Inquiry-based Teaching: An alternative learning structure

by Gregory Reese

> "They give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking, or the intentional noting of connections; learning naturally results." (Dewey, 2004, p.148)

Author's note: this paper was prepared for Education 571 taught by Professor Perry Marker.

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Introduction

There are many familiar structures which contain our learning experiences. When a student sits quietly in a desk and someone is talking, that is a structure. When we hold a book and hear the words playing in our head, that is a structure. When we rap out a rhyme of pride and rebellion, that is a structure. When a child assists their parent to fill the washing machine or gas up the car, that is a structure. The outward forms of participation in the structures of education do not necessarily reflect or identify the inward engagement we experience. Are we proud or ashamed? Are we empowered or oppressed? Is the experience drawing us into a social sharing of information and collaboration or driving us away? The experience of learning cannot be divorced from the structure in which the learning occurs.

The purpose of this related literature review is to define and explore the educational structure: *inquiry-based teaching*. As a high school math teacher I want to deliver the best learning experience that I can to my students, for that reason I am researching inquiry-based teaching as an alternative classroom teaching structure. This paper chronicles my investigation of inquiry-based teaching and summarizes what I feel are the findings most relevant to my teaching practice. First, I review some of the philosophical background that has supported inquiry-base teaching. Next I will consider the national education policy mandate, Common Core, and the current position of government and academic policy making bodies toward inquiry-based teaching. Following that, I will discus Zolkower & Shreyar (2007), a detailed case study in which 6th grade students became accustomed to the social/environmental structure of inquiry-based learning. Next, I examine Saunders-Stewart et al. (2012), which synthesizes and organizes over 200 research articles and books about inquiry-based teaching to distil out categories and definitions commonly associated with inquiry-based teaching. Following Saunders-Stewart et al.

(2012), I will discus Kirschner et al. (2006) in which current related literature was synthesized to uncover the other side of inquiry-based teaching: arguments against, problems encountered, demonstrations that inquiry-based teaching is less successful than direct instruction. Having then completed a broad overview and orientation of what constitutes inquiry-based teaching, I will precede to an analysis of four research studies which compared student test scores from inquiry-based teaching to student test scores from traditional direct instruction. Next: *what do teachers and students think about inquiry-based teaching? I will consider* four research studies which examined inquiry-based teaching by surveying teachers and students participating in inquiry-based curriculum. Then, I discus higher order thinking; having presented my case that inquiry-based teaching can do what traditional instruction does, I presents research that examines how inquiry-based teaching does that which traditional teaching does not do well: develop higher order thinking skills. Finally, my concluding remarks, there remain many questions left to be answered, but in reviewing current research, the case is strong that inquiry-based teaching has demonstrated enough valid success to deserve continued investigation and experimentation.

History and current policy on inquiry-based teaching

At the height of the industrial revelation, Franklin Bobbit proposed that educators bring the power of mass production to the classroom. By introducing the paradigm of assembly-line learning, Bobbit has made efficiency, standardization and specialization the three most universal characteristics of US education over the past 100 years. (Pinar et al., 2008) Supporting this view of education from the perspective of human psychology, Skinner (1971) described the leaning process as one of designing stimulus that precipitates changes in the learner akin to programming a computer or controlling a machine: *pour in the knowledge and push a button*. Although many

curriculum theorists such as John Dewey, Maria Montessori and Nel Noddings have considered the philosophical flaws and deficiencies in the mass production education paradigm arguing that efficiency is not compatible with the way that we know that the human mind learns. (Dewey, 2004; Montessori, 1946; Noddings, 2005)Theorists such as Pinar and Grumet, in rejecting curriculum efficiency argued in favor of the phenomenological nature of learning as a personal experience that transforms the learner. (Grumet, 1976) Rooted in phenomenology, inquiry-based teaching is antithetical to two of the three fundamental principles of the paradigm of mass production education. (Pinar et al., 2008)

In producing No Child Left Behind (NCLB) and Common Core, numerous governmental and academic educational policy making bodies have adopted the standardization aspect of the mass production paradigm for education but rejected the efficiency and specialization tenants in favor of inquiry-based curriculum. (American Association for the Advancement of Science, 1989, 1993, 2000;California Department of Education, 2013; National Board for Professional Teaching Standards, 2006; National Council for Teachers of Mathematics, 1989, 1991, 1995, 2000; National Research Council, National Academy of Sciences, 1996; National Research Council (NRC), 1996, 2000, 2007; National Science Teachers Association (NSTA), 2007; New York State Education Department, 2013) In the design of Common Core state testing, policy makers declared their intention to create a test that would discourage rote memorization and encourage educators to develop students' reasoning, logic and decision making. (McCallumn & Zimba, 2013)

How people learn in a structure of inquiry

Zolkower & Shreyar (2007) examined the guided inquiry curriculum in a 6th grade mathematics classroom. Over the period of a school year, 10 classroom observations were made and the lessons were taped and transcribed. Inquiry-based teaching was the method of instruction and students worked at times in small groups, at times individually and at times as a whole class. The guided form of inquiry studied in Zolkower & Shreyar (2007) was highly structured and student behavior was highly regulated and teacher determined. Whole class discussions were closely controlled by the teacher who questioned individual students and the whole class and regulated the direction and tempo of the discussions. The teacher strategically built the lessons out of contributions from the students making very few content contributions herself, but instead, choreographing the students' contributions in order to lead the whole class to understanding of the content. By coding the transcribed whole class discussions, Zolkower & Shreyar (2007) attempted to portray the method, strategy and authoritarian conversation skills with which the teacher guided the whole class inquiry. As the teacher guided the class in such activities as building mathematical equations out of patterns of numbers, the teacher alternated from questioning the class for observations and appropriate mathematical symbols to express them and ordering the class to write individually in their notebooks for 3 minutes to record what the class had so far learned. Although the class was clearly conducting inquiry, it was also being carefully guided in how to conduct inquiry. Students' efforts were highly structured and moved rapidly along in a predetermined direction.

In Zolkower & Shreyar (2007) the curriculum had multiple objectives. First, it exposed students to mathematical content, mathematical language and the process of generating and testing mathematical hypothesis. Second, it directly instructed students in the process of how to

inquire and more specifically, how to inquire together as a group. Third, the curriculum capitalized on many human traits to engage the students in the curriculum. Namely, it engaged them by accessing their natural curiosity. It engaged them by demanding their verbal and written participation. It engaged them by immersing them in a participatory social structure that publicly recognized their individual contributions to the group's understanding. Finally, the curriculum was designed to reassure the students that their inquiry was moving in a successful direction.

> "Our aim is to contribute to this research literature an analysis of a "thinking aloud" discussion in which a group of 6th grade students exchange mathematical ideas-in-the-making with their peers under the teacher's guidance. We adopt a Vygotskyan perspective in that we view whole-class mathematics discussions as teacher-guided meaning-making experiences that can serve as interpersonal gateways for students to appropriate those meanings." (Zolkower & Shreyar, 2007, p.178)

In order to closely analyze the nuances of the guided inquiry that was occurring, Zolkower & Shreyar (2007) utilized systemic functional linguistics. (Halliday, 1973, 1978, 1994; Halliday & Hasan, 1989; Hasan, 1996) SFL represents discussion as moves and countermoves as in a competitive strategy game. Zolkower & Shreyar (2007) argued that the teacher has an important role as a semiotic mediator to socialize the students in the learning and language of the curriculum. Referring toVygotsky, (1978), Zolkower & Shreyar (2007) contended that the patterns of speech and reasoning practiced by the students in whole group discussion and reinforced in individual and small group classwork become internalized in the students so that in time what students were only able to do as a whole class, they were eventually able to do independently on their own.

Zolkower & Shreyar (2007) relied on Halliday (1978) to support their argument that the language that the student chooses to use to describe and interpret his or her learning experiences internally will be drawn from the language remembered from similar past experiences, thus the language a student uses to reason out a math problem will be similar to the language that the student has practiced in reasoning out math problems with the group. It follows logically from this assertion that practicing the inquiry process of confronting an unfamiliar math problem is a key determinant effecting how the student will behave internally in the future when the student encounters an unknown math problem.

Saunders-Stewart et al. (2012) compiled a synthesis of over 200 research journal articles and published books defining and explaining inquiry-based teaching. Saunders-Stewart et al. (2012) extrapolated from the analyzed research articles that most of the researchers argued that inquiry-based teaching develops critical thinking and higher reasoning skills. Saunders-Stewart et al. (2012) argued that in inquiry-based teaching, content knowledge is *consequential* to practicing the inquiry process:

> "Although traditional approaches may focus on content, inquiry advocates suggest that through a focus on the learning process, students will consequently attain a knowledge base in the subject matter (Aulls & Shore, 2008). Furthermore, through engagement in inquiry, learners should progress beyond declarative knowledge to differentiation, elaboration, qualification, and integration of knowledge (Newmann, 1988)." (Saunders-Stewart et al., 2012, p15)

How people learn: Cognitive architecture

The theories of human cognitive architecture, in juxtaposition to inquiry-based teaching theories, support the virtues of direct instruction by arguing that related knowledge stored in the student's long term memory constitutes a fundamental component of conscious thought. (Kirschner et al., 2006) The theories of human cognitive architecture both complement and contradict many of the most important premises of the theory of inquiry-based teaching. Like inquiry-based teaching, cognitive architecture focuses on the subjectivity of lived experience and learning. Both theories accept that the student's classroom experiences are filtered through the student's subjective outlook, previous experiences and long term memory. Whereas phenomenology and inquiry-based teaching emphasizes the effect of the student's subjective outlook on how the student reacts to and is transformed by new experiences, cognitive architecture emphasizes the limiting or empowering effect of long term memory on perception.

> "The finding that expert chess players are far better able than novices to reproduce briefly seen board configurations taken from real games, but do not differ in reproducing random board configurations, has been replicated in a variety of other areas. (Egan & Schwartz, 1979; Jeffries, Turner, Polson, & Atwood, 1981; Sweller & Cooper, 1985) These results suggest that expert problem solvers derive their skill by drawing on the extensive experience stored in their long-term memory and then quickly select and apply the best procedures for solving problems. The fact that these differences can be used to fully explain problem-solving skill emphasizes the importance of long-term memory to cognition. We are skillful in an area because our long-term memory contains huge amounts of information concerning the area. That information permits us to quickly

> recognize the characteristics of a situation and indicates to us, often unconsciously, what to do and when to do it. (Kirschner et al., 2006, p. 76)

Extrapolating from this perspective, time spent searching long term memory for problem solving tools that have not yet been deposited there, does nothing to add to the sum total of information stored in long term memory. If the cognitive architecture argument that the primary problem solving power of human cognition comes from unconsciously calling upon relevant knowledge stored in long term memory is accepted, then the most direct route to empowering the student to solve diverse new problems is to increase the volume of relevant knowledge that the student has stored in their long term memory. Thus, according to Kirschner et al. (2006), memorizing and organizing facts and information, though difficult and unexciting, is precisely the work that will most directly and rapidly increase the student's problem solving ability. Furthermore, Kirschner et al. (2006) reasons that the inquiry-based teaching technique of withholding information from the student in order for the student to construct their own knowledge in their own way is not only inefficient, but often results in the student constructing inaccurate and incorrect knowledge which must then be unlearned. Kirschner et al. (2006) argues that the exhilarating challenge in learning lies not in trying to solve problems when key pieces of information have been intentionally withheld, but rather that learning exhilaration comes from piecing together and selecting knowledge from long term memory in order to construct the most elegant solutions to the immediate problems at hand, and in doing so, make connections between apparently unconnected threads of information. Hence, Kirschner et al.(2006) proposes maintaining the distinction between teaching a discipline and practicing a discipline; that is, the student should acquire the knowledge that can be applied to solve problems in the field by the

most direct and efficient means possible and *then* utilize that knowledge in the inquiry of solving problems which the student now has the long term memory tools to accomplish.

In summery, Kirchner et al. (2006) states:

> " Scientific inquiry is a systematic and investigative performance ability incorporating unrestrained thinking capabilities after a person has acquired a broad, critical knowledge of the particular subject matter through formal teaching processes." (Kirschner et al., 2006, p. 79)

What is it good for? *examining research that compares student test scores of inquiry-based teaching to traditional direct instruction*

Several research studies have provided comparative evidence that inquiry-based teaching curriculum produces student learning gains equal to or better than traditional teacher centered curriculum on tests similar to the current national Common Core style mandated testing. (Blanchard et al., 2010; Campbell et al., 2010; Liu et al., 2010; Khan et al., 2011) Some important aspects to consider when reading such studies are: what types of questions were included on tests, at what point in the school year were the tests administered, and how can researchers insure quality delivery of inquiry-based instruction.

Liu et al. (2010) studied 27 middle school and high school science teachers who taught their classes in a control year employing their traditional direct instruction curriculum, then in the following school year inserted a one week unit of inquiry-based teaching into the curriculum. The inquiry-based curriculum was prepared by the researchers and designed to cover the same standards and content as the traditionally taught unit that it replaced. Distinct inquiry-based lessons were prepared for each type of science class: biology, chemistry, physics and middle school science. The end of the year assessments were made up of researcher generated test

questions relating to the procedures and specific content of the inquiry-based unit that was inserted into the curriculum. In addition, the researchers also included some general science subject matter questions. Liu et al. (2010) constitutes evidence that inquiry-based teaching produces greater student learning of the kind tested for on NCLB and proposed Common Core assessments than does traditional instruction on the specific content of the inquiry-based unit taught. The groups of students that received inquiry-based teaching scored on average higher than did students who were taught by traditional instruction. The assessments included both multiple choice items and open ended essay responses. The written responses were analyzed on a rubric for 3 characteristics: "(a) generating relevant and normative ideas in response to the question, (b) making a link between the relevant and normative ideas, and (c) providing multiple scientifically elaborated and valid links to explain scientific phenomena." (Liu et al., 2010, p.74)

Liu et al. (2010) broke out and analyzed several student groupings to investigate the results of the quality of teaching on student performance. Students' test scores were separated based on years of experience of their teacher: 0- 5, 6-10, 11-35. Scores were also separated for teachers who attended professional development vs. teachers who did not attend. Also scores were separated for teachers who reported that they needed a high, medium or low degree of support from the researchers in order to teach the unit. Analysis of student grouping evidenced an effect of teacher quality on student test scores with students of more experience teachers scoring higher than did students of less experienced teachers. However, in all the grouping that were examined, students that received inquiry-based teaching scored higher than did students who were taught the same one week unit by direct instruction.

Critically considering Liu et al. (2010), the Bracey principle of research interpretation *what you test for is what you get*: applies to the conclusions. (Bracey, 2006) In Liu et al. (2010),

27 teachers added one week of inquiry-based curriculum to their classes and then at the end of the year, the students were tested on the material. Do the test results indicate how well the students learned from inquiry-based teaching or do they indicate how well the teachers were able to deliver the inquiry-based lesson? Liu et al. (2010) were clearly cognizant of the difference in quality of instruction that the students were receiving and attempted to separate the effect of the method of inquiry-based teaching from the effect of whether the teachers were able to successfully implement the lesson plans that the researchers created. These are two very different research issues, though both issues produce important information to inform future educational policy decisions.

Liu et al. (2010) concern was echoed by Saunders-Stewart et al. (2012) which found that successful inquiry-based teaching is more difficult to implement and requires more professional development and practice than traditional teaching. Further, Saunders-Stewart et al. (2012), and Zolkower & Shreyar (2007) provided evidence that inquiry-based teaching requires a classroom culture that cannot simply be switched on and off. To be adept at inquiry-based learning, students need to practice the habits and skills of inquiry, become accustomed to working in groups and feel emotionally safe to share ideas with their teacher and peers.

Blanchard et al. (2010), likewise compared the performance of students taught with inquiry-based teaching to the performance of students taught by traditional direct instruction. Blanchard et al. (2010), attempted to separate the effect of the quality of instruction from the effect of the method of inquiry-based teaching. Blanchard et al. (2010) compared the performance of high school and middle school students on multiple choice summative assessments to establish a relationship between inquiry-based teaching and student performance on high stakes style multiple choice assessments. 12 teachers observed in the study employed a

guided inquiry curriculum in teaching a one week science unit. A control group of 12 similar teachers at the same schools taught the same one week curriculum unit using direct instruction techniques. Blanchard et al. (2010) administered three multiple choice tests to the 1700 students in the study: a pretest, a summative test at the end of the unit and a follow up test one month later to measure retention. Blanchard et al. (2010) conducted classroom observations of the inquiry-based teachers and ranked the quality of the teachers' delivery of inquiry-based teaching curriculum using the reform teaching observation protocol (RTOP). The students of those teachers who ranked high on RTOP for successful inquiry-based teaching had statistically higher test score increases than students in the control group for both high school and middle school students. By providing research results that removed low quality inquiry-based teaching from the results, Blanchard et al. (2010) was able to analyze only the effect of the method of inquiry-based teaching on student performance on multiple choice assessments.

Khan et al. (2011), in comparing the effect of inquiry-based teaching to traditional curriculum, analyzed student test performance in an all girls public high school in Pakistan. Khan et al. (2011) compared two similar 10^{th} grade chemistry classes. In one class inquiry-based teaching lessons were added to the direct instruction curriculum. The other class received only direct instruction. Both classes were comprised of 35 students and both were taught by the same teacher. A statistical comparison was made of student academic performance in the two classes on a post instruction achievement test. The class in which the direct instruction curriculum was supplemented with inquiry-based curriculum averaged higher scores on the post instruction achievement test. Students in both classes took a pretest before the inquiry-based materials were introduced into the curriculum to insure that there was no average statistical performance difference between the two classes. One unique attribute that Khan et al. (2011) contributes to

the collected research on inquiry-based teaching is that in Khan et al. (2011) most variables of student socio-economic diversity were controlled. The students were all female, all 10th grade, all Pakistani, all from a similar economic background. Thus by limiting many of the variables, Khan et al. (2011) successfully argued that it is highly likely that the observed difference in test scores between the inquiry class and the control class are entirely due to the method of inquiry-based teaching. Of course, the very limited socio-economic representation in the study raises caution flags about generalizing the study results to other socio-economic groups by Bracey principle 4, w*hen comparing groups make sure the groups are comparable*, that is, just because inquiry-based teaching shows a positive result for female ethnic Pakistani students does not prove that other populations will also benefit. (Bracey, 2006) A second unique contribution Khan et al. (2011) makes to the body of inquiry research is that Khan et al. (2011) separated the collected experimental data into high performing and low performing students. Khan et al. (2011) separately analyzed the performance of the top and bottom 27% of the classes. In comparing the inquiry class to the control class, Khan et al. (2011) found no statistical differences in the pretest performance between the top 27% of the two classes, nor did Khan et al. (2011) find a statistical difference in pretest performance between the bottom 27% of the two classes. On the post unit achievement test, Khan et al. (2011) found that scores of both the top performing students and the bottom performing students were on average statistically higher in the class that received inquiry-based teaching supplements to instruction, thus providing some convincing evidence that inquiry-based teaching benefits both low achieving and high achieving students. Although Khan et al. (2011) contributed some unique data to the body of research on inquiry-based curriculum, some important information about the research is not presented. Khan et al. (2011) stated that students were tested before and after receiving inquiry-based instruction

and also that the inquiry class and the direct instruction class took the same tests, but Khan et al. (2011) does not report what the test format was nor what the test questions were designed to measure: was it procedural knowledge covering the exact experiments the students conducted or was it knowledge about the scientific method of investigation or questions about the nature of science? Blanchard et al. (2010) on the other hand, included all three of these types of questions in the tests given to the 1700 students in that study, then separated the test results by the three categories of questions. Lui et al. (2010) included both test questions specific to the one week unit taught, and in addition added related questions designed to be similar to expected question encountered on NCLB state tests. Lui et al. (2010) then separated the research results into students' scores on content questions and scores on NCLB questions. Khan et al. (2011) does not disclose the nature of the test questions. Further, Khan et al. (2011) does not disclose the format of the test, was it open ended questions designed to measure student reasoning and higher order cognitive thought or was it multiple choice questions designed to test for content recollection. In another omission, Khan et al. (2011) did not report the length of time covered by the study, did the inquiry-based instruction last a week, a month or a year and, as the inquiry-based lessons were a supplement to direct instruction lessons, how often were the inquiry lessons given? Finally, what were the qualifications of the teacher in Khan et al. (2011) to deliver inquiry-based teaching? Was there a measure or analysis of the quality of the inquiry-based instruction that the students received? Bracey's principle 2 of research analysis applies to these omissions, *show me the data*. (Bracey, 2006)

In another unique contribution to the research comparing inquiry-based teaching to traditional direct instruction, Campbell et al. (2010) studied the difference in learning outcome from a one week lesson on buoyancy in two high school physics classrooms, one class was

taught with inquiry-based methods and the other by traditional methods. Student learning was measured by administering tests to the students. Both the inquiry class and the traditional class took the same tests. Students were given a pretest, post test and a delayed test one month after the unit of instruction. The pretest and the delayed test were the same test and the post test was a different version but designed to be equivalent. The tests were based on PASKS, Physics, Attitudes, Skills, and Knowledge Survey, a recognized standardized assessment (Piburn et al. 2000) PASKS is designed to measure three aspects of physics class content: nature of science, science reasoning and students' attitudes toward science. Campbell et al. (2010) added additional questions to the PASKS assessment specific to the content knowledge covered in the unit on buoyancy.

In quantitative results, Campbell et al. (2010) found no statistically significant difference in student achievement between the inquiry class and the traditional class on the pretest, post test or delayed test. However, qualitatively, from the observations and recollections of the teacher in the study, Campbell et al. (2010) produced several interesting insights. First, inquiry-based curriculum is not something students are able to do without experiences that prepare them to learn by inquiry. This result echoes observations made by Zolkower & Shreyar (2007): learning the structure of a classroom is itself an important lesson. Campbell et al. (2010) revealed that the classroom teacher observed that in the inquiry-based lessons, students were often off task and chatting, also, some examples of inquiry that the students produced were clearly not productive; for example in the buoyancy experiment, testing objects of different shapes to see if one shape floats more than another regardless of the shape's composition; the teacher noted his impatience that inquiry can be a big waste of time because students test things that teachers could have advised them would not work. (Campbell et al., 2010) Of course, that is also one of the biggest

arguments *for* inquiry-based teaching: that depriving the student of the questions and going directly to the adult established answers really deprives the student of the learning experience and replaces it with rote memorization. (Dewey, 2004)

In designing the research, Campbell et al. (2010) took precautions to try to limit differences between the inquiry class and the traditional class in order to measure only the impact of method of teaching on the student test performance. Therefore the two classes were taught at the same school by the same teacher, in the same school year. One notable socio-economic difference existed, however, between the two groups, the inquiry class had 14 male and 14 female students and the traditional class had 19 male and 7 female students. Sengodan & Iksan (2012) produced research results suggesting that female students respond less favorably to inquiry base instruction that do male students. Because of this indication that gender may be a determinant of success in inquiry-based teaching, by principle 4 of Bracey, the groups may not be comparable since a difference in the gender distribution of the groups casts a possible doubt on the research results. (Bracey, 2006)

What do we think about it?
examining research that surveys students and teachers opinions about inquiry-based teaching and student engagement

Several research studies have surveyed students or teachers about the advantages of inquiry-based curriculum. (Power 2012; Kanter & Konstantopoulos 2010; Uekawa et al., 2007; Otieno & Wilder, 2010) Otieno & Wilder (2010) examined the effects of introducing inquiry-based instruction into middle school math and science classes. Example inquiry-based lessons were designed by the researchers and experienced by students; then a qualitative investigation of the effects of the lessons was conducted. Some of the noteworthy results of the study were that

female students reported that the lessons increased their math and science interest and participation. Also, underperforming students surveyed reported that the lessons increased their ability to understand the concepts and connect the content to their background knowledge. Quantitatively, the lessons increased the number of questions that the students ask and the number of questions that the students answered for themselves. 11 out of 12 of the teachers surveyed stated that they saw an increase in their students' learning and comprehension of the course content from the inquiry-based lessons. The Science Attitude Survey produced by the national science foundation is a survey given to students to gauge their interest, enthusiasm and positive attitude toward science instruction. Students who had experienced the inquiry-based lessons in Otieno & Wilder (2010), reported consistently higher levels of interest in science than did students in the same schools who had not experienced inquiry-based lessons. Otieno & Wilder (2010) argued that increasing the students' interest and enthusiasm for science is likely to increase the students' performance

A second research study that relied on opinion surveys of students and teachers was Kanter & Konstantopoulos (2010) which studied the effect of an inquiry-based PBS science curriculum: *I, Bio*, on middle school ethnic minority students. Students were ask to respond to survey questions about their attitude toward science, their feeling that studying science was relevant to their lives and their desire to take science classes in college. In addition to surveys, Kanter & Konstantopoulos (2010) tested students before and after the three month curriculum was completed. Kanter & Konstantopoulos (2010) found that students on average showed an increase in test scores in both procedural knowledge and ability to draw conclusions and make inferences about what they had studied in the unit. Kanter & Konstantopoulos (2010) also found a reported decrease in student positive attitude toward sconce, a decrease in feeling that science

education was relevant to their lives and a decreased desire to take science classes in college. In order to analyze the effect of the quality of the teacher on student learning, Kanter & Konstantopoulos (2010) ranked the nine teachers based on their background education and years of experience teaching. Quality of teacher appeared to make a statistically significant difference in the students' decreased desire to study science, that is, the higher the quality of the teacher, the greater the students' decline in desire to study science. This result was unexpected to the researchers and not a little depressing, hopefully further research will uncover a more hopeful outlook. The primary goal of this study was to try to find ways to increase minority representation in the fields of science and mathematics based on the hypothesis that increased enjoyment in the subjects of science and mathematics by minority students would lead to more minority students taking science and math classes in college and pursuing careers in science and mathematics. On the specific survey question of *would students like to take science classes in college*, survey results of Kanter & Konstantopoulos (2010) found that after studying the inquiry-based curriculum *I, Bio*, the percentage of minority students who wanted to take science classes in college decreased.

In another research survey of students' opinions about inquiry-based teaching, Power (2012) collected a series of three open ended surveys from 19 middle school students in which students reported their level of experienced engagement in a unit of science curriculum and their opinions about the success of inquiry-based curriculum to increase their content knowledge about the unit. Students were also ask to describe examples of what they had learned in the unit. Students' responses were then analyzed and coded for type of knowledge reported. Those students who reported high levels of engagement were strongly correlated to the students who reported greater learning and deeper comprehension and who were able to provide more complex

and insightful examples of their learning. Power (2012) provides support for the contention that higher levels of student engagement lead to increased learning.

In Uekawa et al. (2007), another study of the effect of student engagement on learning, participating high school students carried beeper alarms that vibrated at random intervals during their daily math class. When the alarm vibrated, students would stop work and record aspects of their classroom environment and internal mental state. Students noted if the class was doing group work, individual work, whole class discussion or direct lecture. Students also noted if they were chatting off topic, confused or working productively. Students then noted if they felt engaged in the class content, bored or drowsy. Uekawa et al. (2007) studied US math and science classrooms in highly diverse urban schools. Uekawa et al. (2007) studied 32 high school classes taught by 16 different teachers in 4 different urban high schools and collected surveys from 10 students if each class for 10 consecutive school days for a total of 3200 total surveys collected. In addition, Uekawa et al. (2007) conducted classroom observations to verify outward evidence of what the students were reporting. The Uekawa et al. (2007) findings supports the assertion that students are less likely to succumb to boredom and drowsiness in inquiry group work than they are during teacher lectures or individual work because of the mixture of stimulations they are experiencing. Thus, even though students may appear to be spending more time on task during direct lecture, in actuality, students are spending more time on task and engaged when working in inquiry groups. Uekawa et al. (2007) also observed, however, that students working in inquiry groups experienced a high incidence of chatting off topic, especially when students were allowed to choose their own groups. Uekawa's et al. (2007) concluded that working in inquiry groups has both beneficial and harmful effects on student engagement which come directly from the students' enjoyment of conversation with other students.

Uekawa et al. (2007) provides statistical evidence that the social structure of the classroom largely determines the level of engagement students experience with the curriculum, and further, that the social structure is largely dependent upon the method of teaching. One pronounced effect of inquiry-based teaching is to shift the social structure of the classroom from a confining experience nearly devoid of any opportunities for students to contribute socially or express themselves to an environment where students are responsible for nearly all the verbal contributions in the room and most individuals talk extensively during the class. While acknowledging that individual students have propensities to certain learning styles, Uekawa et al. (2007) asserted that social opportunities and pressures are a primary determinant of student engagement in the curriculum. Uekawa et al. (2007) concluded that students' commitment to learning is highly dependent on the social structure of the classroom.

Does inquiry-based teaching offer something more?

Marshall & Horton (2011) analyzed 104 middle school science and math lessons taught by 23 teachers in two different middle schools using the electronic quality of inquiry protocol (EQUIP). EQUIP is a record keeping and analysis system for conducting classroom observations developed my Marshal, Horton, Smart and Llewellyn. (Marshall et al., 2008) In Marshall & Horton (2011), the EQUIP records of observed student behavior characteristic of higher order thinking were compared to the EQUIP records of observed behavior characteristics of inquiry-based teaching. Marshall & Horton (2011) found that there was a high correlation between when students were observed practicing inquiry-based curriculum and when students were observed exercising higher order thinking. Marshall & Horton (2011) argued that practicing higher order

thinking in the classroom curriculum will increase students' proficiency at utilizing higher order thinking to solve academic and real world problems.

Conclusion

Theorists have argued, and will continue to argue, over the origin and nature of human consciousness. Is consciousness, as Vygotsky (1976) has suggested, an internal voice that grows out of conversation between the child and parents? Or, alternatively, does consciousness and reason, as proponents of cognitive architecture suggest, spontaneously generate out of the morass of the individual's long term memory? This question has tremendous importance for successful curriculum design. Inquiry-based teaching directly addresses Vygotsky's call for developing the internal knowledge and skills of the individual in collaboration with, and assisted by, more competent others. Inquiry-based teaching, however, is a very inefficient process for filling the individual's long term memory with facts and connecting relationships. (Kirschner et al., 2006) The debate over method of instruction really has three important considerations: will the method fill long term memory with facts and relationships; will the method motivate the student to choose to learn; and, finally, will the method support the student's ability to utilize the contents of long term memory to undertake, complex authentic tasks.

One might argue that there is no practical distinction between what an individual can do and what an individual does do. The question of what motivates a student to learn may therefore, in some sense, be more important for curriculum designers than the question of how a student learns. Following this line of thinking, this paper has presented evidence that inquiry-based teaching motivates students to become engaged in the curriculum better than traditional direct instruction. In addition, evidence has been presented that inquiry-based teaching, in spite of being less efficient, is at least as effective as direct instruction in communicating content

knowledge to the students. Finally, inquiry-based teaching requires students to practice higher order thinking, a skill that is intended to be tested for on Common Core assessments and is needed to perform authentic real world tasks. In conclusion, the research here presented supports the position that inquiry-based teaching deserves further study and may be a viable alternative structure for classroom education in some situations.

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Appendix One: Description of my learning activity:

I created this leaning activity for a group of graduate students pursuing their masters degrees in education. The objective of the activity is for students to familiarize themselves with some of the most important concepts of inquiry based teaching. By exposing students to a hands-on participatory activity I hoped to meet or exceed the educative outcome that could have been obtained by direct instruction. It is my assertion that inquiry based teaching communicates content knowledge to individuals as well as direct instruction and further, that inquiry based teaching possesses several advantages that are superior to direct instruction.

One advantage is that it allows students to access their personal background knowledge and to use what they already know to understand the new content, integrating and linking the new knowledge into the background knowledge that they already possess.

Another advantage of inquiry based teaching is that it is a modality of learning that is effective with a more diverse population of learners. Direct instruction is an effective learning style for some students, but research by Gardner and others has demonstrated that many students have difficulty learning from listening to a teacher lecture.

A third advantage of inquiry based teaching is student enthusiasm and engagement. By giving students an opportunity to participate and discus the content, the students are stimulated by their enjoyment of expressing themselves, contributing and being recognized by the group for their contributions.

Another advantage of inquiry based learning is that students have an opportunity to make a personal meaning for themselves. When students are spoon fed ready-made conclusions, they are deprived of the experience of working through and understanding the content in order to draw their own conclusions, therefore, what they learn is memorized facts not reasoned understanding. By asking students to handle the concepts for themselves and make their own connections, students obtain a deeper and more personal relationship with the obtained knowledge.

Finally, inquiry based teaching trains the students for critical thinking. Like any skill, critical thinking takes practice and benefits from examples and tutelage. By working together in a group with the guidance of a teacher, students develop their skills for approaching problems with critical thinking.

In summery, this leaning activity is designed to communicate factual content knowledge to students as well as or better than a direct lecture could have done, then, it is designed to have several advantages that go beyond direct instruction. It is these other advantages that make inquiry based instruction a better choice for many learning situations.

Inquiry-based learning activity: