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# Examining the effect of inquiry-based learning versus traditional lecture-based learning on students' achievement in college algebra

Elaina Khasawneh [1]*, Angie Hodge-Zickerman [2], Cindy S. York [3], Thomas J. Smith [3], Hayley Mayall [3]

[1] Department of Computing, Information, and Mathematics Sciences and Technologies, Chicago State University, Chicago, IL, USA
[2] Department of Mathematics and Statistics, Northern Arizona University, Flagstaff, AZ, USA
[3] Department of Educational Technology, Research and Assessment, Northern Illinois University, DeKalb, IL, USA
***Corresponding Author:** Ekhasawn@csu.edu

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**ABSTRACT**

The focus of this study was to examine the effect of teaching based on inquiry-based learning versus traditional learning on mathematics achievement scores of undergraduate students enrolled in a college algebra class in a university classified as a Predominantly Black Institution. A college algebra course was chosen in this study due to the critical role it plays as a gateway for college completion and due to the generally high failure rate in college algebra. This study used a quasi-experimental design, with pre- and post-test to determine the effect of the instructional pedagogy on mathematics academic achievement of students. Analysis of covariance results from 41 students revealed, when controlling for college algebra readiness pre-test scores, students in the inquiry-based learning section showed significantly higher mathematics achievement post-test scores than in the traditional lecture section.

**Keywords:** inquiry-based learning, mathematics achievement, student-centered pedagogy, college algebra, lecture-based learning, mathematics education

## INTRODUCTION

There has been increasing concern among policy makers and business leaders that college graduates lack the ability to think critically, solve problems, collaborate, communicate effectively, and transfer knowledge to real world settings (AACU, 2015; Malik, 2018; U.S. Department of Education, 2014). 91% of employers say that critical thinking skills are required to meet the demands of the 21st century and compete in the global market (AACU, 2013, 2015; Partnership for 21st Century Learning, 2016). Critical thinking skills are beneficial to students regardless of their major, and students cannot succeed in life without them (AACU, 2015; Franco et al., 2018; Partnership for 21st Century Learning, 2016; U.S. Department of Education, 2014).

It is necessary for institutions of higher education to align their curricula with economic changes and better prepare college graduates to succeed in the workplace of the 21st century. Educators have the responsibility to shift the focus of their pedagogies from preparing students to pass exams to preparing them to be life-long learners who are able to think critically, collaborate, solve problems, and communicate effectively (Conference Board of Mathematical Sciences, 2016; Eddy et al., 2015; Maron, 2016; Pienta, 2015). The accumulation of information and repeating it is not as important as the ability to find the information and use it in different situations. The traditional learning format may not be the most effective method to prepare students for the new information age. Students must draw on their knowledge, and through the process, they will often develop new understanding (Conference Board of Mathematical Sciences, 2016; Freeman et al., 2014). New pedagogies that reflect the changes in the economy and the advancement in technology should be investigated. One alternative to the traditional way of teaching is inquiry-based learning (Hayward et al., 2016; Kogan & Laursen, 2014; Laursen & Rasmussen, 2019; Rasmussen & Kwon, 2007).

The current study addressed the following research question: What effect does inquiry-based learning intervention have on the mathematics achievement scores of students in a college algebra class? In this study, a college algebra course was designed around inquiry-based learning as an instructional pedagogy. College algebra is a general education course that was intended to teach students how to think critically, solve problems, communicate, and collaborate to succeed in their academic lives and their future careers. A college algebra course was chosen because of the high failure rate in the United States (Larnell, 2016). Failure

This study is derived from the dissertation by Khasawneh (2016). *Examining the effect of inquiry-based learning vs. traditional lecture-based learning on critical thinking skills and students' achievement in college algebra* [Doctoral dissertation, Northern Illinois University].

rates are 55% higher using traditional teaching methods versus more active methods (Freeman et al., 2014). According to a report "Common Vision" from the Mathematical Association of America (Saxe & Braddy, 2015), only 50 percent of students who are enrolled every year in college algebra will finish their course successfully. Many students–in particular, students of color–will repeat the course multiple times, and many will drop out of college because without college algebra they cannot complete their graduation requirements (Larnell, 2016).

In a review of literature on the learning of college algebra, it has been suggested the reason college algebra is so difficult for students is the many cognitive demands of college algebra (Wang, 2015). College algebra is where students must go from concrete reasoning (using only numbers) to abstract thinking (where letters represent numbers) and this is a difficult shift in learning for students (Kieran, 2006; Wang, 2015). For specific examples of student difficulties in college algebra see Herscovics and Linchevski (1994), Kieran (2006), and Linchevski and Herscovics (1996).

Kieran (2006) discussed how literature on the teaching and the connection to the students' difficulties in algebra learning was sparse. This is still the case 30 years after this paper was published. Looking at Tunstall's (2018) conclusions "no new data concerning students' pass rates in college algebra have been aggregated, so it is difficult to discuss (with any certainty) the effects of reform" (p. 633). The current study does just this. The current study aims to contribute to this limited research base in reform teaching of college algebra. The premise leading to the current research project was that a change of pedagogy may better serve the one million students enrolled every year in college algebra (Chapko & Buchko, 2004; Conference Board of Mathematical Sciences, 2016). Hence, inquiry-based learning in college algebra was studied in this research.

Inquiry-based learning is a student-centered pedagogy that focuses on student engagement in sequenced and scaffolded learning rather than the instructor transmitting content (Laursen & Rasmussen, 2019; Lazonder, 2014), and where students are active learners who learn by doing (Reiser & Dempsey, 2012). Students solve real-world problems that enable them to identify problems, offer and examine solutions, and communicate their thoughts (Laursen & Rasmussen, 2019). Inquiry-based learning puts students in the driver's seat. The students bring their prior knowledge and interests into the learning environment; "students engage deeply with coherent and mathematical tasks and collaboratively process mathematical ideas" (Laursen & Rasmussen, 2019, p. 138). Collaboration allows students to provide responses to feedback and answer questions that help them build their knowledge and solve problems at higher level than students who do not collaborate (Care et al., 2016). Students also participate in setting goals, designing learning activities, and designing assessment (Magee & Flessner, 2012). Instructors participate in these activities, "inquire into students' thinking and foster equity in their design and facilitation choices" (Laursen & Rasmussen, 2019, p. 138), guide students, encourage students to reflect, explore more deeply, and become independent learners (Tofel-Grehl & Callahan, 2014).

Inquiry-based learning allows the students to take ownership of their learning and encourages them to think for themselves (Ketpichainarong et al., 2010; Magee & Flessner, 2012; Tofel-Grehl & Callahan, 2014). Inquiry-based learning also allows students to ask questions and develop their own sense of their surroundings. Through these experiences, students develop deep conceptual understanding in addition to procedural understanding (Lewis & Estis, 2020). Effective inquiry-based learning encourages deep engagement in activities and provides opportunities to collaborate with peers through class presentation or group-oriented work (Hassi & Laursen, 2015; Johnson et al., 2016; Kogan & Laursen, 2014; LaForce et al., 2016; Magee & Flessner, 2012).

Unlike traditional lecture-based learning, inquiry-based learning does not restrict students to what the instructor transmits. Rather, it allows them to search, collaborate, evaluate their answers, and understand their thought processes (Darling-Hammond, 2008; Sawyer, 2006). Inquiry-based learning allows students to feel they are part of a group, and they are not isolated. They are informed their instructor is there to guide them and lead them to become critical thinkers and problem-solvers (Darling-Hammond, 2008; OECD 2009; Perkins, 2009; Sawyer, 2006). Inquiry-based learning helps students develop processing skills, deep understanding of the mathematical concepts, and retain information longer (Celikten et al., 2012; Larsen et al., 2015; Simsek & Kabapinar, 2010). Whereas traditional transmission-based (lecture) learning involves students are passive recipients of information and the instructor is the main source of knowledge (Sawyer, 2006), inquiry-based learning is a student-centered method that focuses on students' active participation, and the instructor is a guide and facilitator. Inquiry-based learning pedagogy assumes that students learn best when the subject is meaningful to them and they have the opportunity to engage in authentic tasks that reflect the reality of the subject (Darling-Hammond, 2008; OECD, 2009; Perkins, 2009; Sawyer, 2006). The role of the instructor is to create an environment that triggers students' curiosity, encourages them to think critically, solve problems, collaborate, communicate effectively, work with multiple perspectives, make good decisions, and be lifelong learners (Alberta Education, 2010). The more traditional lecture-based way of teaching is focused on teaching the students procedural knowledge (Perkins, 2009), whereas inquiry-based learning facilitates a deep understanding that occurs when students are active participants and involved in shaping their learning experiences. Davis (2008) stated that the traditional way of teaching, which relies on rote memorization and focused on teaching isolated facts, may allow students to pass a test but will leave them without understanding and unable to use and apply the knowledge in different situations. Students need to be challenged and asked to apply what they learn in real life situations and instructors need to provide them with continuous feedback and scaffolding in order for learning to occur. Unlike the traditional lecture-based teaching, which focuses on summative assessment and on one right answer (Sawyer, 2006), inquiry-based learning provides students with formative and continuous feedback that can help students understand their mistakes, improve their work, and better understand their thought process. It also can help instructors to adjust their pedagogy to help students reach their goal and more deeply understand the task at hand.

In the current study, inquiry-based learning was implemented in the following manner. The instructor presented students with problems that were purposely designed to deeply engage them with meaningful mathematical tasks (Laursen & Rasmussen, 2019). Then the students were required to identify issues and the underlying principles (Celikten et al., 2012; Kogan & Laursen, 2014;

Kuech, 2004; Summerlee & Murray, 2010). Next, students collaborated together to process the mathematical ideas (Ketpichainarong et al., 2010; Laursen & Rasmussen, 2019; Summerlee & Murray, 2010). While this was occurring, the instructor inquired "into students thinking," as well as fostered "equity in their design and facilitation choices" (Laursen & Rasmussen, 2019, p. 138). This process was repeated multiple times, which helped students develop deep conceptual understanding of the mathematical content (Laursen & Rasmussen, 2019), practice how to communicate effectively, and share resources with each other (Celikten et al., 2012; Kogan & Laursen, 2014; Kuech, 2004; Summerlee & Murray, 2010).

## MATERIALS AND METHODS

### Theoretical Framework

The main principles of constructivist epistemology as elucidated in the theories of Dewey, Piaget, and Vygotsky guided the theoretical framework and the design of the inquiry-based learning in this study. The key tenets of constructivism support the pedagogical process of inquiry-based learning. Inquiry-based learning is supported by the following shared ideas:

(a) learning is an active process that requires learners to be active participants in constructing their knowledge and to engage physically and mentally in class activities (Dewey, 1916),

(b) learning is social activity, and does not happen in isolation, and social interactions with peers and instructors are vital to the learner's cognitive development (Dewey, 1916; Vygotsky, 1978),

(c) learning is a process whereby students learn by constructing meaning to their surroundings, and use what they learn to build their new knowledge (Piaget, 1972; Vygotsky, 1978),

(d) the role of the instructor is to foster students' construction of knowledge through inquiry,

(e) instructors are facilitators who support collaborative learning and manage student groups and class discussions,

(f) instructors are facilitators who design learning environments to facilitate the learning process, and help learners develop critical thinking skills (Dewey, 1916; Piaget, 1972; Vygotsky, 1978), and

(g) learning is a lifelong process, and it takes time for learning to occur (Piaget, 1972; Vygotsky, 1978).

Thus, the strength of constructivism and inquiry-based learning allows students to ask questions and develop their own sense of their surroundings; through these experiences, students develop deep conceptual understanding over procedural understanding (Kogan & Laursen, 2014; Magee & Flessner, 2012).

### Study Setting

The current study examined whether inquiry-based learning pedagogy had effects on mathematics achievement scores in a college algebra class in comparison with a traditional, lecture-based method. The study was conducted during the first 12 weeks of the semester at a medium-sized, urban university in the United States of America that was classified as a Predominantly Black Institution. It enrolled a total of 4,340 undergraduate students, of whom 89.4% were considered underrepresented minority students. Approximately 84.8% of students received aid in the form of Pell Grants from the U.S. Federal Government. 29.6% were male students and 70.4% were female students. Approximately 82.6% of the student population was African American, 6.6% were Hispanic, 2.9% were white, 0.8% were Asian, and 7.1% were from unknown ethnicity. Only 25% of the students were between traditional college ages of 18 to 22 years. The average age of students was 28 years. The data were collected from students who were enrolled in two college algebra sections taught by the same instructor (the lead researcher). One section was taught using inquiry-based learning pedagogy and the other section using traditional lecture-based learning method. The two classes met on the same day of the week (Mondays and Wednesdays), in the same physical classroom, each session was for one hour and 40 minutes, the inquiry-based learning section was 9:00 AM to 10:40 AM, and the traditional learning section was 11:00 AM-12:40 PM. The sample size was based on the maximum capacity of each class, originally 50 students. The intervention section had 25 students and the comparison section had 25 students. However, two students dropped the inquiry-based learning class, and seven students dropped the traditional learning class due to their inability to afford the Pearson's *MyMathLab* online homework software, which resulted in a sample size of 23 students for the inquiry-based learning section, and 18 students for the traditional learning section.

The instructor used the same materials in both classes, so there were no demonstrable differences in this regard between the two sections. The textbook used in the course was *Essentials of college algebra with modeling and visualization* (Rockswold et al., 2014). In addition, Pearson Education's *MyMathLab* was used, allowing students online access to the homework assignments and exercises including guided solutions, sample problems, videos, and helpful feedback when students entered incorrect answers. Both sections were assigned the same homework, and students in both sections used a graphic calculator (e.g., TI 83, TI 84, or TI 84 plus) for homework and exams. Topics covered in the course were introduction to functions and graphs, functions and equations, quadratic functions and equations, nonlinear functions and equations, and exponential and logarithmic functions.

### Research Design

The design of this quantitative study was a quasi-experiment with pre- and post-test. The research involved gathering and analyzing data to examine whether inquiry-based learning had an effect on students' mathematics achievement scores in college algebra. The quantitative data were gathered using a pre-test (college algebra readiness exam) provided the first day of the study and a post-test exam (mathematics achievement exam) provided the last day of the study. Analysis of covariance was used to assess group differences in the outcome. The sample was a convenience sample and was not randomly assigned to the treatment condition due to the nature of the educational environment, as students self-enrolled in classes. The instructor had over 22 years of teaching experience, participated in an inquiry-based learning workshop, and been teaching using inquiry-based learning for over two years.

#### *Inquiry-based section pedagogy*

As previously discussed, inquiry-based learning refers to a teaching method where the main role of the instructor is to facilitate, guide students, and ask probing questions that help the group solve problems (Ketpichainarong et al., 2010; Magee & Flessner, 2012). The inquiry-based learning section of the participants was divided into six small groups of three to four students each, where all members in each group would collaborate together to solve a given problem. The small groups were formed based on the descriptive data that were collected. Thus, the groups were diverse in terms of gender, academic ability, age, and year in college. Also, in order for the students to feel accountable and responsible towards the group, each member of the group took a leadership role, rotating through the semester, asking questions, providing feedback, reflecting on the solutions, and discussing the errors and unexpected outcomes. The main role of the instructor was to facilitate and guide students and ask probing questions to help the group solve problems.

The following steps were implemented with the inquiry-based learning section:

(1) at the beginning of each lesson, the instructor presented an overview of the topic and demonstrated some examples using the whiteboard,

(2) groups were formed, a leader for the group was selected by the group, and students were instructed to collaborate together to solve a given problem,

(3) students were asked to think about the problem for five minutes individually before they joined their groups,

(4) the instructor moved between groups listening to their discussions, asking them to explain their strategies in order to uncover their prior knowledge and understand their thought process,

(5) the instructor asked probing questions that engaged students in re-examining their thinking and allowed them to identify the flaw in their strategies and interpretations,

(6) the instructor continued to be a facilitator who provided students with a safe environment that allowed them to share their thought process; the instructor did not provide answers. Instead, hints were provided through probing questions,

(7) the steps were repeated multiple times throughout the lesson,

(8) at the end of the group discussions, the leader of each group was required to write a detailed solution on the whiteboard (which was divided into six sections), explaining the process that led to the solution,

(9) the solutions were compared, and

(10) the members of each group presented their solutions to the whole class, answered questions, and provided explanations.

The instructor's role throughout the presentations was to draw students' attention to certain ideas materialized from the presentations providing content knowledge. Discussion continued until the groups agreed on a solution or had a better understanding of the solutions presented.

#### *Lecture-based learning pedagogy*

The term *lecture-based learning* refers to the traditional method of teaching where lecture is the main source for students' learning. In the current study, students who engaged in lecture-based learning did not actively participate in the class; instead, information was transmitted by the instructor to the students and the students' primary role was to copy the notes that the instructor wrote on the whiteboard. Students did not collaborate together in class to solve problems, nor did they interact with the instructor other than to ask questions. There was no specific treatment for this traditional lecture-based learning section, if students asked questions about a problem, the instructor wrote a detailed solution on the whiteboard while trying to re-explain using different words what the instructor had already said.

### Participants

Participants were 41 students enrolled in college algebra class: 23 in the inquiry-based learning section and 18 in the traditional learning section. Participants were 59.4% female, 40.6% male. Reporting age, 46.74% were under 21 years old. Full-time students comprised 90.77% of the sample. Regarding race, 78.02% self-identified as African American, 7.73% as white, and 14.25% as Hispanic. All participants were non-STEM majors, and a college algebra course was required by all to fulfill graduation requirements.

### Instrumentation

#### *College algebra readiness test (pre-test)*

To determine whether participants from both college algebra sections had similar mathematics abilities prior to the experiment, the instructor-researcher developed and administered a pre-test (college algebra readiness test) to both sections and compared the results. The test contained 25 multiple-choice items measuring students' prior knowledge of mathematics basic operations, equations, inequalities, exponents, polynomials, factoring, roots, radicals, and quadratic equations. The maximum possible test score was 100 points, with students earning four points for each correct item. The reliability of scores from the college algebra readiness test was assessed using test-retest reliability, whereby 23 students from a different college algebra section (not

**Table 1.** Descriptive statistics for mathematics achievement post-test scores

| Section | n | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Inquiry-based learning section | 23 | 78.26 | 11.49 | 52 | 100 |
| Traditional learning section | 18 | 63.11 | 12.76 | 44 | 84 |

participants) were asked to take the test twice. The first time was the first day of classes and the second time was one week later. Test-retest reliability for the scores was high, with r=.997. The content validity of college algebra readiness test was examined by three experienced faculty members from the mathematics department, who agreed that the content of the test matched the objectives.

#### *The mathematics achievement test (post-test)*

A post-test (mathematics achievement test) was developed and administered by the researcher. The test contained 25 multiple-choice items that were a measure of mathematics ability. The test consisted of questions about linear functions, quadratic functions, nonlinear functions, exponential functions, and logarithmic functions. 20 students from another college algebra section (not participants) were asked to take the test twice to determine reliability. The two tests were four days apart. Test-retest reliability was r=.998, indicating strong reliability. The content validity of mathematics achievement test was examined so that the content of the test matched the instructional objectives. Three experienced faculty members from the mathematics department reviewed the test for content validity and agreed that the content matched the objectives.

### Data Collection

Institutional Review Board approval was sought and granted, students were recruited, and the students' signed informed consent forms were received. Participants in both the inquiry-based learning and the traditional learning sections were asked to complete a survey to provide the researcher with demographic data (e.g., age, gender, year in college, employment status, and grade point average). The researcher explained that all students were required to participate in all activities in the class as part of the college algebra curriculum, but only the data from the students who signed and submitted the informed consent form would be included in the study. A college algebra readiness pre-test was administered to determine students' initial knowledge of algebra before the intervention and a mathematics achievement post-test was administered to measure students' academic achievement after the intervention.

### Data Analysis

To determine if there was a statistically significant difference in mathematics achievement between the inquiry-based learning section and traditional learning section, descriptive statistics were computed for both the intervention (inquiry-based learning) and comparison (traditional learning) sections, and analysis of covariance (ANCOVA) carried out. Statistical significance was set at an *a priori* level of α=.05. Analyses were carried out using SPSS version 23.

The dependent variable in the research question was the mathematics achievement test, the independent variable was the instructional pedagogy (inquiry-based learning vs. TL), and the covariate was the college algebra readiness pre-test. The effect size *($\eta^2$)* was calculated to determine the magnitude of the effect. The statistical assumptions of normality, homogeneity of variance, and homogeneity of covariance were inspected and addressed.

In terms of the threats to internal validity, there were three primary potential threats in the study. The first threat was the diffusion of treatment effect, "participants in the control and experimental sections communicate with each other. This communication can influence how both sections score on the outcome" (Cresswell, 2014, p. 175). However, this threat can be controlled by not informing the sections about each other, which the instructor followed. The second threat was testing effect, "participants become familiar with the outcome measure and remember responses for later use" (Cresswell, 2014, p. 175). The instructor controlled this threat by administering different exams before the intervention and after the intervention. The third threat was the instrumentation threat, "the instrumentation changes between a pre- and post-test, thus impacting the scores of the outcome" (Cresswell, 2014, p. 175). The instructor controlled this threat by using the same instrument for the pre- and post-test eight weeks apart.

## RESULTS

The study sought to examine whether inquiry-based learning had an effect on students' mathematics achievement in college algebra. This conclusion was supported by the students' scores on the mathematics achievement test. To control for pre-existing baseline differences between the groups, the researcher used a pre-intervention college algebra readiness pre-test as a covariate when comparing the post-intervention mathematics achievement between the inquiry-based learning section and the traditional learning section.

**Table 1** summarizes the descriptive statistics for the dependent variable (mathematics achievement post-test) in the study. **Figure 1** provides a boxplot of this variable, which indicated no outliers. Shapiro-Wilk's test was conducted on the model residuals, and results indicated the residuals deviated significantly from normality (p=.043), with negative skewness (-2.20) and positive kurtosis (3.72, see **Figure 2**). Next, the homogeneity of regressions slopes was evaluated by assessing whether the interaction effect of the covariate (college algebra readiness pre-test) and the independent variable (instructional pedagogy) on the outcome (mathematics achievement post-test) was statistically significant. The test revealed that the interaction term was not statistically

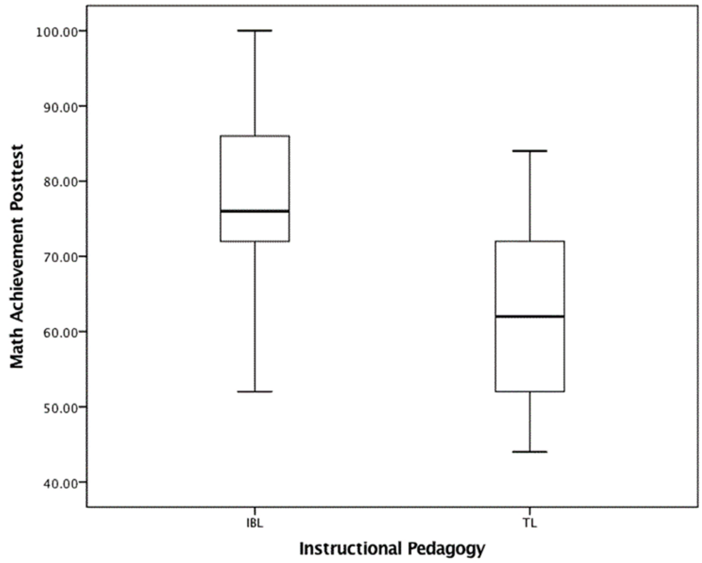


**Figure 1.** Boxplots of mathematics achievement post-test scores (Khasawneh, 2016)

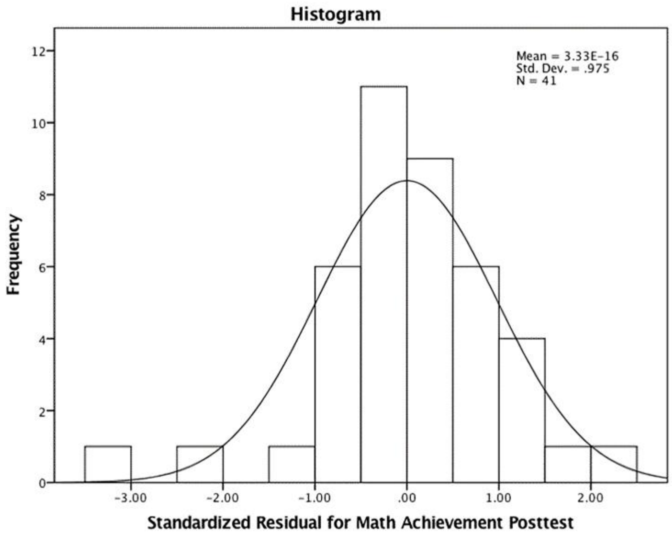


**Figure 2.** Histogram of ANCOVA residuals (Khasawneh, 2016)

**Table 2.** Adjusted means for mathematics achievement post-test scores

| Section | n | Adjusted means | Standard error | 95% confidence interval | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| Inquiry-based learning section | 23 | 77.55 | 1.96 | 73.57 | 81.52 |
| Traditional learning section | 18 | 64.02 | 2.22 | 59.53 | 68.52 |

significant, $F(1, 35)=3.45$, $p=.07$ indicating that the homogeneity of regression slopes assumption was met. Levene's test was not statistically significant, $F(1, 37)=.06$, $p=.81$, indicating the assumption of homogeneity of variance was met. Also, examination of a scatterplot of the mathematics achievement post-test scores on the college algebra readiness pre-test scores showed that the ANCOVA assumption of linearity between the dependent variable and the covariate was met.

ANCOVA results revealed the main effect of the instructional pedagogy was statistically significant, $F(1, 38)=20.70$, $p<.001$, with a large effect size ($\eta^2=.35$). The inquiry-based learning section showed significantly higher mean mathematics achievement post-test scores than the traditional learning section when controlling for the college algebra readiness pre-test scores.

**Table 2** provides the adjusted means, and **Table 3** summarizes the ANCOVA findings for the mathematics achievement post-test.

Due to the violation of the normality assumption, and to cross-validate the ANCOVA results, a non-parametric procedure recommended by Conover (1999) was carried out. This non-parametric ANCOVA using the ranked dependent variable and covariate showed a statistically significant difference between the inquiry-based learning section and the traditional learning section in favor of the inquiry-based learning section $F(1, 38)=16.01$, $p <.001$, with a large effect size ($\eta^2=.30$) which paralleled the results obtained from the ANCOVA carried out on the original scores.

**Table 3.** ANCOVA mathematics achievement showing effects of college algebra readiness pre-test & instructional pedagogy on mathematics achievement post-test

| Source | Type III sum of squares | df | Mean square | F | p-value | $\eta^2$ |
|---|---|---|---|---|---|---|
| College algebra readiness pre-test | 2,323.12 | 1 | 2,323.12 | 34.70 | <.001 | .41 |
| Instructional pedagogy | 1,826.71 | 1 | 1826.71 | 3.67 | <.001 | .35 |
| Error | 3,353.09 | 38 | 88.24 | | | |
| Total | 218,240.00 | 41 | | | | |

## DISCUSSION

Based on the findings of this current study, it was determined that the inquiry-based learning section participants' mean academic achievement score was significantly higher than the traditional learning section. Participants benefited from the inquiry-based learning pedagogy, which was reflected by their superior abilities in constructing knowledge, explaining, reasoning, questioning, and communicating with their instructor and their peers. This conclusion was supported by the student scores on the mathematics achievement test. The results of this current study agree with studies conducted previously by other researchers (Abdi, 2014; Akpullukcu & Gunay, 2011; Fishman et al., 2008; Gordon et al., 2001; Pandey et al., 2011; Summerlee & Murray, 2010). Specifically, Akpullukcu and Gunay (2011) investigated the effect of inquiry-based learning versus the traditional method on academic achievement in science. Their results revealed a significant difference in science achievement in favor of the inquiry-based learning section. Similarly, Pandey et al. (2011) investigated the effectiveness of inquiry training model over a conventional teaching method in teaching physical science to secondary students. Results showed a statistically significant effect of inquiry training model over conventional teaching method on academic achievement. Also, the results of the current study were similar to studies conducted to determine the effects of inquiry-based learning on pre- to post-test growth in student's achievement. Fishman et al. (2008) and Gordon et al. (2001) conducted a quasi-experiment study and concluded that inquiry-based learning increased the science achievement among urban minority students. Also, Yildirim et al. (2014), who examined the effect of inquiry-based learning on science achievement and scientific process skills, found a significant effect of an inquiry-based learning section on science achievement and scientific process skills. Similar results were obtained from an action study conducted by Witt (2010) to identify the impact of using inquiry-based or constructivist instruction in a middle school mathematics classroom on student academic achievement. That study concluded that using inquiry-based or constructivist strategies was effective in increasing student academic achievement. Similarly, Celikten et al. (2012) conducted a study to examine the effect of inquiry-based learning vs. traditional learning on fourth grade science students. Their results showed the inquiry-based learning section had significantly higher achievement scores than the traditional learning section.

The current study's researchers expected inquiry-based learning pedagogy would have an effect on students' academic achievement. Anecdotally, the instructor/lead researcher observed increased engagement on the part of the students, and their commitment to attend every class and be on time. Students communicated to the lead researcher that being a non-traditional student with multiple responsibilities is not always easy, but they put forth more effort to come to class because they felt they were learning, and they actually looked forward to the discussions with their peers. The lead researcher observed that the inquiry-based learning students felt they were a part of their learning process, they enjoyed working together while discussing their answers, explaining, and justifying to each other their approach in solving problems. One student wrote in a course reflection assignment "being able to work individually and then as a group. I liked this because I got to use my own thinking process and then gain other knowledge/understanding from my peers." Another student indicated, "how the instructor had the students work out the problem and then compared answers with the other students. It let me see was I doing the work correct." A third student commented, "I enjoy the group discussion part of class because we got to compare notes and different procedures on solving a problem." They liked the fact that they were given the opportunity to solve problems guided by their instructor, and they appreciated the trust the instructor had in their abilities, which boosted their confidence and motivated them to work harder. A student wrote "The way she asked us about the problem, I like this the most because she didn't give us the answer, she keep giving us hints on what we can do next to get to the answer." To sum it all up, a student stated,

> The aspects of the class I liked the most are: My professor first letting us try to solve the problem ourselves, then working with our peers, and lastly, my professor going over the problem as a class. I like this method of teaching because it makes me understand more and makes the work less complicated for those who are not great at algebra.

This current study contributes to the body of knowledge with findings that can motivate instructors to try pedagogies that encourage students to be active participants in the classroom, while giving students a chance to be responsible for their learning process. It adds to the knowledge of instructors in all subjects, especially mathematics instructors who struggle every day to facilitate student engagement and allow students to take control of their own learning. The study addressed the impact of inquiry-based learning on students' mathematics achievement. It provided instructors with a description of inquiry-based learning pedagogy and explained when and how this intervention was used to create learners who are capable of critical thinking and problem-solving.

Inquiry is no longer just the language of science and mathematics; it now contributes in direct and fundamental ways to business, finance, health, and defense. For students, it opens doors to careers. For citizens, it enables informed decisions. For nations, it provides knowledge to compete in a technological economy (National Research Council, 2007). Inquiry requires more than an instructor working alone to implement an inquiry-based learning environment successfully; all stakeholders should be on board and support the use of inquiry-based learning (Larsen et al., 2015). Instructors should be given the opportunity to get the appropriate training in order to learn *how* to implement inquiry-based learning successfully. All stakeholders should know that the 21st century requires different skills than the 20th century. Focusing on rote memorization and on standardized tests does not provide students with the skills needed to succeed. Schools should shift from focusing on skills that can be easily automated and focus on skills that technology cannot replace, one of which is the skill of critical thinking. These skills will help open doors for students in the workforce and in the global market. It is everyone's responsibility to make students and instructors aware of the importance of these skills, not only for themselves but also for their community and their country.

Instructors should be aware of their different responsibilities when adopting an inquiry-based learning environment. They should change their plans from how much material they can cover to how can they demonstrate to students the relevancy of what they are learning, and how they can apply skills in different situations. Instructors implementing inquiry-based learning no longer are standing in front of classrooms transmitting information. They are facilitators who create an environment where everybody can be active and motivated to learn. Instructors should focus on the learners, guide them how to learn, help them to be able to self-direct, and take responsibility for their learning. When instructors achieve that, students will be more prepared and have a better chance at graduating, joining the workforce, and becoming productive members of society (Blumberg & Pontiggia, 2011).

A final implication of this study is the potential impact of the inquiry-based learning pedagogy on retention of students (Laursen et al., 2014). Retaining students in these introductory, 'gatekeeper' courses is necessary and has a potential to help increase graduation rates. Even though retention was not the major focus in this study, there was an overall retention rate of 92% for the inquiry-based learning section versus 32% for the traditional learning section. This is an important topic for future research.

## CONCLUSION

### Main Conclusions

Based on observations and conclusions of other literature, the researchers of this study believe that instructional pedagogies based on constructivist principles should be integrated into curricula and should be implemented into the classroom. Instructors should encourage students to be active participants in their learning process, they should consider students' individual levels, experiences, and interests. The lead researcher had been teaching for 21 years at the same institution and was able to experience first-hand the change in students' confidence in their ability to do mathematics. Implementing the constructivist principles using inquiry-based learning in the classroom resulted in noticeable changes in the learning environment and the way students thought and behaved toward the class. Students in the inquiry-based learning section remained attentive while listening to the instructor lecturing for almost two hours and spent their time solving problems and collaborating with their peers knowing the instructor was there to guide them and help them identify their strengths and their weaknesses.

Inquiry-based learning facilitated students' learning and helped them take ownership of their learning and motivated them to work harder, helped them develop more independent and sophisticated ways of reaching capability and confidence (Abdi, 2014; Akpullukcu & Gunay, 2011; Fishman et al., 2008; Gordon et al., 2001; Pandey et al., 2011; Summerlee & Murray, 2010). Therefore, learning by using inquiry-based learning pedagogy could be considered as a more exciting and meaningful way to increase students' level of academic achievement, whereas in a traditional lecture-based learning environment, students are passive recipients of the knowledge dispensed by the instructor, and students rely on memorizing knowledge learned through rote manipulation, which can quickly be forgotten.

In conclusion, to provide students with scaffolds to help them reach their potential, it is important to recognize diversity among them, appreciate each student as an individual, understand their background and their thought process, make them feel safe, respected, and valued so they can participate in the process without fear of being judged by their instructor or their peers. To promote better learning, instructors should design questions that will cognitively engage students, enable them to tap into their prior knowledge, and find the relevancy between their prior knowledge and the new knowledge they gained.

### Limitations

The current study had limitations: as a convenience sample, the sample was not selected randomly nor was random assignment employed. The study was confidential, voluntarily, and students could choose to withdraw any time without penalty. The study was delimited to students who were enrolled in the college algebra sections the lead researcher taught and it was delimited to 12 weeks.

### Possible Future Studies

Future research could include replication of a similar study in other mathematics courses such as pre-calculus, calculus, etc. Because college algebra students often go into non-STEM (science, technology, engineering, and mathematics) fields, it would be interesting to conduct a similar study in mathematics courses where students desire to be in a STEM field upon graduation. In addition, this study did not examine gender effects. Other studies have found that women outperform men in mathematics courses when inquiry-based learning techniques are used (Cooper et al., 2015) in pre-calculus courses. Is the same true for college algebra courses?

A qualitative study conducting interviews with students in both types of courses would also be of interest to the mathematics education community. This would give a more in-depth understanding of why there are differences in achievement between students in the traditionally taught college algebra classes and the inquiry-based college algebra courses. Overall, this study provides insight into the teaching of college algebra, and it also provides a springboard for many other mathematics education research studies on inquiry-based learning.

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