The Effects of Inquiry-Based Pedagogy

Catherine Elise Barrett, Ed.D.

Fayetteville State University, 1200 Murchison Road, Fayetteville, North Carolina 28301

910-672-1700 – cbarret1@uncfsu.edu

Kristi Whitesell

University of North Carolina, Pembroke, 1 University Drive, Pembroke, North Carolina 28372

910-986-1971 kms003@bravemail.uncp.edu

Jessica Yates

University of North Carolina at Pembroke

University of North Carolina, Pembroke, 1 University Drive, Pembroke, North Carolina 28372

910 987-6877 Jky005@bravemail.uncp.edu

Abstract

This article reports the results of a comparative study conducted at a community college in the southeastern United Stated to determine the effectiveness of implementation of inquiry-based pedagogy as compared to traditional didactic teaching methods. The goal was to determine if this teacher-facilitated model was useful in improving learning for students with highly diverse learning needs. The community college setting used for this research was significant given the broad disparity in academic background knowledge that is often associated with students of nontraditional ages. This research sought to determine if the effects of inquiry-based education had a more positive outcome on student learning than traditional pedagogical approaches.

Research Objective

Inquiry-based teaching and learning is a pedagogical model driven by students' natural curiosities. Compared to traditional classroom approaches where the instructor dispenses information and solutions, an inquiry-based approach shifts the role of the instructor from dispenser of knowledge to facilitator of student learning via independent student research and discovery. Within the model used in this research, students actively seek answers and develop new questions through a more natural student-driven process of research, and instructors work in tandem with students as facilitators to support gaps and increase knowledge. Using inquiry-based teaching methods, students not only gain knowledge of the given topic, but they also learn the process of research, develop and nurture critical and analytical thinking, and learn how to solve real problems.

Inquiry-based science education has been debated as a viable teaching method as educators persist in finding better ways to reach the needs of an increasingly diverse population of students at all levels of public and private education. Proponents argue that through first-hand experiences, students are able to learn skills and information associated with national and specialized professional standards as well as gain useful life experiences through problem solving (Sing & Chew, 2009). Opponents argue that without specific guidance from a more didactic approach, students' knowledge in a particular subject area will diminish while the student wades through an infinite body of knowledge on the subject matter (Kirschner, Sweller, Clark, 2006).

This research sought to determine if the effects of inquiry-based education with the teacher as facilitator had a more positive outcome on student learning than traditional pedagogical approaches within a community college setting in the southeastern United States. The setting

was significant to the research given the variation in students' ages which ranged from upper adolescence to more nontraditional-college-age students, between 25 and 45 years of age. Data was collected from one fall semester General Biology course taught with more traditional lecture-based methods and was compared with data from one spring section of a General Biology course taught with inquiry-based methods and instructor facilitation.

The research reported within this paper was conducted over two sixteen-week semesters in General Biology classes during the 2013-2014 academic years. The courses were utilized to implement and compare pedagogical outcomes. Data was generated from the course work of 117 students within the two courses and were included in this research.

The institution's population is reported as: 59.6% White, 21.8% Black, 4.3% Native American, 7.8% Hispanic, 1% Asian, 0.1% Hawaiian, 2.3% multiple, and 2.9% unknown. The average student age at the research site is 26 years, and the demographic population of the site is 35.3% male and 64.7% female. The average age of the students is a relevant factor to consider because it can be a factor in how long a student may have been absent from an academic setting. According to Barrett (2005), those who have been absent from the school environment for an extended period typically experience more challenges than those with more recent experiences in a school setting and often struggle with the academic texts and language associated with traditional academic settings and teaching methods; students of nontraditional college age reported these factors as significant barriers to learning. In addition, prolonged absence from the academic realm can also be an indication of gaps in background knowledge.

The educational background of each student can be a critical and significant element when planning effective instructional experiences and should be an important consideration within instructional design. According to Barrett (2005), academic background often reveals the level of

prior knowledge for individuals or variance in knowledge within a given group of pupils. Therefore, the one-size-fits-all model of traditional instruction may no longer adequately support the needs of today's diverse student populations.

Prior knowledge matters for teaching and learning purposes, as students with exposure to high-level conceptual knowledge, such as that provided in advanced high school classes, likely have an advantage in further knowledge acquisition. In addition, students with more recent experience with concepts have an advantage. However, the challenge for instructors is the vast diversity of prior knowledge found within a single course section. General demographic educational level and background data for the broader population of the research site included in this research is, 7.5% GED, 4.3% 8th grade, 3.5% 9th grade, 4.7% 10th grade, 2% 11th grade, 62.9% 12th grade high school diploma, .5% GED, 1.4% adult high school diploma, 2.7% vocational degree, 6.7% Associate's degree, 3.5% bachelor's degree or higher, and .8% with an advanced degree. The research site acquires academic readiness levels from institutional databases, Ellucian or Colleague. At the institution, over half, 52.8%, of the students reside in the rural county where the community college is located, and the remaining students commute primarily from surrounding rural counties.

Researchers incorporated inquiry-based science education into several course labs, but the General Biology course was transformed so that every lab was transformed into an inquiry-based learning model with instructor facilitation. In order to adequately prepare instructors, labs were designed and implemented in the summer of 2013. Instructors returned to traditional lab instruction in fall 2013 and collected data for this research and then implemented an inquiry-based teaching and learning model during the spring of 2014. The objective of this research was to collect data, analyze the data, and compare data from the traditional fall sections containing 60

students, and the spring 2014 sections with 57 students to determine instructional effectiveness of inquiry-based education with instructor facilitation and support. A review of the literature, further descriptions of methodology, and a discussion of the results follow in this paper.

Literature Review

A review of relative literature resulted in the selection and examination of three sources with in-depth data analysis pertaining to inquiry-based learning. Inquiry-based learning has been researched for approximately 50 years (Kirschner, Sweller, Clark, 2006). The review of subsequent research demonstrates the broad variance in perceptions within this area of pedagogical research.

Chin's work on inquiry-based learning was conducted in 2005 and published in 2007, explores specific discussion and questioning methodology associated with facilitated learning or minimal teacher guidance pedagogies and found that this teaching model has the potential to expand and inform instructional design to improve outcomes. Within Chin's (2007) research, inquiry-based learning is considered synonymous with similar facilitated learning constructs such as constructivist, discovery and experiential learning.

Chin's (2007) research used four specific methods of teacher questioning with particular attention given to questioning methods that increased productivity through student inquiry. Socratic seminar requires students to derive ideas from reasoning and prior knowledge through the process of asking a series of focused questions. In addition, the verbal jigsaw is also questioning technique used to reinforce technical and scientific terminology through student verbalizations and associations with new vocabulary terms. The third method, called the semantic tapestry questioning is an approach whereby students view a problem from multiple angles; once completed, a series of questions may result in problem-solving by weaving in

answers from multiple perspectives, modes of observation, and levels of detail to form a broader understanding of the topic. In each situation, through framing questions, the instructor can guide students to more independently scaffold a problem or topic and structure an ensuing discussion with a follow-up summary. Teacher questioning inherently affects students' abilities to think critically and construct logical scientific concepts. In Chin's (2007) discussion of research results, the four questioning techniques led to the conclusion that active student participation did not result in loss of classroom control. Instead, students typically reluctant to verbalize responses became more socially competent. This type of interactive instruction was counter to the passive aspects of lecture and required students to question fundamental mechanisms of knowledge. According to Chin, students enthusiastically followed the teachers' lead and guidance when exploring various aspects of the problems they were presented. Chin (2007) suggests that traditional didactic methods of asking students to recite learned information or IRE (initiate, response, evaluate) still have a valuable role in education; however, such strategies should be used as a supplement in addition to an active learning experience.

Kirschner, Sweller and Clark's (2006) research offers a counter perspective of inquiry-based learning showing why inquiry-based learning if used without appropriate support can inhibit student success. Consideration of this perspective has the potential to further inform processes associated with inquiry-based learning within this research and in tandem with instructor facilitation. The issue at hand with minimal teacher guidance pedagogies focuses on short-term working memory, defined as "the cognitive structure in which conscious processing occurs" (p. 77). According to Kirschner, Sweller, and Clark, short-term working memory can address very limited new ideas simultaneously, and therefore, any of the minimally guided pedagogies would be incompatible with the normal cognitive function and working memory of the brain. For the

limitations of working memory to have an insignificant impact on more independent learning, a vast accumulation of prior knowledge is essential prior to the inquiry-based learning experience. Vast research performed throughout the 1980s and 1990s support the notion that giving students a problem and merely asking them to solve it is generally not productive, as learners with lower aptitudes or minimal prior knowledge in the targeted area of instruction will perform poorly on post testing. The authors of this research also agree that building prerequisite knowledge is essential for facilitation or minimal guidance methods to be successful (2006).

According to McLoughlin's (2009) research in which the researcher compares traditional and inquiry-based learning in learning math, the author postulates that inquiry-based learning (IBL) is content-centered; whereas, a traditional classroom setting is instructor-centered. A content-centered setting is based on the notion that everything is driven by content, and without content, inquiry does not exist. An instructor-centered setting is one that is completely directed by the instructor. All information is freely and easily furnished directly to the students via presentations, texts, expositions, and lecture methods. McLoughlin (2009) argues that this approach inhibits students from learning and understanding a presented topic, but forces students to merely memorize the information without engaging in more complex cognitive processes that support long-term retention and understandings of critical information. McLoughlin extends this argument by stating, "…to place a student in a situation where finished, polished, or elegant solutions, arguments, proofs, etc. are presented denies the student the experience of discovery, of inquiry, of authentic academics" (2009, p. 14). Conclusions drawn from this research suggest that in order for students to learn, they must actively engage in cognition. Therefore, students research the topic, present research findings to the class or groups of fellow classmates, and quiz the presenting student; McLoughlin argues that it is through this volley of ideas and information

that an active learning environment is created and maintained. McLoughlin (2009) criticizes passive traditional teaching practices as being strict, rigid, and boring, believing that due to this rigidity in learning, knowledge is not learned, but bestowed on a surface level at best.

The three uniquely different assessments of inquiry-based learning demonstrate some of the pros and cons to the debate on this instructional methodology. For this research, Chin's (2007) position appears to be the most balanced accepting aspects of traditional pedagogies that also provide support and consideration for learners with varying levels of aptitude and prior knowledge. For example, Chen's model supports learning new terminology associated with discipline specific information and discourse and provides opportunities for students to fill in the gaps. Without consideration for developing content specific language as well as instructor facilitation, students with less prior knowledge and skills will likely struggle (Barrett, 2005).

Kirschner, Sweller, and Clark (2006) and McLoughlin (2009) occupy positions that applied in isolation have the potential to leave gaps in student learning. Kirschner, Sweller and Clark's (2006) over reliance on teacher-centered pedagogical design limits or restricts experiences that have the potential to address and enhance individual learning needs and styles. McLoughlin's (2009) perspective could be viewed as lacking critical prior knowledge and support to effectively support students. Chin's model recognizes the value in traditional questioning methods used by teachers and accepts that well designed inquiry-based lessons facilitated and supported using appropriate questioning techniques allows students to discover and address their own learning needs and learn in their own unique ways (2007).

Research on inquiry-based instructional design shows a history filled with many points and counter points regarding the topic. However, most researchers agree that when designed appropriately, inquiry-based learning promotes critical thinking (Balcaen, 2011). With such

broad views on this topic, the research must be narrowed and focused to have meaningful results. It is important to have comparable groups and to maintain scientific objectivity when analyzing data. Student assignments and overall averages of students' work in both groups will be analyzed free of bias to maintain scientific integrity.

Methodology

Researchers incorporated inquiry-based science education into many of course biology labs such as, Human Anatomy and Physiology, General Biology, and Microbiology. However, the General Biology lab had the most complete shift in pedagogy, as every lab was transformed into an inquiry-based learning model with instructor facilitation. Labs were designed and implemented during the summer session of 2013 to adequately prepare instructors for research implementation during the spring of 2014. In the fall of 2013, labs were taught with traditional methods for comparison with the inquiry-based lessons implemented in spring 2014. Analysis and comparison of the traditional fall sections containing 60 students, and the spring 2014 sections with 57 students, was conducted to determine if the effects of inquiry-based education had positive outcomes on student learning.

Inquiry-based learning methods were incorporated into freshman college level General Biology labs. The researchers' purpose was to determine if a teaching and learning method different from traditional lecture methods changed student success. Research groups included three sections from a traditional fall 2013 semester with 60 students total and three sections from the inquiry-based spring 2014 semester with 57 students total. Each semester consisted of 14 class meetings lasting two hours and 50 minutes that met once per week. Time spent on subject content during each semester was equitable across classes according to instructional design.

Traditional lecture-based teaching methods had been in place for at least ten years prior to preparation and implementation of the inquiry-based teaching methods at the community college site. During a traditional lab, students were presented with all information necessary via lecture and visual presentations to complete the lab activity and adequately prepare for a summative assessment. The presentation of information was conducted via PowerPoint presentations, overhead projector notes and diagrams, use of chalk or white boards, and instructor demonstration. The lecture presentation of information took 60 to 90 minutes. Information sessions were followed by 30 to 60 minutes of lab activities that were facilitated by the instructor. Students were allowed to work on activities independently or in small groups. Notes, data, and conclusions collected during activities were retained by the students and used to prepare for the lab test. The follow-up lab test was 20 to 30 minutes in duration and was administered at the beginning of the next lab meeting. There were twelve tests given during the semester that followed the traditional protocol. Lab tests were equally weighted and averaged for the student's final grade in the lab portion of the traditional class sections.

The inquiry-based labs were created during summer 2013 prior to implementation in spring 2014. During the summer 2013 design phase, every lab was restructured from traditional teaching methods to inquiry-based teaching and learning. All labs within the inquiry-based model incorporated a uniform instructor-created lab report to serve as a guide for students. All lab reports consisted of background information and terminology, materials, procedures, data collection and analysis, and summary/conclusion sections. Within the inquiry-based courses, students were given lab reports one week in advance for each lab meeting. During the week before the lab meeting, students researched the background information on each lab. At the beginning of the lab meeting, the instructor provided 15 to 30 minutes of instructor guided

review and clarification of the background information and terminology, demonstrations when required, and laboratory safety and procedural guidance. The remaining 140-155 minutes was utilized by students as partners in the inquiry process to cooperatively gather materials, complete procedures, and obtain, organize, and analyze data, and form conclusions. The instructor provided guidance and active support throughout the lab experience, but did not provide the correct answers as the students worked. At specific points of completion, students were required to show their work to the instructor to obtain a signature of approval before moving to the next step. If approval was denied, students were required to review their work for errors in the process before trying again. Students turned in a final draft lab report at the end of class for a grade. Lab report point values varied depending on the amount of time invested in each experience. The number of written test assessments was reduced to three per semester versus 12 in traditional courses. Two of the written tests were revised to consist of 50% practical knowledge and identification, while the third test remained similar to the traditional test.

Results

Overall analysis of data focused on determining which teaching methods were most effective in overall student success in learning and overall success in the course. The two methods studied and compared were inquiry-based teaching versus more traditional didactic teaching methods. The research was carried out over the course of one academic year beginning in August at the start of the fall semester and ending in May at the end of the spring semester.

The first group in the study was the fall 2013 General Biology students. This group received a traditional lecture presentation of information with follow-up tests for evaluation. Subsequently, the spring 2014 semester group of students was presented with an inquiry-based method of teaching and learning that required students to research, complete lab reports, and

think critically with guidance and questioning from the instructor rather than lecture. Inquiry-based instruction was primarily modeled after Chen's (2007) model.

Students' grade averages from fall 2013, a traditional semester, and spring 2014, an inquiry-based semester were compared and analyzed. Initially, the raw data was a listing of students' numerical grades earned and the final average of these grades for the semester. Students' grades were listed by student number with correlating letter and numerical averages earned to ensure anonymity. Next, data was organized as to how many students from each semester earned each possible letter grade; A, B, C, D, and F. The data taken from these tables were graphed multiple ways to compare the findings.

The comparison of fall and spring semesters' letter grades earned by each possible letter grade (A, B, C, D, and F) found that nine out of 60 students in the fall semester earned an A average as compared to 15 out of 57 students in the spring semester. Seventeen out of 60 students in the fall received an average grade of B, as compared to 26 out 57 students in the spring earning a B average; 12 out of 60 earned an average of C in the fall as compared to eight in the spring; 15 out of 60 in the fall earned a D average as compared to 7 out of 57 in the spring, and 8 out of 60 earned an F average as opposed to one out of 57 in the spring earning an average of F. When the two semesters are compared, clear differences in student success are obvious. Fewer fall 2013 students had A's and B's than did the spring 2014 students. The students from fall 2013 had more grades of C's, D's and F's as compared to the students from spring 2014. Students' overall numerical and letter grade averages were higher in spring 2014 than in fall 2013.

Bar graph comparisons of each student's numerical overall average also clearly indicate and demonstrate a much higher rate of success for students in the spring inquiry-based instruction

courses than for fall students in traditional instruction courses. Another comparison examined the overall grade point averages for each semester comparing the mean or class averages for fall 2013 to the overall class mean for spring 2014; the overall class mean for fall 2013 was a 77% grade point average, or a C average, and the overall class mean for spring 2014 was an 84%, or a B average. The results disclose a seven point increase in the classes' overall averages between fall 2013 and spring 2014. This is a notable increase in students' overall grade point averages and also shows significantly fewer lower grades of D and F.

The results suggest that the inquiry-based pedagogical method is a more productive teaching technique than traditional teaching methods when teaching students with varying levels of background knowledge. Such findings may have noteworthy merit in supporting educators planning instruction in settings where students' background content knowledge, academic language, or skill levels may have substantial variances. This research also supports Chin's (2007) findings in that teacher questioning, inquiry-based structure inherent in lab reports, and active instructor support positively enhanced students' ability to think more critically and organize scientific concepts logically. Researchers also concur with Chin (2007) that traditional didactic methods continue to have merit in a limited capacity, but that such strategies should be supplemental to an active learning experience.

The analyzed data results from this research suggest that inquiry-based science instruction has a positive impact on the students' grades and overall success when exposed to inquiry-based teaching methods. Therefore, this research suggests inquiry-based science teaching is the more operative teaching method when compared to traditional teaching methods.

Conclusions

Grades were used as raw data for this research. The instructors averaged each student's grade using quizzes, lab reports, and exams. Once each student had an overall course average, the data was analyzed to illustrate the results of the research. The researchers analyzed the data using tables and graphs. Interpretation of the data suggests the inquiry-based method appears more effective in terms of student proficiency on quizzes, tests, and lab assignments. When the inquiry-based science method of teaching was implemented, the spring 2014 semester's overall averages were seven points higher than when the course was taught using traditional didactic lecture-style teaching methods in the fall 2013. The key finding was that by implementing inquiry-based science methods, students' overall averages and course success was higher.

Limitations and Implications

A limitation of this research was that data could have been collected to reflect more specific information. For example, data collected on active student participation had the potential to add substantial contributions to this research. Also, student feedback could have provided more in-depth information on affective aspects of students learning with implications for learning and motivation. Placing overall averages into a graph did accomplish the task of determining which teaching method was more effective, so from this perspective, the research accomplished its goals. However, if data had been collected to reflect broader, more detailed information, perhaps more definitive conclusions and contributions could be garnered from this research.

In future research, individual course assignment data could be collected and analyzed to gather more comprehensive information from lab reports, quizzes and exams. Collecting and analyzing supplementary data for each assignment has the potential to add to the literature on

active learning, student affect with regards to learning and motivation, and levels of prior knowledge and nontraditional students.

Therefore, a viable future extension of this research would be to analyze demographic information in correlation with student success examining specific background information and comparing the students' grades when organized by education level, prior knowledge, or similar criteria. The results could further inform the inquiry-based model for teaching science and other subjects and improve and expand learning opportunities to more diverse learning needs. In addition, it would be highly beneficial to collect student feedback through surveys and conduct student interviews to hear first-hand how students feel about the experience. Additional data collection and research with more student groups within General Biology and branching out to other science classes would create a larger data pool. More student data would obviously generate more conclusive results.

Contributions

With the knowledge gained from this research, researchers will modify pedagogical practices and gradually transform lesson design to more inquiry-based learning. Results of this research suggest that the inquiry-based method is a more effective way for students to learn and achieve academic success. Implementation of the inquiry-based model will include more experiential activities, projects, practical examinations, and assignments with instructor support and added support for learning discipline-related terminology and discourse. Such course revisions have the potential to provide intrinsic motivation and confidence and encourage students to engage in self-directed reading and research on a given topic, rather than receiving all of the information and answers from instructors.

While this research was conducted analyzing data collected from adult community college students, this work has positive implications for implementation with middle and high schools students as well.

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