inquiry due to the comments on the open ended portion of the survey, only noted one barrier, time.

Table 2: Perceived Barriers Implementing Inquiry in the Science Curriculum

Inquiry Barriers	Teacher 1	Teacher 2	Teacher 3	Teacher 4	Teacher 5	Teacher 6	Teacher 7
Limited Material and Resources		x	x	x			
Time Constraints	x	x	x	x	x	x	x
Loss of Classroom Management		x	x				
Low Performing Students	x		x	x		x	
Pressure of High Stakes Testing		x		x	x	x	
Lack of Professional Development							
Lack of Understanding							

Discussion

Barriers of Inquiry Based Education

Limited time and classroom resources. Three of the seven teacher saw that classroom resources were a barrier to inquiry while all seven teachers noted limited time as a barrier to inquiry education suggesting a commonality in all the potential barriers. Lotter, Rushton, and Singer (2013) conducted a year long study following 36 teachers in which each teacher implemented inquiry based lessons into their classrooms succeeding a two-week professional development session during the

summer. Workshops were provided throughout the school year and teachers were observed twice during the academic year yet the teachers considered to have more negative conceptions of inquiry, stated that lack of time and materials prevented them from using inquiry in their classrooms throughout the year (Lotter et al., 2013). This claim is supported by Morrison (2014) who conducted a similar study in which participants frequently mentioned time as a constraint as well as limited materials for students to use to continue exploring concepts following lessons.

Classroom management

Two of the seven teachers found classroom management to be a barrier for inquiry implementation. Many teachers fear that using inquiry means losing control over classroom management (Gengarelly & Abrams, 2008). This was expressed by a teacher in Morrison's study (2013), who stated that she loses complete control over the class when allowing students the freedom to explore content further through inquiry. However, Morrison (2013) notes that the teachers in her study most afraid of classroom management issues were the teachers that implemented the least inquiry in the classroom.

Low academically performing students

Four teachers of seven found low academically performing students as a barrier for implementing inquiry in their classroom. This suggests that teachers stray from using inquiry in the classroom because students are not considered high level performers resulting in low student motivation and further classroom management issues. Teachers who tend to marginalize students' academic abilities see inquiry as something done to students rather than a process carried out by the students (Koballa, Dias, & Atkinson, 2009). A teacher in Lotter, Rushton, and Singer's (2013) study stated that her students skills are so low that she had to instruct them what to do rather than guide them, suggesting students prefer to be told what to do rather than think for themselves (Mumba, Mejia, Chabalengula, & Mbewe, 2010). Due to the pressures of adapting to inquiry practices, some students grow frustrated causing adverse reactions to inquiry such as insecurity, confusion, and rebellion (Heppner, Kouttab, & Croasdale, 2006) which increases the burden of classroom management on the teacher (Geier et al., 2007).

Pressure of high stakes standardized testing

At a National Science Teacher Association Convention in Georgia, session leaders recognized that increased high stakes testing is a common barrier preventing teachers from implementing inquiry (Koballa, Dias, & Atkinson, 2009). Four of the seven teachers in this case study agreed that high stakes testing was a barrier of implementing inquiry. High stakes testing creates pressure on teachers and administrators as state funding is allocated and statutory accreditation is based upon student's tests scores (Geier et al., 2007) resulting in teacher directed instruction, termed "teach to test" to raise test scores rather than achieve content understanding (Blanchard et al., 2010). A teacher in Morrison's study (2013) stated that inquiry uses more time and limits the amount of content covered per lesson, placing them behind the district curriculum pacing guide for end of the course exams. Even teachers considered emerging enactment teachers, a higher conception of inquiry, in Lotter, Rushton, and Singer's (2013) study, feared meeting the standards required for high stakes tests, suggesting that high stakes testing worries teachers who are successfully implementing inquiry and thwarts other teachers from trying to implement it.

Lack of professional development and scientific inquiry understanding

A review of the 10 most highly recognized government-based reports on inquiry as education reform by Burton and Frazier (2012) revealed that teachers need year round support in the implementation of inquiry based teaching methods. Similar results were founded from the review of the NSTA session leaders; 50% of the session leaders noted that teachers are inexperienced with inquiry and therefore are uncomfortable teaching inquiry, ultimately ignoring inquiry based teaching methods in the classroom (Koballa, Dias, & Atkinson, 2009). To implement inquiry, teachers must overcome a series of obstacles such as: the addition of a new teaching role, content knowledge, and skills (Jones & Eick, 2007). Without professional development and ongoing support throughout the academic year inquiry teaching methods are often ignored due to the teacher's lack of comfort. Comfort levels continue to decline when teachers experience a lack of support and understanding from the administration level, jeopardizing teacher's confidence in trying a new teaching method such as inquiry (Morrison, 2013).

Pozuelos, Gonzales, and Canal de Leon (2010) found variance in teachers' professional development suggesting the departments of science teachers are not homogeneous in their ability to implement inquiry. Though variance in professional development exists, none of the seven teachers

in this case study thought they lacked the professional development or understanding as a barrier impeding the implementation of inquiry based instruction. A study by Kazempour (2009) found that teachers needed effective inquiry-based professional development opportunities to affect the conceptions of inquiry-based teaching and increase its implementation in the classroom.

None of the seven teachers in this case study thought they lacked the experience or professional development needed to implement inquiry. Is it possible that teachers think they have the experience needed to implement inquiry or do teachers not want to admit that they lack the experience needed to implement inquiry? Or did previous professional development sessions address the barriers of inquiry and provide solutions for how to overcome those barriers to effectively implement them?

Overcoming Barriers of Inquiry

Low academically performing students

It is possible that the first time a teacher tries inquiry in their classroom that it is the first time the students have been exposed to this teaching method. Hart (1997) urges teachers that it takes time to shape and develop students to successfully implement inquiry as noted by his hierarchical ladder of organizational principles defining the levels of student participation. Heppner, Kouttab, and Croasdale (2006) also suggest teachers considered developmental levels of students for at earlier levels, students cannot recognize that knowledge is experimental and the teacher is a facilitator rather than just the expert (Freire, 1970). This results in teachers avoiding inquiry, accrediting its failure to their students inability to "do" inquiry. Even though this barrier exists, Griset (2010) urges teachers to use inquiry in the classroom stating that students may not respond to it at first but after time inquiry becomes routine. Routine in any classroom creates a safe and successful environment for students to learn and grow accustomed to inquiry based teaching.

Resources and high stakes testing

Teachers can gain professional support through curriculum based programs to assist with providing inquiry learning experiences to students which are aligned with state and national standards ensuring standards are met for high stakes testing. The Center for Learning Technologies in Urban Schools (LeTUS) developed learning technologies along with supplementing curriculum design, development, and enactment while providing professional development to teachers (Geier et al.,

2007). LeTUS provided Detroit Public Schools (DPS) a series of 8- to 10-week units on air quality, water quality, and Newton's Laws (Geier et al., 2007).

Curriculum based inquiry units along with professional development for proper implementation provide teachers with a supportive structure and the resources needed to implement inquiry (Jones & Eick, 2007). Geier et al. (2007) conducted a three year study working with LeTUS and DPS which impacted 37 teachers and approximately 5,000 students enrolled in 18 different middle schools. Concluding each academic, year all students in DPS participated in the Michigan Education Assessment Program (MEAP), which are considered high stakes tests in the state of Michigan affecting the accreditation and funding of all Michigan Schools (Geier et al., 2007). Results compare students involved in LeTUS units to other DPS students not taking LeTUS units. Cohort 1 took the MEAP 2000 test and had a 19% increase in passing rate while Cohort 2 took the MEAP 2001 test and had a 14% increase in passing rate compared to other DPS non- LeTUS students (Geier et al., 2007).These results suggests that inquiry does not hinder high stakes testing score but increases the likelihood to pass compared to other students who lacked inquiry teaching methods. Also discredited by these results is the fact that students have to be of high performance to successfully "do" inquiry. Many of the students in the DPS district have a substantially high amount of student dropout rates and low performing at risk students.

Professional Development.

Bottom-Up Approach. The purpose of professional development is to implement ideal teaching methods to actual classroom experiences (Jones & Eick, 2007). However, many professional development sessions tend to focus on a top-down approach, which is defined by Jones and Eick (2007) as a lecturer discussing curriculum and pedagogy. In order to obtain sustainable education reform through inquiry based teaching, professional development sessions must utilize a bottom-up approach, focusing on pragmatic issues (Jones & Eick, 2007) conceived as inquiry barriers. Lotter, Rushton, and Singer (2013) also state that successful professional development sessions take account of teacher's beliefs and transmit those beliefs into classroom practice. As Butron and Frazier (2012) indicate the need for students to experience authentic learning through inquiry Morrison (2013) states it is vital for teachers to experience authentic inquiry themselves to achieve education reform and potentially alter the negative connotation associated with the term inquiry.

Collaboration. An overwhelming amount of evidence suggests that professional development of inquiry methods are most successful when teachers partner with scientists, professors, curriculum programs, and other teachers. In a study conducted by Morrison (2013), high school teachers job shadowed scientists and interviewed scientists about their views pertaining to: the nature of science, science education, and the importance of students learning science. When teachers were not observing scientists, teachers and scientists both participated in group discussions, authentic inquiry activities, and designing inquiry based lessons. Concluding the professional development summer program teachers attended follow-up workshops in which scientists would assist in small group discussion and continued a bottom-up approach of authentic inquiry activities (Morrison 2013). The comparison of Views of Scientific Inquiry (VOSI) survey supports partnering professional development with scientists as 43% of teachers had a good, great, or outstanding view of scientific inquiry on the pre VOSI Survey moved to 100% on the post VOSI survey (Morrison, 2013).

Similar results were found in Jones and Eick (2007) where professional development programs provided opportunities co-teaching in the classroom with collaboration of a pre-service teacher, in-service teacher, and a university professor enhancing learning through inquiry activities. Results from this collaboration illustrate efficient management of the following: materials, class time, students, and complex procedures or apparatuses (Jones & Eick, 2007). The relationship between the preservice and inservice teacher enriched the scientific content of each lesson as preservice teachers had different backgrounds in education than their inservice teachers thus deepening student learning (Jones & Eick, 2007). In the current education of preservice teachers, they are encouraged to make connections to learning inquiry as a student and teaching inquiry as a teacher (Kang, Bianchini, & Kelly, 2013), which many inservice teachers lack due to changing professional development practices to meet inquiry based reform in universities. Co-teaching alleviates the perceived challenges derived from implementing inquiry and enables learning to go beyond instruction which engages students and deepens their learning (Jones & Eick, 2007).

Conclusion

Inquiry-based education aims to reform current teaching practices to provide students with authentic learning experiences of real world phenomena and an opportunity to develop explanations through scientific investigations. Despite the research recognizing the many benefits of inquiry based education, teachers are choosing to forgo inquiry teaching practices for more teacher directed

methods. There are pragmatic issues that teachers face when implementing inquiry that often form barriers ceasing inquiry practices. The barriers that impede inquiry implementation can be overcome through appropriate professional development sessions in which teachers experience authentic inquiry themselves. Partnership with scientists and collaboration with co-teachers alter teachers views on inquiry and ensures the effectiveness and sustainability of inquiry teaching. When professional development includes curriculum based resources it not only provides specific and well developed support for teachers implementing inquiry. These resources also raise high stakes test scores improving school districts' ratings. Professional development has the opportunity to empower teachers, supporting their efforts to successfully implement inquiry without barriers to sustain authentic learning experiences for students. Though the teachers in this study may believe they are above the norm in terms of professional development, the trends found among the seven teachers that participated in the case study should be examined further on a larger scale.

Appendix A:

Essential Features of Classroom Inquiry and Their Variations (adapted from NRC 2000)

The variation in each box are the different ways that the essential features of inquiry might be demonstrated in student investigations.
The observer will circle the variation that was most prevalent in the lesson.

Key Features of Inquiry	Variation A	Variation B	Variation C	Variation D
Student engages in scientifically oriented questions.	Student poses a question.	Student selects among questions and poses new questions.	Student sharpens or clarifies questions provided by the teacher or materials and other resources.	Student engages in a question that is provided by the teacher or materials and other resources.
Student gives pirority to evidence in responding to questions.	Student determines the evidence to be collected and how to collect it.	The student is directed to collect certain data by the teacher.	The student is given data and asked to analyze it.	The student is given data and told how to analyze it.
Student formulates an explanation from the evidence collected.	Student formulates an explanation after summarizing evidence.	Student is guided in the process of formulating an explanation from the evidence.	The student is given possible examples to use evidence to formulate an explanation.	The student is provided with evidence only.
Student connects explanations to scientific knowledge.	Student independently examines other resources and forms connections to scientific knowledge.	Students are directed toward areas and sources of scienctific knowledge.	The student is given possible connections.	The student is told possible connections.
Student communicates and justifies explanation.	Student forms a reasonable and logical argument to communicate an explanation.	Students are coached in the development of communication.	The student is provided broad guidelines to sharpen communication.	The student is given a series of steps and procedures for communcation.

Teacher Centered
Student Centered
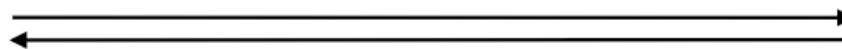
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