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Examining the Understanding of Inquiry-Based Learning and Teaching Among Undergraduate Teachers and Students

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Examining the Understanding of Inquiry-Based Learning and Teaching Among Undergraduate Teachers and Students

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ABSTRACT

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One of the main aims of inquiry is to engage students as active, not passive, participants in science. The purpose of this study is to describe science educators' and students' views about inquiry-based instruction in order to better understand and improve implementation of evidence-based teaching strategies. Inquiry-based techniques have been shown to improve student understanding of scientific concepts, yet, there continue to be challenges in implementing these techniques. This research project utilizes Q Methodology, a research method that captures both common and disparate measures of subjectivity, to identify commonalities and defining viewpoints about inquiry-based teaching and learning. Three significantly different viewpoints were identified and each viewpoint represents differences in teaching styles and classroom environments. Additionally, consensus items reveal students and instructors highly value relating science to everyday life; however, a lack of importance is placed upon peer learning and use of open-ended questions.

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CHAPTER 1

INTRODUCTION

Inquiry-Based Instruction

Inquiry-based instruction relies on students' use of scientific knowledge to ask questions, collect data, analyze evidence, and develop explanations and then communicate that information to peers (National Research Council 1996). Depending on classroom dynamics or students' background an instructor may employ structured, open, or guided inquiry.

When using structured inquiry, educators provide students with broad research questions with examples of methods that can be used to answer these questions. Students are not informed of expected outcome, but instead expected to answer the research questions and analyze and evaluate the results (Colburn 2000). Structured inquiry can be used in introductory level courses where students have not yet developed the necessary skill to work more independently.

Inquiry can also be guided in which the educator provides students with the initial research question, but allows the students to define their own methods. The educator's purpose is to be a facilitator for the students when they have questions, but it is not to be the primary source of information. In this type of inquiry, students are also required to analyze and evaluate their own results (Kuhthau et al. 2015). Guided inquiry is frequently used within laboratory courses where students are given a common problem, but must create their own hypotheses and experimental design.

Authentic inquiry instruction relies heavily on the student and places them in total charge of the learning process. Students will establish their own research question, define methods to answer that question, and analyze and evaluate data gathered through their methods (Colburn 2000). Individuals will create their own projects based upon independent research and carry out experiments. Many third and fourth year students who participate in undergraduate independent research with a faculty member are engaged in authentic inquiry.

Some examples of large-scale inquiry-based techniques used in the class room today include Process Oriented Guided Inquiry Learning (POGIL), Course-based Undergraduate Research Experience (CURE), and Research Experience for Undergraduates (REU). POGIL originated in college chemistry departments in 1994, but now has more than 1,000 implementers in a wide range of disciplines in high school and colleges around the country (Moog et al. 2006). POGIL is a classroom and lab technique that seeks to teach content and key process skills such as the ability to think analytically and work effectively as part of a team. Implementation of POGIL consists of any number of students working in small groups on specially designed guided inquiry materials. These materials supply students with data or information followed by leading questions designed to guide them toward formulating their own valid conclusions. The instructor serves as a facilitator, observing and periodically addressing individual and classroom-wide needs (Moog et al. 2006).

Course-based Undergraduate Research Experiences (CUREs) are another implementation of inquiry learning (CUREnet 2017). CURES are becoming more widespread among biology departments and courses as a means of helping students understand core concepts in biology, develop core scientific competencies, and become active, contributing members of the scientific community. CUREnet is a web-based program that organizes in-person meetings to establish these projects. Individuals are assembled with diverse expertise (instructors, researchers, information technology specialists) who represent diverse institutions and a variety of projects in terms of data (genomic, phenotypic, ecological). Through this web portal, students can browse current projects or propose their own. The Science Education Alliance (SEA) is currently offering a program in which students identify and characterize bacteriophages from their local surroundings, annotate the phage genomes, and submit the annotated sequences to the National Center for Biotechnology Information GenBank database (SEA 2017). This program, SEA-PHAGES, is a national research-based lab course targeting early education science students. During the 2016-17 year "more than 4,100 mostly first-year students from 100 different colleges and universities took part in [SEA-PHAGES], generating more than 20 peer-reviewed publications" (SEA 2017).

Research Experience for Undergraduates (REU) is another inquiry-based program sponsored by the National Science Foundation that supports active research participation by undergraduate students in any of the areas of research funded by the National Science Foundation (NSF 2017). The areas of research funded by the NSF are quite vast, literally ranging from A to Z with every science in between. This program gives students an opportunity to engage in inquiry based upon their own proposals.

Inquiry instructions comes in many different forms, but always relies on students' ability to ask questions, gather data, analyze evidence, develop explanations, and then explain this information to others.

Science Process Skills

Science process skills are defined by a set of broadly transferable abilities that are used in several science occupations and indicative of real scientists' behavior (Padilla 1990). Science process skills include more basic skill sets which provide a foundation to understanding science as an investigative process and include more complex skill sets in which basic science processes are applied to synthesize new knowledge and formulate new questions.

Basic processing skills include observing, inferring, measuring, communicating, classifying, and predicting. More complex skills are controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, and formulating models (Padilla 1990). Knowledge of basic science processing skills will be essential to reach more complex skills which define actual scientific research. These skills are necessary to succeed in not only scientific occupations, but also other disciplines such as technology, engineering, and mathematics. These areas will require the use of scientific analyses, argumentation, engineering design, and communication (National Research Council 2012).

There is a need for broad reforms across K-16 science education in order to develop a growing STEM workforce and inquiry-based instruction provides a means to help students develop necessary problem-solving and critical thinking skills. In several classrooms, science education practices do not give students the skills needed for developing scientists (Drake and Long 2009). Many science courses focus on memorizing facts and increasing content knowledge, but do little to promote and develop problem-solving skills (Furtado 2010). For students to excel in science courses, science processing skills need to be emphasized over memorization of facts (Aydeniz et al. 2012). When students can examine, reason, and unify information through inquiry learning, they are better able to gain new knowledge (Minner et al. 2010; Graham and Retinger 2012).

If the United States is to continue to be economically competitive then the nation must create a strong STEM-capable workforce (National Science Foundation 2015). One report has found that if sub-baccalaureate STEM workers are included, then there may be as many as 26 million jobs in the U.S. that require significant STEM skills, representing 20% of all U.S. jobs (National Science Foundation 2015). The U.S., however, has one of the lowest ratios of STEM to non-STEM bachelor's degrees among developed nations (National Science Board 2014). This study aims to better understand how instructors utilize inquiry-based strategies in hopes of improving the opportunities that students have to develop essential STEM skills.

Crosscutting Concepts

Framework for K-12 Science Educators (2012), was published to help address the problems of defining inquiry. They argue that science education is not organized systematically across multiple years of school, emphasizes discrete facts with focus on breadth over depth, and does not provide students with engaging opportunities to experience how science is done. The Framework is designed to directly address and overcome these weaknesses. Students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves. Actively participating and performing work as a scientist or engineer can engage students' curiosity, capture their interest, and motivate their continued study.

The Framework addresses three major dimensions in which students need to be actively engaged. The first dimension is Core Ideas. These Core Ideas should come from physical science, life science, earth and space science, as well as engineering and technology (National Research Council 2012). The second of these dimensions is Scientific and Engineering Practices. Within this dimension; students need to be asking questions and defining problems, using models, planning and carrying out investigations, and analyzing and interpreting data. This dimension focuses on science processing skills discussed in the previous section. The third dimension is Crosscutting Concepts which focuses on concepts learned that unify the study of science and engineering through their common application across fields.

Crosscutting concepts integrate both content and skills which provides a knowledge-based context in which students can apply scientific skill sets. These concepts include patterns, cause and effect, systems and system models, energy and matter, structure and function, stability and change, and scale, proportion, and quantity. These concepts allow for students to have "an organizational framework for connecting knowledge from various disciplines into a coherent and scientifically based view of the word" (National Research Council 2012). By capturing the viewpoints of educators and students, we can better determine how well these kinds of polices translate into classroom practices and affect change in K-12 and undergraduate education.

Previous Results

The following study builds on a previously unpublished study conducted at a large research-intensive state university that used Q methodology to "uncover the viewpoints science educators at all levels of instruction have today and examine the types of inquiry activities incorporated in their courses" (Hiatt 2011). Within this previous work, three distinctive perspectives were found within the population of interest. Given the introduction of new science education policies and the rise in implementation of more contemporary teaching practices since the previous study, this study aims to better understand how viewpoints about inquiry-based strategies may have changed and seeks to tackle new and interesting information that undergraduate students may provide.

In the 2011 study, the first of the three viewpoints was defined as a "naïve teacher". These educators do not fully comprehend the nature of inquiry-based teaching and learning. They do not differentiate between active learning and inquiry. Most of the educators in this viewpoint are undergraduate pre-service teachers with very little experience teaching. When completing the Q sort, they usually chose 'buzzwords' such as engagement and active learning. When discussing hands-on activities within the classroom, they typically prefer ready-made kits as opposed to problem-based activities.

The second viewpoint was defined as “active learning, student-centered teacher”. These educators focus on student-centered activities such as individualized learning and improving critical thinking skills. They are similar to the naïve teachers in that they utilize active learning strategies more than authentic inquiry-based strategies. A common characteristic was that creativity is encouraged within the classroom. All educators within this viewpoint were found to have between 0 and 5 years of teaching experience and included K-12 and college instructors.

The final viewpoint described was the “experienced, problem-based teacher”. These educators typically use authentic scientific examples and problem-based teaching methods. Current research and literature are used to direct their teaching as well as understanding misconceptions students may have about their subject of interest. All educators within this viewpoint have some teaching experience, ranging from 2 to 21 years and included both K-12 and college instructors. Many of these educators also conducted scientific research.

Within these three factors there were also consensus statements, or statements upon which all participants agreed/disagreed. All participants agree that teaching science should focus on improving critical thinking skills. All participants neither agreed nor disagreed (remained neutral) when asked if their students were guided towards investigations and asked to provide explanations. All participants disagreed with statements regarding teaching inquiry using peer-mediated learning and discovery-based learning

This study was conducted in 2011 in response to the goals outlined in the *National Science Education Standards* (1996) as well as *Vision and Change in Undergraduate Biology Education: A Call to Action (*American Association for the Advancement of Science 2009). Within these documents, a need for teaching science to reflect the nature of scientific exploration was addressed by asking educators to incorporate inquiry into teaching and learning science. The results of this study provide a snapshot into the use of inquiry within the classroom.

Since this study, more documents and related polices have emerged supporting the use of inquiry-based teaching within the classroom (Minner et al. 2010; Freeman et al. 2014; Beck et al. 2014). Shortly after *Vision and Change (*American Association for the Advancement of Science 2009*)* another report, *Framework for K-12 Science Educators* (National Research Council 2012), was published to help address the problems of defining inquiry. They argue that science education is not organized systematically across multiple years of school, that it emphasizes discrete facts with focus on breadth over depth, and does not provide students with engaging opportunities to experience how science is executed. The framework is designed to directly address and overcome these weaknesses. Students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves. The actual doing of science or engineering can engage students' curiosity, capture their interest, and motivate their continued study.

Today an increasing number of important professions, including the fields of science, technology, engineering, and mathematics, will require applicants to use scientific analyses, argumentation, communication, and engineering design (National

Research Council 2012). Introducing science processes skills such as these is critical in educating a new generation to be competent employees in the 21st century workforce.

This current study is necessary to determine what changes have emerged in the past 6 years as momentum has increased in implementing evidence-based approaches to teaching and learning, particularly the use of inquiry teaching and learning within the classroom. Some changes have been made in relation to the population from which the original study was drawn. Within the current study, participants came from undergraduate educational fields. The current study also sampled both educators and students to determine if teaching instruction is perceived similarly between both groups.

Literature Review

In 2011, the *Vision and Change* (American Association for the Advancement of Science) report placed an emphasis on inquiry based teaching and learning. Inquiry based science needs to introduce scientific process early in education and integrate it into all undergraduate biology. Learning goals need to be clear and associated with core concepts. Some of these core concepts include: the ability to apply the process of science and quantitative reasoning, ability to use modeling and simulations, ability to tap into interdisciplinary nature of science, ability to communicate and collaborate with other disciplines, and the ability to understand the relationships between science and society. Students need to relate abstract concepts to real-world application on a regular basis. Educators are encouraged to cover fewer concepts with greater detail (American Association for the Advancement of Science 2011). Evidence-based approaches, such as active learning and inquiry, have been shown to be effective in science courses (Minner et al. 2010; Beck et al. 2014; Freeman et al. 2014).

Inquiry-based instruction has been studied on a large scale and found to have positive outcomes. The Inquiry Synthesis Project synthesized findings from research conducted between 1984-2002 to investigate what exactly is inquiry science instruction in k-12 in relation to student outcomes. Analysis of 138 studies indicate a clear, positive trend favoring inquiry-based instructional practices (Minner et al. 2010). Inquiry in K-12 education has been found to have positive effects in not only assessment scores, but also a student's comfort with the material. These effects, however, are not limited to k-12 education but can also be used in higher education.

Another review of 142 papers from 2005-2012 also indicated a positive effect of inquiry based teaching reforms on students learning of science (Beck et al. 2014). Most of the studies within this review were subdisciplines of life sciences where guided inquiry was used within the course. These studies were focused on undergraduate biology laboratory courses, supporting the use of inquiry through postsecondary schooling.

Freeman et al. (2014) conducted a meta-analysis of 225 studies comparing traditional lecturing versus active learning. From this analysis, they found that classrooms that implement active learning have higher student performance on examinations and concept inventories compared to traditional lecturing. This is one of the largest and most comprehensive meta-analysis of undergraduate STEM education published to date (Freeman et al. 2014). Undergraduate science, technology, engineering, and mathematics courses were examined within this study. Inquiry-based instruction has application in not only science courses, as the previous studies have examined, but also other STEM disciplines. These analyses raise questions about the continued use of traditional lecturing as a control in research studies and supports inquiry and active learning as the preferred, empirically validated teaching practice in the typical classroom.

Statement of Problem

Inquiry-based instruction has been shown to improve academic success and learning in STEM disciplines. In the past 15 years, many reports have asked STEM educators to integrate inquiry-teaching into their classrooms (National Research Council 1996, 2000, 2003, 2005, 2012; American Association for the Advancement of Science 2011). Education researchers have shown the value of inquiry-based instruction within the classroom, but it is unclear if this is the main form of teaching methodology within the current STEM classroom.

Objectives

The purpose of this study is to describe science educators and students' views about inquiry-based teaching and learning. Inquiry-based techniques have been shown to improve student understanding of scientific concepts, however, there are discrepancies in how educators define and implement these techniques in their classroom. The objectives of the current study are as follows:

- To determine the views of life-science faculty in regards to their use of inquiry-based teaching within the classroom

- To determine the views of science major students on the use of inquiry-based activities within the classroom.
- To determine the understood application and definition of inquiry based teaching in both educators and students.

Hypotheses

1. Trends will be observed in faculty as well as students that indicate multiple distinct viewpoints on the definition and implementation of inquiry-based learning within the classroom. If this is true, then analysis will reveal multiple factors of differing viewpoints related to inquiry and traditional teaching methods that students and faculty will be organized into.
2. Alternatively, if there is no trend in faculty or student experience on the viewpoints of the definition and implementation of inquiry-based learning then a one solution factor will be seen. This would indicate that there is no discernable difference between educators that use inquiry-based learning versus traditional lecture. This would also indicate that students are unable to detect the differences in teaching and learning experiences within the classroom.

CHAPTER 2

THEORETICAL FRAMEWORK

Influential Investigators

Learning has been a subject of investigation for as long as humans have been investigating themselves. In his works dating back to 400BC, the philosopher Socrates often used questions to guide his discussions. The Socratic Method, which is still in use today, is a form of classroom experience in which there is shared conversations between the learners and educators which are both in charge of maintaining the dialogue through further questioning. In this inquiry process the teacher is just as much a participant within the discussion as they are a guide (Reich 2003).

In the late 1600s John Locke's philosophy saw that the mind is a *tabula rasa*, or blank slate. He thought that at birth, the mind was a blank slate containing no pre-existing concepts. We are not born with knowledge, but instead it is only created by experience with the world through the senses (Locke 1689). In this viewpoint, the world must be experienced to attain knowledge and continue growth and learning. This idea of knowledge being gained through sense-experience gave rise to the philosophy of empiricism, from which the empirical method was later derived. This methodology is standardly used in the scientific method today.

The philosopher Jean Jacques Rousseu later built on the work of John Locke, and shared some of his ideas based on learning. He believed that education should be focused on experiences within the world, especially in relation to developing the senses, as opposed to being solely a consequence of lectures and reading (Rousseau 1979).

By learning from actual experience within the world, the child should be able to make inferences about situations they have not encountered from past situations in which they succeeded.

The commonality between Socrates, Locke, and Rousseau is the idea that learning and education should be student-centered. Learning does not usually take place in a silent space in which questions and discussions are absent. Knowledge is also not innate and must be gained by experiences with the world. Through these experiences, knowledge can be attained and later used to make inferences about future decisions. From these philosophers and their ideas of learning, more researchers began to investigate what can be defined as a student-centered learning approach.

John Dewey (1859-1952) was an American philosopher and educational reformer (Martin 2002). He was one of the founders of the philosophical tradition of pragmatism, a philosophy that emphasizes the practical application of ideas by testing those ideas in human experiences (Friesen 2014). In this view, to understand the world around the learner, the reality must be experienced. Children will have the highest amount of learning when they are interacting with their surroundings and are actively involved with the learning process.

In Dewey's view of a classroom, there is an equal voice between the educator and the students. The educator should not be seen as an instructor, but instead a facilitator of learning. Students need to be active partners in learning and should be able to link content to previous learning and experience. This does not just hold for one area of the curriculum, but instead encompasses a view that education should be interdisciplinary (Dewey 1916).   Dewey's ideas of student-centered learning can still be found today in methods of inquiry-based learning.

Zone of Proximal Development

Vygotsky was the founder of the cultural-historical theory of cognitive development. Though incomplete, the theory emphasized the large impact that an individual's culture plays in the development of higher mental processes. For children, cognitive development occurs through social interaction. In this view, interactions that children have with parents or educators guide the child in their learning. With the guidance of someone knowledgeable, the child will be able to perform much more complicated tasks than he or she would be able to alone. This knowledgeable individual is not always an educator, however, and can often be a parent, peer, coach, or relative.

A task that the child can do, but not without guidance from a more experienced individual, is said to lie in the zone of proximal development (ZPD). This area involves the skills that are too advanced for the learner to gain on their own, but can be attained with appropriate guidance.

The ZPD is the area in between what a learner can do with help and what a learner cannot do at all. This is an area in which a learner can do task, but requires guidance to do so. Vygotsky defined this as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peer" (Vygotsky 1978). Individuals learn best when working together. By working with an individual with a larger skill set, learners gain new concepts, psychological tools, and skills (Shabani et al. 2010). Effective instruction needs to be aimed at a learner's proximal zone of development, or as Moll (1992) called it "upper threshold of instruction". What a learner performs with guidance, the individual will later be able to do alone (Moll 1992).

Scaffolding

Though Vygotsky did not coin the term scaffolding, the concept of ZPD helps to form the basis of it (Daniels 2001). Bruner (1976) developed a theory of scaffolding in which learners need active support from more skilled individuals to learn new concepts. Early on, leaners are dependent on support, but as they acquire new skills and knowledge, the support can be decreased (Wheeler 2014). A teacher or knowledgeable student would help peers to organize and structure learning tasks for the new learner to complete the task effectively. This is the use of scaffolding within Vygotsky's ZPD. As students gain more knowledge and can perform more tasks alone, support can be gradually lessened throughout the course. This allows for students to be more involved with their own learning and to be able to think independently.

Post-Positivism

Post-Positivism is based upon empirical objectivity and mathematical certainty similar to positivism, however, it does not attempt to show causation and instead focuses on correlation (Lederman and Abell 2014). In a positivist perspective, research should be firmly supported by logical reasoning and empirical data that are self-evident and verifiable (Schwandt 2001). Post-positivism, however, admits that culture, personal value systems, and surroundings influence our perception of the world in positive and negative ways (Phillips and Burbules 2000). Rather than only relying on previous experiences, researchers aim to collect empirical data methodically and compare data objectively. Common methods of data collection would include comparative experimental designs or surveys designed to find correlational explanation (Lederman and Abell 2014). In this perspective, naturalistic settings are rarely used. To apply this perspective to inquiry-based practices, a large-scale survey could be used to collect data. Using a large-scale survey would allow a gain of perspective into the view on many different educators and students across multiple geographic regions. After data collection, commonalities and differences that exist within the population could be examined.

Interpretivism

Interpretivist focus on the localized meanings of human experience (Lederman and Abell 2014). An interpretivist perspective holds that people construct their understanding based on their experience, culture, and context. They focus on cultures, language use, classroom interactions, and actual experiences of individuals (Wong 2002). Because of this individualistic understanding, interpretivist do not expect that their results can be generalized directly to educational policies or strategies (Becker et al. 2012). In this perspective observations, interviews, and descriptive narratives could be used to measure and define inquiry-based practices. Data is normally collected in naturalistic environment, as opposed to experimental conditions. Using interpretivist methods could give a better understanding of the individual experience of a student or educator.

Situated Cognition and Cognitive Apprenticeship

The Situated Cognition Theory states that the attainment of knowledge cannot be separated from the context where knowledge is gained (Brown et al. 1989). Information that is acquired by the learner is situated in activities that are physically, socially, or culturally-based. In a classroom, the use of case studies or lab simulations could be used to have students apply knowledge within context.

The Cognitive Apprenticeship Model relies on students to work side by side with an expert (educator) to gain the necessary skills that serve within the subject area (Collins et al. 1989). This model relies on context as being key to learning, building upon the Situated Cognition Theory. Collins et al. (1989), described six principles between the educator and learner: modeling, coaching, scaffolding, articulation, reflection, and exploration. Modeling allows students to build a concept map of a task by having the educator demonstrate it. During coaching a student will attempt the task and receive feedback from the educator. Scaffolding is done by the educator and allows for creating strategies to improve the student's education experience. Context and skills are suited to students' skill level and aimed to move them farther than they can attain on their own. Once a student can perform task independently, support can be lessened. Articulation allows for the student to give an in-depth discussion of knowledge and skills learned. Reflection allows for both student and educator to compare their own experiences with each other as well as peers. Exploration encourages students to tackle concepts and skills learned in real world settings.

CHAPTER 3

METHODS

The purpose of this study is to investigate the opinions and beliefs of educators and students in postsecondary educational institutions to better understand how undergraduate biology experiences have changed since the emergence of the K-12 Framework. For this reason, Q method was recognized as the most appropriate way of obtaining this information to allow for the participants' viewpoints to remain the main component of the analysis. When used appropriately "a well-delivered Q study reveals the key viewpoints extant among a group of participants and allows those viewpoints to be understood holistically and to a high level of qualitative detail" (Watts and Stenner 2012). This method is suitable for researching the range and diversity of subjective perspectives, experiences, and beliefs. It can identify similarities, construct broad categories of the subjectivities being investigated, and explore patterns and relationships within and between these categories (Shinebourne 2009). This methodology has been used in studies of health and illness (Stenner et al. 2000) as well as examination of emotions (Watts and Stenner 2005).

Participants

When recruiting participants for use in a Q method study, a focused and purposive sample of participants are needed to secure a variety of viewpoints among a specific demographic (Gravley-Stack et al. 2016). The number of statements to be sorted is typically larger than the number of participants within a Q study (Brouwer 1999), with results that are statistically significant with as little as twelve participants

(Barry and Proops 2000). The aim of this study was to gather 20-30 respondents for each P-set, or group of interest: undergraduate students and educators.

A total of 53 participants were recruited for this study under the approval of ETSU IRB#: c0217.9e. Most of the responses, 98%, were collected at a large southeastern regional conference of biologists in Spring of 2017. The remaining responses were collected from a regional southeastern university within the same time. Of these participants, 23 were science educators teaching primarily at 2 or 4-year college institutions. The experiences of these instructors ranged from 0 to 21 years. The remaining 30 participants were college students at 2 and 4-year institutions with experience in at least one introductory level science course. Students ranged in grade from freshman to seniors.

Q Method

Data was collected using Q methodology (Brown 1993) to gain insight into how science education is taught and experienced in the undergraduate classroom. Q Methodology is used to identify a set of opinions that characterize individuals, then compare individuals to a distribution of sets.

Participants received a set of statements, referred to as the Q set, which are drawn from a larger set of ideas about the subject that is being researched (Brown 1993). The larger set, referred to as the concourse, is broken down to a number of statements chosen by the researcher.

Educators were asked to sort these statements in relation to how they conducted their introductory science courses. Students were asked to sort the statements in relation to their experience in introductory science courses. Participants placed statements most like their views on the right and most dissimilar to their views on the left. These items were sorted into a forced distribution, approximate to a normal distribution (See Figure 1) referred to as a Q sort.

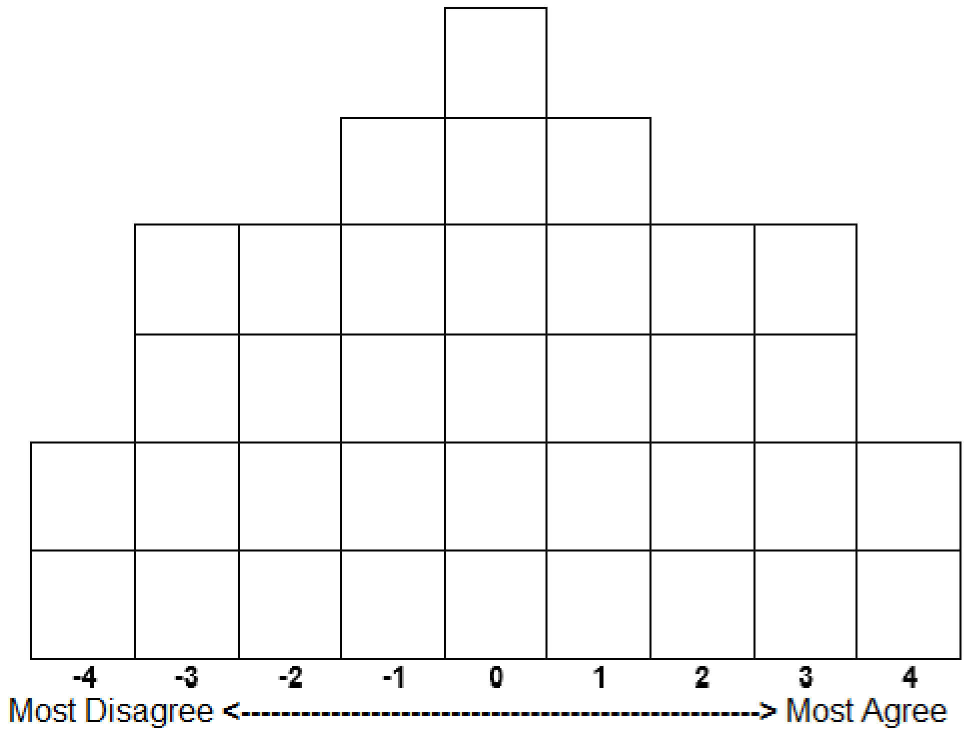

Figure 1. Forced-choice frequency distribution in Q-sort

Each statement within the sort was randomly assigned a number between 1 and 36. After completing the sort, participants were asked to record the statement's number in a corresponding sort on their records sheet (see Appendix C). At the bottom of the record sheet a short demographic survey was also completed. Some participants also chose to provide a first name or code name and phone number for a follow-up confirmatory interview regarding results.

Data was analyzed using PQ Method, a statistical program created to the requirements of Q studies (Schmolck 2014). It calculates intercorrelations among sorts, which are then factor-analyzed with the Centroid or Principal Component method (Schmolck 2014). The resulting analysis reports a variety of tables on factor loadings, statement factor scores, discriminating statements within each factor, and consensus statements across factors (Schmolck 2014).

Follow-up interviews are commonly used within this methodology from each resulting factor. The interviews allow for a greater understanding of the subjective views that arise from analysis and help to confirm the qualitative analyses conducted (Watts and Stenner 2012).

Designing the Q Set

The Q set for this study was composed of 36 statements printed on 2 x 2 inch laminated cards. Each card consisted of one statement, a randomly selected number between 1 and 36, and a hook-and-latch backing. Cards could adhere to the distribution board when being sorted. The Q set was created from a comprehensive literature review of inquiry-based teaching, two prominent educational documents Vision *and Change* and *Framework for education*, as well as statements created for use in previous work with Q method on the study of inquiry within the classroom (Hiatt 2011). These statements included information about different examples of classroom environment, teaching methods, assessments types, and educational materials (see Appendix A).

Delivering the Q Sort

Q sorts were conducted in face-to-face interviews with participants. Prior to beginning data collection, participants were asked to read a consent form that gave a brief description of the study and outlined the risks and benefits (IRB#: c0217.9e). Participants were then given a written copy of instructions for the Q sort (see Appendix B) as well as verbal instruction. Both students and educators were given the same statements and sorting procedure, however, the prompt for each differed slightly. If students were first or second year undergraduates, they were prompted with the question of “how were you taught this past semester?”. Third and fourth year undergraduate students were prompted with the question of “how were you taught during your introductory level courses?”. Educators prompted with the question “how do you teach introductory level courses?”.

Participants were then asked to sort the 36 statements into three piles based upon the prompt question. The first pile consisted of statements that were most like their views, the next pile was statements that were most unlike their views, and the third pile consisted on any statements in which the participant did not have strong feelings either way. After this initial short, participants placed the cards the Q sort board in the order which best described their views. After completion of the Q sort, participants recorded the statement number in the correspond box on the records sheet. Lastly, if the participant chose to do so, they completed a short demographic survey and contact information for the follow-up interview.

<u>Analysis with PQ Method</u>

All responses were analyzed using PQ Method (Schmolck 2014). A principal components analysis was performed and a Varimax rotation was used to determine the resulting factors. Factor analysis examines a correlation matrix to determine how many factors, or viewpoints, were evident in the sample set (Brown 1993). Participants with significant loadings in each factor were flagged. Loadings represented to what extent participant's Q sort correlated with each found factor. A loading score of +/- 0.50 is considered significant.

Z-scores were calculated for each statement on each factor, and statements were ordered in calculated array positions. Z-scores are the score for a statement indicative of an average of the scores given to that statement by all the Q sorts within that factor (Brown 1993). These are interpreted by the Q-sort value, which ranged between -4 and +4. The higher the number indicated that the statement was descriptive of the factor. The lower the number indicated that the statement did not describe the factor. Based upon these distinguishing statements, viewpoints were assigned to each factor.

Follow-Up Interviews

Follow-up interviews were conducted 3-4 weeks after the initial sort was completed to confirm qualitative analysis. Participants who scored high and purely on a single factor loading ($r>0.50$) were contacted for confirmatory interviews if they provided a phone number on the records sheet. Each factor was summarized and this information was presented to participants (see Appendix D). Participants were then asked to confirm if the summary provided was an accurate representation of their teaching style/classroom experience.

CHAPTER 4

RESULTS

Identifying Factors and Significant Loadings

Each respondents sort was entered into PQ method which performed a principal components analysis and a Varimax rotation was used to determine the resulting factors. Participants with significant and pure loadings in each factor were flagged. Participant information is provided in Table 1 about respondent occupation and information about years teaching experience or years enrolled in postsecondary education. Individual participant loading scores can be found underneath each factor.

Table 1. Factor Loadings

Participant			Factor		
Faculty	Years Teaching Experience	Participant Number	A	B	C
	0	F0A	0.4185	-0.0054	0.0754
	1-2	F1A	0.3521*	-0.0996	0.1316
		F1B	0.3629	0.4146	0.1796
	3-5	F3A	0.3688	0.3150	0.3674
		F3B	0.5096	0.1079	0.5909*
		F3C	0.2537	0.4818	0.1559
		F3D	-0.2163	0.5011*	0.4200
		F3E	0.3588	0.4769	0.2460
	6-10	F6A	-0.0879	0.5883*	0.3529

Table 1. (continued)

		F6B	0.3453	0.1986	0.1093
		F6C	0.0240	0.5532*	0.0825
		F6D	0.1509	0.4708	0.0203
		F6E	0.0625	0.5408*	-0.2105
		F6F	-0.0716	0.6051*	0.0026
		F6G	0.4112	0.1791	0.5334*
	11-20	F11A	-0.3957	0.5603*	0.1397
	21+	F21A	0.1707	0.4691	-0.0305
		F21B	-0.0065	-0.0161	0.4507
		F21C	-0.1088	0.1169	0.2068
		F21D	-0.3143	0.6115*	-0.0629
		F21E	0.6017*	0.0177	0.0224
		F21F	0.0222	0.0854	0.6790*
		F21G	0.1950	0.1434	0.5136*
Student	Years College Completed				
	1	S1A	0.7302*	-0.0959	0.1949
		S1B	-0.3371	0.4330	0.0988
		S1C	0.3726	0.1911	0.3613
	2	S2A	0.2837	0.2944	0.2538
		S2B	0.2083	0.2761	0.3401
		S2C	0.2871	0.6347*	0.1711
		S2D	0.2871	0.6347*	0.1711

Table 1. (continued)

		S2E	0.1470	-0.2099	0.4381
		S2F	0.3630	0.0542	0.3139
		S2G	0.1557	0.1074	0.3439
	3	S3A	0.3866	-0.0127	0.2883
		S3B	0.7112*	-0.1861	0.2128
		S3C	0.3693	-0.0067	0.6132*
		S3D	-0.4087	0.1887	0.4948
		S3E	-0.1088	0.0861	0.2403
		S3F	0.1853	0.0255	0.1718
		S3G	0.2567	0.3611	0.1532
		S3H	0.7961*	0.0392	0.0594
	4	S4A	-0.3944	0.5820*	0.2351
		S4B	0.5663*	-0.2465	0.0019
		S4C	0.0915	0.3738	0.4814
		S4D	0.6097*	0.0848	-0.1178
		S4E	0.4946	-0.2190	0.5681*
		S4F	0.5607*	0.2249	0.3216
		S4G	0.2442	-0.0736	0.3449
		S4H	0.61620*	0.2515	0.2713
		S4I	0.3831	0.2954	0.0399
		S4J	-0.1157	0.6647*	0.0616
		S4K	0.4567	0.2084	0.2065

Table 1. (continued)

		S4L	0.3925	0.1146	0.5458*
* Denotes a defining sort for the factor.					

Z-scores were calculated for each statement in each factor and converted to Q-sort values by weighted averages that created a factor array, a representative Q-sort for each factor. These values ranged between -4 and +4 and were used to determine the location of each statement within a representative factor array. The higher the number indicated that the statement was descriptive of the factor. The lower the number indicated that the statement did not describe the factor. Table 2 shows the average Q sort value for each statement for each factor A, B, and C respectively.

Table 2. Q Sort Values for Each Statement

Statement	Factor		
	A	B	C
1. Resources beyond the textbook are frequently used	1	4	2
2. Students are often afraid of investigating questions on their own	2	-1	-2
3. Lecturing is effective for preparing students for science proficiency test	1	-3	1
4. Students develop hypotheses and design their own experiments	-2	2	3
5. Students questions/interests are used to plan lessons	-1	-1	-2
6. Pre-assessments are used to determine what students already know	3	0	-1

Table 2. (continued)

7. Common misconceptions students have about science are addressed	0	3	0
8. The textbook is depended upon heavily	-1	-4	1
9. Students are required to do reflective writing after assignments	-3	-2	-1
10. A large portion of class time is used for group discussions	-3	0	-3
11. It is important to explain the relevance of science concepts to everyday life	2	3	3
12. Students frequently need to memorize content	4	-2	3
13. Students are excited to learn science	-1	1	0
14. All students follow the same step-by-step process for the scientific method	2	-3	2
15. Science should focus on improving critical thinking skills	3	4	4
16. A quiet classroom in needed for effective learning	1	-4	-3
17. Students are encouraged to find answers to their own questions	0	1	0
18. Students work in groups to improve communication skills	1	2	1
19. Lessons are focused on more detail within sections instead of trying to cover all material	0	1	-1
20. Interactive models and simulations are used frequently	0	2	0
21. Multiple choice tests are used for assessment frequently	3	0	3
22. Students work on different research questions during class time	-4	1	-3
23. Peer evaluation is an important aspect of class	-1	-1	-2
24. Most classroom activities have predetermined results	-3	3	0

Table 2. (continued)

25. Assessments embedded in class activates are used to monitor student progress	0	0	2
26. Students teach at least one lesson during the semester	-3	-2	-4
27. Lessons content show the relationship between science, technology, and society	0	3	1
28. Most questions from assessments are open-ended	-3	-2	0
29. Not having the right answers available promotes thinking things through independently	2	1	1
30. Students are given introductory activities such as simulations before a lesson	-2	0	-1
31. Students are in control of their learning process and the professor helps facilitate that learning	-2	3	-4
32. After completing research assignments, students communicate their finding to the class	-4	0	2
33. The professor spends as much time listening to students' questions as speaking during class	-1	2	-3
34. During class, students spend the majority of time listening to lecture and taking notes	4	-3	4
35. Lesson plans are built around local resources and environments	-2	-1	-2
36. Students get frustrated easily when asked to design their own experiment	1	-1	-1

Positive extremes (3 and 4) and negative extremes (-3 and -4) represent distinguishing statements for each factor and represent those that are most like (positive) and least like (negative) the viewpoint each factor describes. A summary of these statements and ranks for each factor can be found in Table 3.

Table 3. Defining Statements for Each Factor

Factor	Distinguishing Statements (p<0.01)	Rank
A	12. Students frequently need to memorize content	4
	24. Most classroom activities have predetermined results	3
	22. Students work on different research questions during class time	-4
	32. After completing research assignments, students communicate their findings to the class	-4
B	1. Resources beyond the textbook are frequently used	4
	7. Students are in control of their learning process and the professor helps facilitate that learning	3
	8. The textbook is depended upon heavily	-4
	34. During class, students spend the majority of time listening to lecture and taking notes	-3
C	12. Students frequently need to memorize content	3
	25. Assessments embedded in class activities are used to monitor student progress	2
	26. Students teach at least one lesson during the semester	-4
	33. The professor spends as much time listening to students' questions as speaking during class	-3

Three consensus statements exist to which all participants within all factors agree or disagree with. Each consensus statement also outlines the Q-value for each factor (A, B ,C respectively). See Table 4.

Table 4. Consensus Statements ($p<0.05$)

11. It is important to explain the relevance of science concepts to everyday life (2,3,3)
23. Peer evaluation is an important aspect of class (-1.-1.-2)
24. Most questions from assessments are open-ended (-3,-2,0)

Table 5 is a summary of demographics for participants with significant loadings ($r>0.50$) within each factor. Grouping type, faculty or student, as well as years teaching/years enrolled are recorded for each factor.

Table 5. Demographics Summary for Participants with Significant Loadings

Participant type	Years Teaching	Factor A (n=9)	Factor B (n=10)	Factor C (n=7)	*Years Teaching Totals*
Faculty	1-2	1 (11%)	0 (0%)	0 (0%)	*1 (8%)*
	3-5	0 (0%)	1 (10%)	1 (14%)	*2 (15%)*
	6-11	0 (0%)	4 (40%)	1 (14%)	*5 (38%)*
	11-20	0 (0%)	1 (10%)	0 (0%)	*1 (8%)*
	21+	1 (11%)	1 (10%)	2 (29%)	*4 (31%)*
	Factor Totals	*2 (22%)*	*7 (70%)*	*4 (57%)*	

Table 5. (continued)

Student	Years Enrolled				*Years Enrolled Totals*
	1	1 (11%)	0 (0%)	0 (0%)	*1 (8%)*
	2	0 (0%)	1 (10%)	0 (0%)	*1 (8%)*
	3	2 (22%)	0 (0%)	1 (14%)	*3 (23%)*
	4	4 (44%)	2 (20%)	2 (29%)	*8 (62%)*
	Factor Totals	*7(77%)*	*3 (30%)*	*3 (43%)*	

Post Sort Interview

Following analysis, 21 of the 26 participants with significant loadings had given contact information for a follow-up interview. Of the 21 contacted, a total of 6 follow-up interviews were conducted with two participants per factor who loaded significantly. All six interviewees confirmed that the summary of the teaching style/classroom experience was an accurate representation of their views. Some faculty participants also included specific teaching strategies used within their classrooms.

CHAPTER 5

DISCUSSION

Viewpoints

The Q-method study revealed 3 significant factors, or distinctive viewpoints about inquiry-based teaching and learning among students and educators. Six participants with significant loading scores (r>0.50) were contacted in follow-up interviews to confirm viewpoints. All participants who completed a follow-up interview confirmed that the factor accurately described their viewpoint. Below is a description of each viewpoint.

1. Factor A: Teacher-Centered viewpoint represents a lecture-centered classroom. In this viewpoint students spend most of class time listening to lecture with little peer interaction. Instructors prefer to use ready-made activities and fewer problem-based activities. Students do not develop their own hypotheses or design experiments.

   The majority (77%) of participants who fell into this viewpoint were students. Most of these students (44%) were 4th year undergraduates with some beings 3rd year (22%) and a small amount of 1st year (11%). Only 22% of faculty fell into this this category, split between 1-2 years of experience (11%) and 21+ years of experience (11%).

2. Factor B: Student-Centered classrooms place the student in control of their learning. This classroom does not use lecture as the main form of learning, instead models and simulations are used frequently. Instructors

focus more on depth of topics instead of attempting to cover all the material. Addressing common misconceptions is a high priority. Students are encouraged to do more problem-based activities, with few activities having predetermined results.

The majority (70%) of participants who fell into this viewpoint were faculty. Most of these educators (40%) had between 6 and 10 years of teaching experience. The remaining faculty (30%) were split between 3-5 years (10%), 11-20 years (10%), and 21+ years (10%). 30% of students fell into this this category, with most (20%) being 4th year students and the remainder (10%) being 2nd year students.

3. Factor C: Outcome-Based classroom is focused on students achieving pre-determined goals. This viewpoint relies heavily on the textbook or other resources, with content being a high priority. Pre-assessments are not frequently used, but multiple assessments embedded in class activities are used to monitor student progress. Students do not work on individualized research, but do use group work to discuss results.
Faculty (57%) and students (43%) were split between this viewpoint. Most faculty (29%) within this viewpoint had 21 or more years of experience, with a small amount having 3-5 years (14%) and 6-11 years (14%). Most students (29%) were 4th year students, with the remaining being 3rd year (14%).

There was high agreement among all participants that relating science to everyday life is important; however, much less value is placed upon peer learning and use of open-ended questions (see Table 4.).

Most educators view themselves as using some type of inquiry (factor B and C), with the majority focused on student-centered classrooms (factor B) instead of outcome-based classroom (factor C). Students, however, seem to perceive their introductory level science courses as very teacher-centered (factor A) compared to educators' views. In this study, there is a discrepancy between educators and students views of their typical introductory level science courses. Educators appear to have confidence in their use of inquiry techniques within the classroom but students' perception of introductory level classrooms are still very teacher-centered with little use of inquiry.

Inquiry in the Classroom

The purpose of this study was to describe science educators and students' views about inquiry-based teaching and learning. Trends were observed in faculty as well as students that indicate multiple distinct viewpoints on the definition and implementation of inquiry-based learning within the classroom.

Within this study, the teacher-centered classroom is most representative of a traditional view of teaching in which the educator possesses all the knowledge and passes it onto the students. Most of class time is spent lecturing, with content being a high priority. Group work and peer discussion are minimal and testing consists of multiple choice questions with little open-ended questions. The outcome-based classroom uses some inquiry activities, such as developing hypothesis, designing experiments, and group work, but still relies heavily on content and memorization. Multiple choice tests are used frequently with little class time devoted to whole class discussion. The student-centered classroom uses inquiry activities frequently, such as external resources, real world applications, and connecting information across disciplines. Most of class time is not spent on lecture, but instead group work or models and simulations.

Though many faculty (85%) reported that they used some type of inquiry (student-centered or outcome-based) within their classroom, the majority of students (54%) perceived their introductory level courses as teacher-centered. The discrepancy that exists could be due to the implementation of the inquiry activities within the classroom.

Almost 40 years ago, some of the most common reasons educators were not using inquiry within the classroom included: confusion about the actual meaning of inquiry, the belief that the use of inquiry learning only works well with high-functioning students, educators feel inadequately prepared to teach inquiry, or inquiry teaching is seen as difficult to accomplish (Welch et al. 1981). More recently, we can still see that a lack of understanding of inquiry and its implementation is a common problem within the classroom due to instructional support (Grant and Hill 2006), student motivation (Edelson, 1999), or educator motivation (Davis 2003; Loucks-Horsley et al. 2003). Instructional support is key to implementing inquiry within the classroom. Within institutions in which standardized test score are of high value, teachers of influenced by this culture of factual memorization for students to pass the test (Dole 2016). For an educator to move into inquiry based teaching, students must also be motivated to work within this new classroom dynamic. When students are not motivated by their own interest in the investigations, they may fail to participate or will participate in a disengaged manner that is not conducive to learning (Edelson 1999). Some educators may also find problems with their own motivations for practicing inquiry within the classroom. Educators tend to teach by implementing the methods by which they were taught, usually relying on lectures, textbooks, and demonstration labs rather than inquiry based activities (Davis 2003; Loucks-Horsley 2003). Even those who are motivated may become overwhelmed with the time that is necessary when preparing and implementing inquiry activities. It takes time to learn new methods and apply them within the classroom.

Implementation Fidelity

Implementation fidelity is the degree to which an intervention is delivered as intended and is critical to successful translation of evidence-based interventions into practice (Breitenstien et al. 2010). Kisa and Correnti (2015) studied 31 schools that were a part of America's Choice reform to assist low preforming schools. They found that teachers only successfully changed their practice toward reform-aligned instructional goals in schools demonstrating high growth in reform-aligned professional development. The schools which spent more time on educating teachers on the new reform content and professional development were more likely to succeed with the new changes to the curriculum. A larger study examined implementation fidelity in a sample of 454 teachers engaged in inquiry science programs (Penuel et al. 2007). This study points to the importance of teachers' perceptions about how coherent their professional development experiences were for teaching learning and program implementation. The authors also found that the time to plan for implementation and provision of technical support were also significant for promoting program implementation (Penuel et al. 2007). Failure to establish implementation fidelity limits the outcome of educational interventions. Though many studies do address this when introducing different teaching strategies, they vary widely in how it is measured (Foster and Missett 2015). This suggests a need for increased methodological rigor in education research to ensure that teaching methodologies are correctly being implemented within the classroom.

Advancing Inquiry

Some of the most important elements necessary for faculty to translate contemporary or transformative teaching practices into successful classroom implementation includes a recognition and redefining of the instructor's role (Walker and Shore 2015), providing examples of use within the classroom (Twigg 2010; Pecore, 2012), redefinition of grading scales (Dana 2014; Li et al. 2017), and access to proper resources and support (Kuhlthau 2015).

To effectively use inquiry-based methods, a redefinition of roles needs to be assigned to the student as well as the educator. In a traditional classroom, students are passive learners, interaction among peers is low and lecture is heavy. The educator's role is to give information to the student, typically dominating the conversation with coverage of textbook and curriculum. Most of class time is not used for completion of assignments or group discussions; instead whole-class instruction is common, with mastery of facts and skills (out-of-context) becoming the focus of learning (Tomlinson 2005).

In an inquiry-based classroom, students need to become the main speakers during class time. Students need to spend time solving problems, which will include making mistakes and struggling. Group discussion is common, allowing students to use peers to compare and generate ideas. The educator's role will change significant as well, no longer spending the class controlling the conversations. Educators need to facilitate students during problem solving activities. This is not necessarily a switching of roles, but more of a diversification of role for both students and educators. Both learner and educators will need to switch from passive recipient to active collaborator continuously (Walker and Shore 2015).

For teachers to begin to implement inquiry within the classroom, they need concrete examples of how this can be achieved (Twigg 2010). During class time, students should have multiple task to complete. This could be compromised of clicker questions, case studies, reflective writings, brain storming sessions, model construction, and presentations. The time spent gaining new concept information, such as readings from textbook, should be done outside of class. Class time should be spent allowing student to apply the knowledge they have gained to solve problems. Educators are responsible for creating these activities and facilitating students to achieve their own conclusions. These examples can be given during training sessions, which as necessary when executing a new inquiry programs.

To have an effective transition to inquiry-based teaching, grading schematics must also align with teaching methods (Li et al. 2017). Teacher evaluation also needs to align with the teaching methods of the course (Dana 2014). In traditional classrooms, exams and final papers are weighted heavily. This puts a large amount of stress on students to achieve high scores on the tests. In inquiry-based teaching, critical thinking and learning to learn are highly valued skills. Grades should be assigned in accordance with what is expected from students in the day-to-day classroom. Exams are still used, but do not hold the majority of the student's grade. Homework, participation, and presentations are instead the driving force. Students will have many assignments within each class period, some as small as only a few clicker questions delivered at the beginning of the course. This type of daily involvement can accumulate over the semester. Participation is also of high value within an inquiry-based classroom. This allows students to be consistently interacting with others to develop and define their ideas and conclusions. Presentations are also frequently used. This assignment not only allows students to have the opportunity to present information to a large group, but also to communicate their individual findings and conclusions for public feedback.

Giving information about other useful resources is crucial in training faculty (Kuhlthau 2015). Educators may feel as though they understand the material being presented during training, but then are unable to properly implement them within the classroom once training is completed. Providing additional resources, either in a handout or online reference, would be extremely beneficial in dealing with difficulties of implementation within the classroom. Giving educators external resources will also significantly help in assignment and task development for the classroom.

If educators are to use their time and resources to move to a more inquiry-based or active-learning classroom, then knowing how much change is necessary is of value.

Knight and Wood (2005) found that even devoting a small amount of time to more student-centered activities could lead to learning gains. In this study, lecture accounted for 60-70% of class time while the remaining 30-40% of time was spent on student participation and cooperative problem solving. In-class assessments, pretest and posttests, and homework problems were used to gage learning gains. Their results indicated significantly higher learning gains and better conceptual understanding in the course with more time devoted to student-centered instruction. Eddy and Hogan (2014) found that adding a moderate level of active-learning within a course significantly increased learning gains in all student populations, but worked disproportionately well for African American students and first-generation students. Connell et al. (2016) found that increasing student-centered activities within the classroom from moderate to high produces even higher learning gains. In this study, high student-centered courses consisted of many active-learning pedagogies, consistent formative assessment, and cooperative groups. Moderate student-centered courses were defined as fewer active-learning pedagogies, less formative assessment, and no group work. Students in the high student-centered courses had significantly higher exam scores and self-reported views about their learning and understanding of biology.

Assessments

It is important to engage students as active, not passive, participants in all biology courses. Multiple modes of instruction can be used to continuously involve students and differing forms as assessment can be used to improve and enhance learning. (American Association for the Advancement of Science 2011).

What students know and what they can do will be determined by use of different types of assessments. Student assessment data can be used in a continuous cycle throughout the school year to improve the classroom. By using formative and summative assessments through the course student progress can be monitored continuously.

Formative assessments are used to monitor student learning and can be helpful to both the instructor and student by identifying strengths and weaknesses of the target areas (Carnegie Mellon University 2015). This type of assessment is usually low stakes. One form of formative testing is diagnostic, or pre-assessments, given at the beginning of the courses to identify what knowledge that student already possess about the topic area. This diagnostic test can help in planning lessons throughout the semester by focusing class time of subject areas where students have the least knowledge. This type of assessment can also help in addressing misconceptions which students may hold upon entering the classroom. Pre-assessments can also be used throughout the course prior to each lesson for a more in-depth look at students' knowledge base of the lesson's focus. Other forms of formative assessment that can be used throughout the course are concept maps, journaling, quizzes, and group discussions just to name a few. Concept maps can be used to understand how student organize and scaffold knowledge. This type of activity can help relate the specified topic to the larger subject area that is being addressed. Journaling is a useful way to allow the student to self-reflect on what has been learned within the course. Burrows et al. (2001) found that reflective journal essays on assigned reading enhanced performance on multiple-choice quizzes compared to students who did not complete reflective essays. Quizzes can be a useful tool to check student understanding of the current material presented. Questions can come in many different forms such as multiple choice, true or false, open-ended, matching, short answer, essay, or fill-in-the-blank. Questions should be varied depending on what type of information the instructor would like to gain. Closed-ended questions, such as multiple choice and true or false, are helpful in assessing content knowledge. These questions do not always require students to think in depth about the topic, but instead are helpful for understanding the content knowledge that exists. More open-ended questions, such as essay or short-answer, are helpful in assessing the student's ability to think critically by requiring them to use content knowledge to analyze and evaluate an issue. Group discussion can be used to allow for students to work with peers. Allowing students to discuss the topic with peers will allow for verbalization of their understanding as well as practice in efficiently communicating information to their classmates. This type of assessment also allows for students to exchange ideas with each other and examine their own understandings based upon peer feedback. This type of activity is also very useful in fostering communication and teamwork skills for the students.

Summative assessments should also be used within the classroom. These types of assessments are used to evaluate student learning by comparisons against a standard or benchmark (Carnegie Mellon University 2015). This type of assessment is generally high stakes with examples such as an exam, research papers, or final presentations. Summative assessments are useful for the institution where the course is being taught. By examining the scores from summative assessments, institutions can evaluate the learning goals of the course and see if students are consistently meeting these goals and learning outcomes. This will allow for changes in the curriculum if there are areas which students seem to be consistently not meeting expectations.

Student achievement data gained through the different forms of assessment outlined above should be used when making instructional decisions for the classroom. Data gained from formative assessments can be used throughout the course to monitor student progress. Student scores of these assessments will allow the educator to change the lessons as needed for more efficiency in addressing areas of knowledge where students are lacking. Information from assessments such as journaling and concept maps can be used to teach students to examine their own knowledge and set learning goals. Summative assessment can be used for not only improving the lesson plans for the course, but also the design and construction of the curriculum by the institution.

Professional Development Implications

Educators can be hesitant to attempt inquiry-based instruction because they are unfamiliar with the practices (Kazempour 2009). Many teachers were not taught with inquiry-based instruction during their educational instruction. Increasing educators' awareness of how to use inquiry within their classroom can be achieved through quality professional development. Professional development can increase educators' knowledge and change ideas relating to how students learn and how effective their teaching is within the classroom (Kazempour 2009). It is imperative for educators to obtain effective professional development if science instruction is to be improved in the United States (Buxton et al. 2008). For inquiry-based instruction to be the main form of instruction within the classroom, educators must model inquiry-based instruction, utilize inquiry-based learning curricula and lessons, and guide other educators in using inquiry-based learning in their classroom (Thoron and Myers 2011). The most common reasons that faculty fail to implement contemporary teaching strategies successfully are a small support system and lack of proper training.

If an educator is to succeed in transitioning to inquiry-based teaching, then a support system that is continuous, multidimensional, and personalized to meet the changing needs of educators must be in place. This support system is not just administrators and teachers, but also involves student and parent involvement (National Research Council 2000). Some of the dimensions included in the support are professional development, administrative assistance and support, providing instructional materials, kits and equipment, communication with parents and public, student assessment procedures aligned with the outcomes of inquiry, promoting inquiry and problem solving in others subject areas, and teacher evaluation consistent with inquiry teaching (National Research Council 2000). Though much of education literature is now pointing towards a more inquiry-based classroom, there is little support for educators within the institution. Educators needs to have opportunities in professional development to gain new skills and training to properly use inquiry in the classroom. Administrative assistance and support are also a key form of support for educators. Providing a community of acceptance within the institution for contemporary teaching methods will increase the likelihood of educators continued use of their new skills and training. This environment will require a redefinition of teacher evaluation as well. If educators are to change their teaching styles, then their evaluative processes also need to reflect this change. Having an adequate budget for instructions materials, kits, and equipment will also increase the likelihood of educators use of inquiry-based materials. Support comes in many different forms, but regardless is an essential component for success is implementing contemporary teaching strategies (Darling-Hammond 1995).

Future Directions

In conclusion, the analysis found that both educators and students of the life sciences do possess distinctive viewpoints about their educational experience. Most of the faculty within this study view that they are using some type of inquiry within their classroom but most students perceive their introductory level courses with minimal inquiry based instruction. In the previous study (Hiatt 2011), three distinctive viewpoints were found among faculty. Of these, the naïve viewpoint is most like the teacher-center viewpoint found within this study. The naïve viewpoint made up 70% educators self-reported view in 2011, but only 15% of educators within this study have a teacher-centered viewpoint. Reports such as *Vision and Change (*American Association for the Advancement of Science 2009*)* and *Framework for k-12 Science Educators* (National Research Council 2012) do seem to be influencing change within the educator's view of the classroom. Most students within this study, however, still viewed their introductory level courses as teacher-centered. The discrepancy that exists could be due to the implementation of the inquiry activities within the classroom. By increasing support system, professional development, and comfort levels with inquiry teaching educators will be able to use inquiry more effectively within the classroom.

Q methodology was used to gain insight into the current views of undergraduate science educators and students in relation to the use of inquiry within their classroom. This methodology could be extended to other institutions to gain insight into the current views of inquiry in the classroom. This could be used as a tool to assess changes within undergraduate education in response to increasingly recommended inquiry-based policies and educational research.

By also gaining the student perspective within this study, it can be seen that even if educators are attempting more innovative teaching methodologies, the implementation of those methods may not be as effective. The majority of undergraduate students within this study were 3rd and 4th year students. Future, more controlled, studies could examine more 1st and 2nd year students to see if viewpoints among students vary from those found here when enrolled in a heavily inquiry-based course. More must be understood about the discrepancies between instructor and students' experiences. Pairing this type of analysis with a teaching observation protocols such as the Reformed Teaching Observation Protocol (RTOP) (Piburn and Sawada 2000) or Classroom Observation Protocol in Undergraduate STEM (COPUS) (Smith et al. 2013) could also help gauge the efficacy of faculty development and accuracy of self-reported data on the use of evidence-based approaches in teaching and learning science. Better understanding the way in which faculty introduce new teaching practices into their classrooms and evaluating the subsequent effect on student perceptions can greatly influence faculty development strategies. Ultimately, this would lead to the improvement of K-12 and undergraduate science education practices that produces a more competent STEM-capable citizenry.

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APPENDICES

Appendix A: Q Statements

1. Resources beyond the textbook are frequently used
2. Students are often afraid of investigating questions on their own
3. Lecturing is effective for preparing students for science proficiency test
4. Students develop hypotheses and design their own experiments
5. Students questions/interests are used to plan lessons
6. Pre-assessments are used to determine what students already know
7. Common misconceptions students have about science are addressed
8. The textbook is depended upon heavily
9. Students are required to do reflective writing after assignments
10. A large portion of class time is used for group discussions
11. It is important to explain the relevance of science concepts to everyday life
12. Students frequently need to memorize content
13. Students are excited to learn science
14. All students follow the same step-by-step process for the scientific method
15. Science should focus on improving critical thinking skills
16. A quiet classroom in needed for effective learning
17. Students are encouraged to find answers to their own questions
18. Students work in groups to improve communication skills
19. Lessons are focused on more detail within sections instead of trying to cover all material
20. Interactive models and simulations are used frequently

21. Multiple choice tests are used for assessment frequently
22. Students work on different research questions during class time
23. Peer evaluation is an important aspect of class
24. Most classroom activities have predetermined results
25. Assessments embedded in class activates are used to monitor student progress
26. Students teach at least one lesson during the semester
27. Lessons content show the relationship between science, technology, and society
28. Most questions from assessments are open-ended
29. Not having the right answers available promotes thinking things through independently
30. Students are given introductory activities such as simulations before a lesson
31. Students are in control of their learning process and the professor helps facilitate that learning
32. After completing research assignments, students communicate their finding to the class
33. The professor spends as much time listening to students' questions as speaking during class
34. During class, students spend most time listening to lecture and taking notes
35. Lesson plans are built around local resources and environments
36. Students get frustrated easily when asked to design their own experiment

Appendix B: Q Sort Instructions

Directions for Sorting Q Statements

Thank you for agreeing to participate in this study. Please make sure you have the materials in front of you. You should have a Form Board and an envelope containing 36 cards, each with a statement printed on it describing ideas about inquiry. You will need a pencil later.

Step 1: *Teachers*: Please read through the statements and sort them into three (3) piles according to the question: "**How do you teach?"** *Students:* Please read through the statements and sort them into three (3) piles according to the question: "**How were you taught this past semester?"**

The pile on your right are those statements that are **most like** what you think about the question and the pile on your left are those statements that are **most unlike** what you think about the question. Put any cards that you don't have strong feelings about in a middle pile.

Step 2: Now that you have three piles of cards, start with the pile to your right, the "most like" pile and **select** the two (2) cards from this pile that are **most like** your response to the question and place them in the two (2) spaces at the far right of the Form Board in from of you in column 4. The order of the cards within the column-that is, the vertical positioning of the cards-does not matter.

Step 3: Next, from the pile to your left, the "most unlike" pile, **select** the two (2) cards that are **most unlike** your response to the question and place them in the two (2) spaces at the far left of the Form Board in front of you in column -4.

Step 4: Now, go back to the “most like” pile on your right and select the four (4) cards from those remaining in your **most like** pile and place them into the four (4) open spaces in column 3.

Step 5: Now, go back to the “most unlike” pile on your right and select the four (4) cards from those remaining in your **most unlike** pile and place them into the four (4) open spaces in column -3.

Step 6: Working back and forth, continue placing cards onto the Form Board until all of the cards have been placed into all of the spaces.

Step 7: Once you have placed all the cards on the Form Board, feel free to rearrange the cards until the arrangement best represents your opinions.

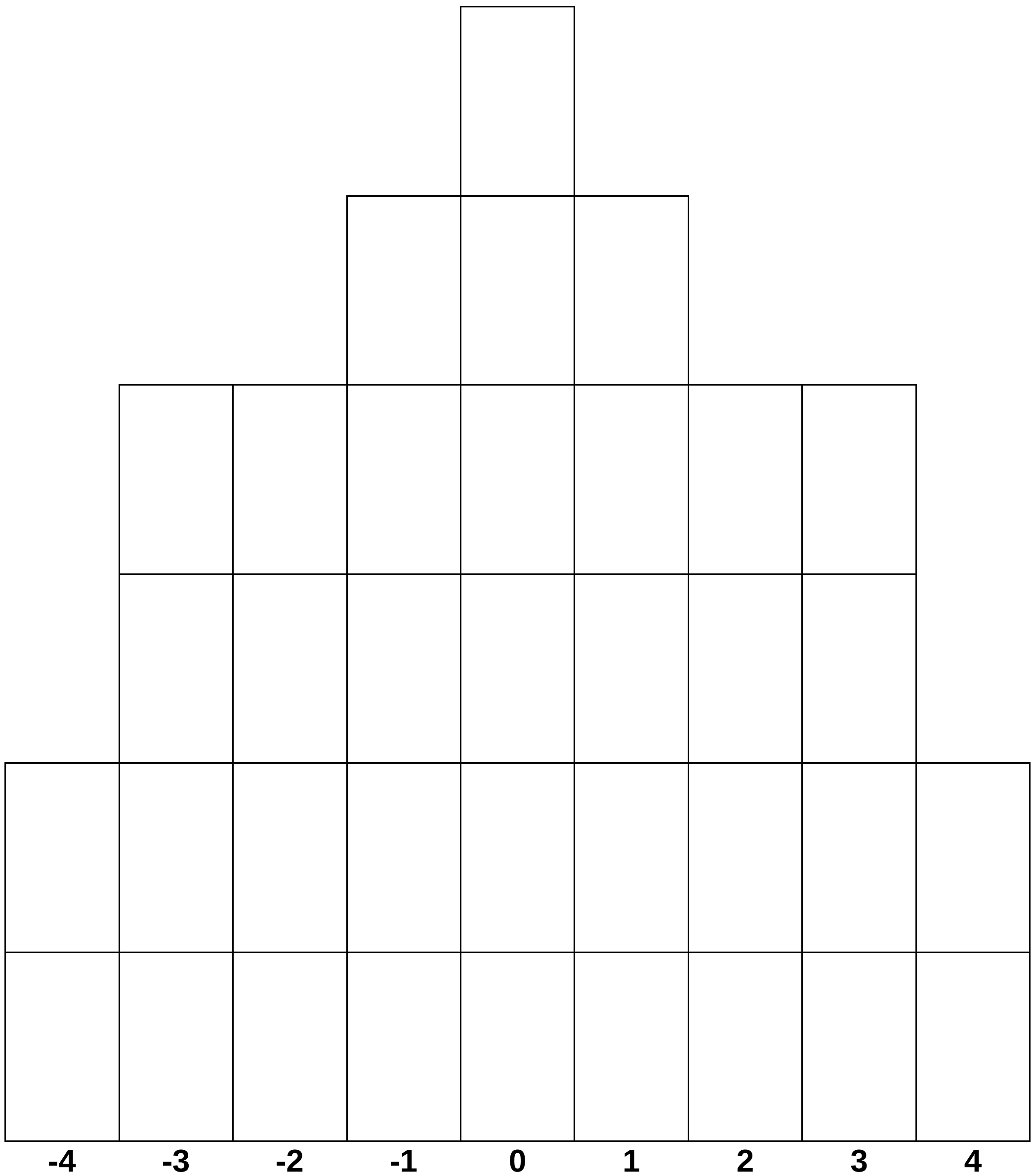
Step 8: Record the number of the statement on the Record Sheet.

Finally, please complete the survey attached to the Record Sheet and add any comments.

Thank you for your participation!

Appendix C: Records Sheet

Records Sheet



Demographic Survey

Ethnicity	**Describe Your Status**	**Teaching Experience**
O African American O Asian American O Caucasian O Hispanic/Latino(a) O Native American O Other, please specify	Select all that apply: O 1st Year Undergraduate Student Major: ____________________ O 2nd Year Undergraduate Student Major: ____________________ O Education Researcher O Teacher Educator O Other, please specify	O 0 years O 1-2 years O 3-5 years O 6-10 years O 11-20 years O 21 years or more

What is your current job title?

____

What else would you like to say about the ideas on the statements you sorted?

A follow-up phone interview may be conducted to clarify results. If you would be willing to participate in a phone interview, please write your first name (or a code name that you will know) and a telephone number at which you can be reached.

(CODE) NAME ______________________ PHONE ___________________________

Appendix D: Follow-up Script

Post Sort Telephone Interview Script – Factor 1

Thank you for agreeing to participate in this research study and for consenting to a follow up interview. This interview should only take about ten minutes, is this a good time for you?

One of the things that the aggregate results of the research study has shown is that people who sorted like you have a lecture-centered, guided classroom. The distinguishing characteristics include a frequent need to memorize content, use of classroom activities with predetermined results, students are often afraid of investigating questions, and pre-assessments are used to determine what students already know.

What do you think of this?

What type of pre-assessments are frequently used?

The characteristics that are most unlike your classroom include students work of different research questions during class time, students communicate research finding to peers during class time, and students develop hypothesis and design their own experiments.

What do you think of this?

What type of research activities are used within your classroom?

Thank you again for your participation!

Bye!

Post Sort Telephone Interview Script – Factor 2

Thank you for agreeing to participate in this research study and for consenting to a follow up interview. This interview should only take about ten minutes, is this a good time for you?

One of the things that the aggregate results of the research study has shown is that people who sorted like you have a constructivist classroom, where students learn through their experiences. Lecture is not used as the main means of communicating information. The distinguishing characteristics include that resources beyond the textbook are used frequently, common misconceptions students have about science are addressed, and students are in control of their learning process and the professor helps to facilitate that learning.

What do you think of this?

What type of resources are frequently used?

The characteristics that are most unlike your classroom include that the textbook is heavily depended upon, most activities have pre-determined results, all students follow the same step-by-step process for the scientific method, and during class spend the majority of time listening to lecture and taking note.

What do you think of this?

During class, what do students spend the majority of time working on?

Thank you again for your participation!

Bye!

Post Sort Telephone Interview Script – Factor 3

Thank you for agreeing to participate in this research study and for consenting to a follow up interview. This interview should only take about ten minutes, is this a good time for you?

One of the things that the aggregate results of the research study has shown is that people who sorted like you have an outcome-based classroom. The distinguishing characteristics include students need to frequently memorize content, students communicating finding from research to their class, and assessments are embedded in class activities to monitor student progress.

What do you think of this?

What type of assessments are frequently used?

The characteristics that are most unlike your classroom include students work on different research projects during class time, students teach at least one lesson during the semester, and the professor spends as much time listening to students questions as speaking during class.

What do you think of this?

During class, what do students spend the majority of time working on?

Thank you again for your participation!

Bye!

VITA

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	September 2017 – present
	ETSU Graduate and Professional Student Association (GPSA)
	August 2016 – present