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The Effects of Inquiry-Based Learning and Student Achievement in the Science Classroom

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THE EFFECTS OF INQUIRY-BASED LEARNING AND STUDENT ACHIEVEMENT IN THE SCIENCE CLASSROOM

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Abstract

Research has demonstrated inquiry-based learning (IBL) engages students in the processes of scientific discovery and can make science relevant toward their real-world concerns. However, in most science classrooms, teachers still use traditional learning, or direct methods of instruction for scientific terminology and other types of discrete knowledge students need to master for standardized testing. Existing research and studies have identified the various impacts of inquiry-based learning in the science classroom and its relationship between student achievement, student motivation and long-term knowledge retention.

Research has shown implementation of inquiry-based learning has a positive and direct relationship to student achievement. Planning and developing inquiry-based learning lessons can be time consuming and resources can be limited. However, students can make direct connections and experience deeper learning through hands-on and experiential learning which has an overall positive benefit for student achievement, knowledge recall and retention. This research study examined existing studies and research to understand the relationship between inquiry-based learning and student achievement and success in the science classroom and the varying benefits and methods to implement inquiry-based learning in the classroom.

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Introduction

Inquiry-based learning (IBL) is a widely used and highly recommended teaching strategy within the science curricula and across education (Aldahmash et al., 2016; Dunne et al., 2013; Wang et al., 2014). Mäeots et al. (2011) define IBL as a method of identifying and examining relationships, with students creating and developing hypotheses and experimentations by designing and applying experiment methodologies and analytical observations (p. 83). Within this learning approach, scientific concepts and methods are presented to students in a learner-centered strategy. IBL enables students to research by conducting and experimenting, incorporate theories and hypotheses, and apply content material to understand and assimilate solutions to an identified problem or concept (Savery, 2006)

In contrast, traditional learning (TL) is a strategy developed and centered around the instructor. Information is typically taught by the instructor or from resources including textbooks and lectures (Khalaf, 2018). Through use of the TL strategy, the monitoring of student achievement progress is an important aspect of education and curriculum. TL focuses on the students' ability to answer content knowledge questions through standardized testing and a multitude of assessment options, and mainly lacks the capability for students to make stronger, deeper, and personal connections to scientific material (Khalaf, 2018). McIntyre and Munson (2008) discuss how TL is not able to engage students and impedes their ability to process, recall, and retain information (p. 12). Studies conducted shows in a traditional classroom setting scientific information can still be presented and taught, but there is a disconnect between the long-term retention and application of scientific knowledge (Aligaen et al., 2016). Through TL, there has been a lack of student motivation because students do not understand the relevance of learning the content material (Wilhelm & Wilhelm, 2010). Within TL, there is a development of non-active learning and engagement among students due to the formulation of the learning process from the students receiving it (Khalaf, 2018). TL classes do not support active learning or student engagement and motivation because the learning process focuses on the teacher's role as opposed to the students and how effectively teachers are presenting lesson material (Khalaf, 2018). Student motivation and engagement is not present within the TL method because students are not being given a relevant reason as to why they are learning the content material and how it can impact them as learners (Dorier & Maab, 2012).

Purpose

For student success and achievement, students must be capable of understanding and applying content material (Darling-Hammond et al., 2020). In order for long-term knowledge to occur, students must interact and engage with the content material and create connections and applications to real-world situations (Theall, 1999). This interaction helps develop an understanding of the relevance of the material being presented. With the implementation of IBL, students have a sense of ownership and power, independence and understand the relevancy for learning (Cox et al., 2008).

There are many inquiry-based learning tactics and instructional methods (Baker & Robinson, 2018; Schmid & Bogner, 2015; Johnson & Cuevas, 2016). The purpose of this research study is to conduct a meta-analysis and systematic review of the effectiveness, efficiency, and impact of inquiry-based learning and the relationship between student knowledge recall and retention and student motivation and achievement.

Problem Statement

Inquiry-based learning engages students in the processes of scientific discovery and can make science relevant towards their real-world concerns (Darling-Hammond et al., 2020). However, in most science classrooms, teachers still use traditional learning (TL), or direct methods of instruction on scientific terminology and other types of discrete knowledge students need to master for standardized testing. In previous years, within science education and testing, student knowledge recall and retention became vital and was necessary to be taught. However, in today's science education and testing system, the application of scientific knowledge is more important and significant.

Rationale for the Study

Multiple research studies (Baker & Robinson, 2018; Schmid & Bogner, 2015; Johnson & Cuevas, 2016) have shown the positive impacts of implementing inquiry-based learning into the science classroom. Research suggests with the incorporation of inquiry-based learning within the classroom, IBL can lead to strong increases in student engagement, student motivation, and student academic achievement with long-term knowledge retention.

Definitions

5E Learning Cycle Model a method of instructing and organizing inquiry-based learning lessons through use of engagement, exploration, explanation, elaboration, and evaluation.

Collaborative Inquiry Groups a structured method where members will work together to identify problems and develop solutions through use of inquiry-based learning.

Constructivism Theory an approach to teaching, instructing and learning that is based upon scientific study and observation and allows the learner to actively develop their own understanding and knowledge of the world through life experiences and reflection.

Critical-Thinking Skills the ability to think logically and rationally about connective ideas and engage with introspective and individualistic thinking.

Inquiry-Based Learning an educational practice and method which puts the responsibility of the learning process onto the student. This form of active learning and teaching allows students to ask questions, form solutions to problems, explore and discover content material, and reflect upon learning processes to have deeper understandings of content material.

Knowledge Building Classrooms a method of implementing inquiry-based learning where students can utilize learning components of inquiry-based learning through the development of collaboration among peers to find solutions between a shared class goal.

Knowledge Retention the process of building upon previously learned knowledge and absorbing and remembering newly learned knowledge.

National Survey of Student Engagement a survey instrument used to measure the level of student participation as it relates toward learning and engagement within specific classes.

Online PhET Simulations a collection of online, research-based, interactive computer simulations for instructing students about physics, chemistry, math, and other sciences.

Problem Solving Skills the process and ability to determine and understand how to solve issues and problems promptly and effectively.

Traditional Learning an educational method of teaching where the educator provides direct instruction to students through lectures and presentations. The responsibility of learning and the flow of learning of information and knowledge is guided by the educator.

Literature Review

Inquiry-based learning has many strong benefits and aspects for science educators to implement within their classrooms. The importance of inquiry-based learning can allow students to have deeper knowledge and connections to content material while also taking ownership and responsibility for their learning. On the succeeding pages, I present a review of the current literature relating to IBL and student achievement, other benefits, and the effective IBL classroom activities. This research project will conclude with my research analysis question and a description of the methodology I followed to conduct a systematic review and meta-analysis.

Effective Inquiry-Based Learning Methods

There are varying strategies for IBL methods which can increase students' creativity and ability in scientific learning (Sidiq, 2015; Madhuri et al., 2012). The presence of the IBL method is very significant in science education along with the presence of methods and strategies to enable student achievement of lesson objectives (Sidiq, 2015). Educators should have a complete method of transferring and sharing scientific knowledge to their students. Sidiq (2015) describes the IBL teaching method as one which highlights the learning processes dynamically, in attempts for students to acquire proficiency in each of the learning objectives. Using proper IBL teaching methods is intended for solving the problems resulting in the learning process (Sidiq, 2015). Sidiq (2015) believes the inquiry model is best used in the scientific problem learning process. This model guides students to discover the problem and then apply procedural knowledge to solve the problems scientifically. The inquiry model is developed around the constructivism theory, where learning is an active process in which learners construct new ideas or concepts based on previous experiences and knowledge (Andrini, 2016).

Another IBL method is detailed by Barlow (1985). Barlow (1985) discussed the implementation of knowledgeable inquiry as a procedure of developing scientific knowledge with students and guiding them to discover and organize the scientific concepts and principles into an order of significance. Ssempala (2017) described IBL as a learning model which is intended to instruct students on examining scientific problems, issues and questions based on scientific facts, theories, and laws. The inquiry model highlights the processes and procedures of pursuing and discovering. The responsibility of students in this model is to pursue and discover their own solutions and explanations for a scientific concept topic while the educator provides guidance and supports students' learning (Ssempala, 2017). Overall, IBL is a progression of scaffolding knowledge and includes the activities of observing, communicating relevant questions, critically assessing the concepts and other sources of information, planning investigation or experiments, evaluating information already known, carrying out experiments or procedures by using a tool to collect, analyze and interpret the data, formulate predictions, conclusions and communicating the results (Williams, 2007).

The IBL model is a strategy used in the scientific learning process for students to develop the capability to ask questions, problem-solve, or investigate the world around them. IBL involves the students' ability to explore and investigate in a methodical and systematic, critical, rational and logical, analytical and reasoned process so students can formulate their own scientific hypotheses and conclusions.

Increasing Student Achievement Through Inquiry-Based Learning

Research has shown implementation of IBL is more effective than TL for increasing student achievement (Baker & Robinson, 2018). Saunders-Stewart et al. (2012) discovered and established 23 learning aspects and outcomes through IBL and showed recall and retention of knowledge were more predominant with IBL strategies. For example, Abdi (2014) conducted a study in a fifth-grade primary school in Kermanshah, Iran and found that students who were instructed using IBL had stronger and higher academic achievement than students in a TL classroom. Throughout the study, a control group of 20 female students and an experimental group of 20 female students were compared. While the control group was given a lesson through traditional teaching strategies such as direct instruction, the experimental group received a lesson through inquiry-based instruction. Abdi (2014) began the study by giving both groups an academic achievement pre-test. The test contained 30 multiple-choice questions to assess student achievement. Both groups were taught a lesson on three units on the fifth-grade content including topics of the nervous system, human diseases and environment (Abdi, 2014). Both groups were given a lesson presented by the same instructor and classroom observations were conducted to ensure the implementation of the treatments. Students within the experimental group were given lessons and activities designed around a learning model called the 5E Learning Cycle Model, which consists of five cognitive learning developments including engagement, exploration, explanation, elaboration, and evaluation and is centered around cognitive psychology and practices in science education (Bybee & Landes, 1990, as cited in Abdi, 2014, p. 38). The control group was given the lesson through direct instruction, lecture and discussion in order to present the concepts. After the lesson, a post-test identical to the pre-test was given to the students. Based on the results, the mean score from the pre-test to post-test for the experimental group increased by 4.15 points. In contrast, the mean score from the pre-test to post-test for the control group only increased only by 3.4 points (Abdi, 2014, p. 40). Abdi concluded there is a significant relationship between inquiry-based learning and student achievement, and those students exposed to inquiry-based learning had a deeper understanding of the material and could further interpret the information.

Through implementation of IBL, students interact with the relationships of scientific material, obtaining long-term knowledge and retention. Science knowledge and information should be transmitted through active and critical thinking of the learner (Cakir, 2008). Abdi (2014) discussed how IBL can be implemented to increase student achievement as well as longer term retention and application of interpretation. IBL allows learners to construct and develop long-term ideas and knowledge through scientific experiences and skills (Schmid & Bogner, 2015). Schmid and Bogner (2015) conducted a study in Bayreuth, Germany with 138 ninth graders from 10 classes and four schools to examine the effects of inquiry-based science education on learning outcomes and long-term knowledge. They hypothesized students who participated in a structured inquiry-based science unit would have a significant increase to their content knowledge. Their theory was developed around the idea of exposure to IBL and its connection of long-term knowledge retention. Within IBL, students can activate prior knowledge, build upon newly gained information and retain content knowledge based upon relevant and personal connections (Abdi, 2014). Schmid and Bogner (2015) also hypothesized students learning and experiencing through IBL would develop a deeper understanding and long-term retention of the content material in both student genders.

Throughout the study, Schmid and Bogner (2015) presented a topic on air and sonic waves to both an experimental and control group. Both groups were instructed by the same instructor to ensure teaching style was consistent. The control group consisted of 64 students from three classes and they did not take part in IBL. The experimental group consisted of 74 students from seven classes and were exposed to IBL for long-term knowledge retention. The experimental group was given four questionnaires which were completed over the course of a 14-week schedule. The questionnaires included a diagnostic test which was presented two weeks prior to the unit lesson, a post-test which was presented directly after the lesson, and a second and third post-test which were given at the six- and 12-weeks mark after the lesson. The unit consisted of three sequential lessons at 45 minutes each, all relating to the topics of how humans hear and the definition of sound (Schmid & Bogner, 2015). In the experimental group, students conducted inquiry-based projects in small groups. Each group member was given a role that was switched between the four members of the group. The roles included reading text out loud, collecting correct experimental equipment from areas, conducting the experiment, and writing the group's analysis and conclusions. Schmid and Bogner (2015) explained the instructor is only a guide to lead students to a solution when issues were raised, and students' only source of information was the inquiry lesson (Schmid & Bogner, 2015, p.56). The results showed through the diagnostic test there was a mean score of 5.9 and rose significantly on the post-test given directly after the inquiry lesson to a mean score of 12.00. The second post-test given six-weeks after the lesson had mean score of 9.9, showing a slight decrease. The post-test given at 12 weeks after the inquiry lesson had a mean score of 9.8 showing a slight decrease from the six weeks post-test (Schmid & Bogner, 2015). These results strongly support the hypothesis IBL promotes formation of long-term retention and recall of knowledge. The control group did not practice content knowledge skills through the repeated completion of the content knowledge tests and there were no significant impacts on their knowledge scores of the four assessments (Schmid & Bogner, 2015).

Other Benefits of Inquiry-Based Learning

Along with the benefits of student achievement and retention of scientific knowledge and information, IBL implementation shows students will become more motivated and engaged with their development of critical-thinking skills (Johnson & Cuevas, 2016). For example, Duran and Dökme (2016) conducted a study in Muğla, Turkey in a sixth-grade secondary school and determined students who were instructed and exposed to IBL yielded a more positive effect toward their critical-thinking skills and achievement than students who were instructed through TL strategies. Throughout the study, a control group 45 students and an experimental group of 45 students were compared. While the control group was given a lesson through traditional lecture strategies such as direct instruction, the experimental group was instructed by guided IBL. Duran and Dökme (2016) began the study by giving both groups an academic pre-test and post-test and were instructed on a sixth-grade unit about the structure of matter. Within each lesson instruction, the primary researcher presented the lesson in the experimental group, and the science and technology teacher instructed the lesson in the control group. Students within the experimental group were aware of the application of the IBL strategy and received a book of application material to follow throughout the research process. The main purpose of the IBL activities was to have students ask questions and discuss scientific process while activating critical-thinking skills. Within the experimental group, the IBL was instructed within eight weeks and a post-test was given upon completion of the lesson. Based on the results, the experimental group had a higher mean score on the critical-thinking post-test versus the control group. The findings and discussions related to the critical-thinking skills, the post-test critical thinking mean scores of the experimental group were measured to be 55.08 and 46.00 whereas the post-test critical thinking mean scores for the control groups were measured to be 40.27 and 35.91 (Duran

& Dökme, 2016). Duran and Dökme (2016) concluded there is a significant difference between the critical-thinking skills and score of the experimental group and the control group. Within the experimental group, Duran and Dökme (2016) discovered a strong relationship between IBL and increased development and use of critical-thinking skills.

Across education, one of the biggest concerns is trying to help students see worth and value in the curriculum being taught (Hough, 2015). Many students seek and question if the content and lesson material presented is worthy of their time and effort. By implementing IBL, students can make real-life connections, become engaged, understand the lessons being presented and connect the relevance and relatedness in the classroom (Madhuri et al., 2012). Madhuri et al. (2012) observed a study and described by teaching relevance in the classroom allows students to identify how lesson material can be used in real-world applications. The study examined the relationships between teaching relevance in an engineering chemistry class and student application of the course content on research and everyday activities (Madhuri et al, 2012). The study began with instruction of material on how engineering chemistry can be applied to real-world situations (Madhuri et al., 2012). The material was presented through IBL for students to apply their knowledge of chemistry (Madhuriet al., 2012). The experimental group consisted of 25 students who were instructed a lesson of engineering chemistry with IBL strategies, and the control group consisted of 25 students who were instructed a lesson of the same engineering chemistry topic but with TL strategies of direct instruction, lecture and note taking. Students within the experimental group had the option to create their own connections and relationships of engineering chemistry and applicable everyday situations through completion of IBL laboratories and experimentations (Madhuri et al., 2012). The results of this study showed by implementing an IBL lesson and activity to the experimental group, participation and in successful completion of assignments and activities were highly positive as compared to the control group. (Madhuri et al., 2012). Madhuri et al. (2012) concluded since relevance was presented to this lesson material through IBL, student engagement was more active, and students could understand relatedness and connections beyond the classroom.

Inquiry-Based Learning and Student Learning Outcomes and Strategies

In the whole education effort, the learning process and learning development is the most important activity. Within science education, one strategy to implement IBL is through student collaboration. To understand scientific discussions and experiments, students should be learning in collaborative inquiry groups to create and apply knowledge to develop scientific practices (Scott et al., 2013). Knowledge building classrooms are defined as a method of implementing inquiry-based learning where students can utilize learning components of inquiry-based learning through the development of collaboration among peers to find solutions between a shared class goal. Chan et al. (2012) conducted a study in Hong Kong on the impact of knowledge building strategies to promote science achievement. Knowledge building classrooms were developed to allow students to identify concept problems, create hypotheses, conduct research and experimentations in order to refine their hypotheses, revise their problem statements and strategies, and communicate and display the development of the collaborative community towards its purposes of scientific research (Scott et al., 2013). Within the aspects of knowledge building classrooms, the outcomes and goals are a strong strategy to implement IBL. The research goal of Chan et al. (2012) was to have students connect abstract ideas and concepts in chemistry on the microscopic level of elements and atoms. Chan et al. (2012) had an experimental group of 34 students participate in a knowledge-building class using a computer-supported collaborative learning classroom and a control group of 35 students participate in a

10th grade chemistry course. Both classrooms were taught the same course and chemistry curriculum, from the same instructor but the experimental group used a virtual collaborative practices, while the control group used lectures and textbook exercises in individual practice (Chan et al., 2012). The students within the experimental group were able to collaboratively ask questions, inquire about methods, and experience and share viewpoints and ideas, whereas students from the control group were limited to group discussion throughout the textbook and were unable to expand beyond concepts (Chan et al., 2012). The results showed the experimental group had a mean score of 80.6% and the control group had a mean score of 70.1% based on assessment of their scientific understanding of applicable critical-thinking and problem-solving skills in relation to scientific content material. The groups were also tested a year later on a standardized state test to learn if the experimental group had developed a sustainable relationship between applicable science problem-solving skills and understanding of scientific knowledge. The results showed that on a scale of one-to-five, the experimental group had a mean score of 3.8 and the control group had a mean score of 3.5, representing a statistically significant difference (p. 211). Chan et al. (2012) concluded that knowledge building classrooms, through the implementation of collaborative inquiry lessons are able to facilitate both scientific information and science and student achievement as well as showing positive effects of knowledge sustainability.

Through the process of defining educational outcomes, there are learning objectives that will be achieved in each lesson in the form of individual changes in behavior of learners (Andrini, 2016). The effectiveness of the learning model is determined by the proficiency of educators in presenting lesson materials. In presenting the education material, educators need a stable and solidified insight about teaching and learning activities (Andrini, 2016). An educator must have an overall objective and agenda of the certain development of scientific teaching and learning that occurs. An educator must identify which learning objectives are essential so that educational tasks and objectives can be performed and completed with the desired achievement results (Andrini, 2016). The IBL method can improve student learning outcomes (Andrini, 2016). Jensen et al. (2012) described learning objectives and outcomes as demonstrations of specific tasks a student can complete with proficiency at the conclusion of a lesson and can be observed from perspectives of both the students and educators. Effective use of IBL is able to provide growth in the teaching and learning development in the classroom and other related factors that will affect student learning, motivation and engagement. Using IBL strategies within the classroom can give students the ability to solve the problems that they find in their everyday life. Zimmerman and Risemberg (2006) studied assurance and cognizance from the teacher allows students to become independent learners, and research data showed a strong correlation with academic achievement, development, and improvement.

To incorporate IBL into the classroom, another strategy suggested is to implement experiential learning and inquiry-based activities for students to experience and question the scientific concepts presented. With a strong combination of inquiry-based activities and experiential learning, students have an opportunity to develop higher critical-thinking and problem-solving skills and more capability to retain content knowledge and material (Skelton et al., 2014). The incorporation and development of experiential learning and inquiry-based activities originates with basic scientific knowledge and skills. It proceeds to intuitive inquiry and acquisition and concludes with advanced problem-solving and critical-thinking skills which provide opportunity for students to exhibit mastery of scientific content knowledge and formulate conclusions based upon their learning (Skelton et al., 2014). Skelton (2018, pg. 228) conducted a study to define if middle school students instructed through IBL and experiential learning involving "scientific skill development, scientific knowledge and scientific reasoning, were more likely to meet their respective science grade level expectation." Participants within the study included six 6th grade science classes and five 8th grade science classes (Skelton, 2018). Students within the 6th grade science class received instruction and enrichment activities regarding soil pH. pH refers to the quantitative measurement of the acidity or alkalinity of a sample solution and is typically measured on a scale of 1 to 14. Neutral solutions, such as water, have a pH of 7, acidic solutions have a pH lower than 7, and alkaline solutions have a pH higher than 7. Students within the 8th grade science class received instruction about water chemistry and data analysis. Both classes examined the effect of plant growth based on their guiding topics of soil pH or water chemistry. Skelton (2018) used the first week of research to instruct basic scientific principles and skills to test for pH and water chemistry. Throughout instruction, students were provided the content knowledge, demonstration of laboratory techniques and processes of collecting data (Skelton, 2018). One IBL strategy Skeleton (2018) used throughout the study was incorporating guided inquiry-based questions and approaches toward the content material. Students were given the opportunity to examine a specific problem and conduct the procedure to investigate their questions (Skelton, 2018). Within the classes, students were broken in groups of three and "students developed hypotheses and devised their own procedures to test their hypotheses. Following their procedures, the students designed conducted their own experiments. Upon completion of the experiments, they were required to explain the problem, their hypothesis, procedures utilized, and present conclusions to their classmates" (Skelton et al., 2018. In Press). Skelton (2018) measured the science comprehension by assigning and providing a pre-test and a post-test which were developed to analyze the change in students' scientific knowledge and development of laboratory and scientific reasoning skills. The results showed through the 6th grade classes' pre-test including science knowledge, skill and reasoning, the science comprehension mean score was 3.62 and the 8th grade classes' pre-test science comprehension mean score was 4.07 (Skelton, 2018). After progression of the inquiry-based teaching strategy and lesson, students took the post-test to examine the change in scientific knowledge, skill and reasoning. The results showed the 6th grade classes' post-test science comprehension mean score had risen to 6.35 and the 8th grade classes' post-test science comprehension mean score had risen to 6.05 (Skelton, 2018). Active learning, reflection and engagement in inquiry-based approaches are found to be strong and beneficial methods of presenting scientific instruction (Rutherford & Ahlgren, 1990; Barron & Darling-Hammond, 2008). Data from this study determined beneficial science knowledge increases and demonstrated how IBL strategies promote scientific learning and skills (Skelton, 2018). As a result, educators and teachers should incorporate IBL strategies as a regular routine and learning method for classroom instruction (Skelton, 2018).

In science education, there are many options and strategies to incorporate IBL into daily lessons. Barrows (1986) detailed the multiple methods of IBL are identified on a range from the directness of the problem scenario to the self-directed learning (p. 482). Directed learning can be classified as student-directed learning, partial student- and teacher-directed learning, or only teacher-directed learning (Tawfik et al., 2020). IBL is strongly recommended and suggested to develop student-directed learning in order for students to solve real world problems and scaffold upon prior science content knowledge (Tawfik et al., 2020). Research has shown implementation of IBL through student-directed learning is strongly effective and beneficial in helping students conceptualize content knowledge and develop problem-solving skills (Lazonder & Harmsen, 2016; Loyens et al. 2006; Tawfik et al., 2020; Walker & Leary, 2009). Tawfik et al. (2020) examined the level of directedness in student-directed learning, partial student- and teacher-directed learning, and teacher-directed learning and how each varied in facilitating students gaining of conceptual knowledge of content material. Participants within the study consisted of 96 students in a business management class and were instructed to solve real world problem scenarios (Tawfik et al., 2020). During the first week of the study, a pre-test was provided to establish baseline data of the students' knowledge (Tawfik et al., 2020). Students were randomly placed into the different levels of directedness of either student-directed, partial student- and teacher-directed, or teacher-directed learning (Tawfik et al., 2020). In student-directed learning, students were provided with the information for a sales marketing problem scenario (Tawfik et al., 2020). In the student- and teacher-directed learning, students were presented with a week-long lecture explaining the relevant conceptual knowledge in regard to problem solving scenarios and were then instructed to provide solutions to the presented problem scenario (Tawfik et al., 2020). Students within the teacher-directed learning were presented with a two week-long instructor led class discussion about solving problem-based scenarios. At the conclusion of all levels of directedness, students were instructed to develop and submit a conceptual map of possible solutions for the problem scenario (Tawfik et al., 2020). At the conclusion of the study, students were given a post-test to examine the effect of the instructional strategy on their conceptual knowledge (Tawfik et al., 2020). The results showed significant changes among the conceptual knowledge and understanding based on the directedness of instruction (Tawfik et al., 2020). The pre-test mean score for the student-directed learning was measured to be 12.97, the student- and teacher-directed pre-test mean score was measured to be 12.18, and the teacher-directed pre-test mean score was measured to be 11.86 (Tawfik et al., 2020). After the treatment on each class group, the student-directed learning post-test mean score had risen to 14.35, the student- and teacher-directed learning post-test mean score had risen to 12.89, and the teacher-directed learning post-test mean score had risen to 12.54 (Tawfik et al., 2020). While all of the class groups' mean scores had risen, the student-directed learning group had the highest increase in understanding of conceptual knowledge (Tawfik et al., 2020). Based on the results of this study, it was determined with the higher degree of student directedness and control of their learning, students had the ability to process deeper conceptual knowledge and understanding of topics (Tawfik et al., 2020).

Methodology

This research study utilizes a meta-analysis and systematic review of existing studies and research to examine the similarities and disparities of the effectiveness of IBL and TL and the effects of each instructional method within the science classroom.

Ahn and Kang (2018) define a meta-analysis as an effective and independent method to examine and analyze different scientific results and data and compare to existing data and results. This logical research strategy can provide a deeper analysis of multiple existing studies to consider benefits and relative significance. The purpose of a systematic review is to distinguish, assess, and synopsize the outcomes and results of applicable research studies about IBL (Gopalakrishnan & Ganeshkumar, 2013). Northcentral University (2020, pg 1) defines a systematic review as “a high-level overview of primary research on a particular research question that systematically identifies, selects, evaluates, and synthesizes all high-quality research evidence relevant to that question in order to answer it.”

Method of Inquiry

A distinct research question was developed to conduct the research and process. The research question developed details the incorporation of inquiry-based learning within the science classroom and how IBL can lead to strong increases in student engagement, student motivation, and student academic achievement through ability of long-term knowledge retention.

Data Collection and Analysis

Data and research studies and results were gathered and examined from published studies. Peer-reviewed articles and studies chosen for analysis and examination are centered on inquiry-based learning in the classroom setting. Research studies assess the qualitative and quantitative data and results and assist in deeper understanding of findings. The research studies were analyzed to include relevant and reliable studies only.

In relation to such topics as assessment (Fry, 2014), knowledge retention (Abdi, 2014), and obstacles (Edelson et al., 1999), further examination consisted of how educators experienced using inquiry-based learning in their lessons and if they saw a beneficial effect towards student achievement and growth. Research was also analyzed to look at how educators measured student growth through types of assessments. Based upon the literature review, analysis and examination also consisted of relationships between student retention and recall and inquiry-based learning (Schmid & Bogner, 2015).

Data Analysis

Four research studies were meticulously and methodically assessed and evaluated to determine the common ideas and topics in refer towards IBL and its effect on student motivation, achievement, and long-term knowledge recall and retention. Criteria of analysis for each study in this synthesis are: 1) use of IBL to promote student interactions with scientific content material, student achievement, motivation, and long-term knowledge and recall; 2) use of varying IBL instructional strategies and methods; and, 3) research conducted on classes where IBL could be applicable and relatable toward course content material. Detailed descriptions of those studies follow.

Irwanto Irwanto, Anip Dwi Saputro, Eli Rohaeti, and Anti Kolonial Prodjosantoso's (2018) research showed the experimental group with IBL scored higher on the post-test results in regard to problem-solving and critical-thinking skills. The data also supported through "participating in inquiry-based activities, students can recognize the nature of science, the phenomenon, and scientific concept; develop their ability in evaluating scientific data critically and participate in scientific community (Löfgren et al., 2013)." With this study, the experimental group showed strong correlation between exposure to IBL and increased acquirement of scientific knowledge and processes.

Francis Adewunmi Adesoji and Mabel Ihuoma Idika (2015) detailed the experimental group with more directed inquiry-based instruction was found to have a significant increase on students' scientific knowledge achievement. The results described the probability of the data and discussed how IBL "was imperative for understanding the students' prior knowledge in order to know what the student need to know… [and] support the process of transfer of learning whereby students can make connections between classroom instruction and the outside world (Adesoji & Idika, 2015)."

Beth Archer-Kuhn, Yeonjung Lee, Savannah Finnessey, and Jacky Liu (2020) showed the results of their study confirmed the participants had a strong increase in higher-order learning of conceptual knowledge succeeding the participation in IBL. Results also discussed the positive increase in ability of reflection and integration of students' learning with exposure to IBL. Participants of this study detailed the deeper knowledge and understandings of connections between course content and the real-world could be observed. Results showed a strong correlation between IBL and student engagement and higher order thinking with the ability to apply, synthesize, analyze and create deeper understandings of content knowledge.

Lia Yuliati, Cycin Riantoni, and Nandang, Mufti (2018) indicated study results had displayed a strong correlation between IBL and students' ability of problem-solving skills. The results showed the experiential group who was exposed to IBL tactics had a stronger capability to use problem-solving skills and find viable solutions to presented challenges. Results showed with students who were not exposed to IBL methods demonstrated less ability to problem-solve issues and challenges and struggled to make deeper connections of content material toward possible solutions. The results concluded students should be exposed and instructed to active learning tactics and IBL to develop stronger problem-solving skills.

IBL is a pedagogical method and strategy which "inherently encourages co-creation of knowledge and, therefore, shared power, an important component of social justice (Archer-Kuhn et al., 2020)." IBL enables students the power of choice and freedom within their learning and studies show how the strong teaching and learning partnership is able to apprise the learning process and accept modifications in curriculum activities and design and pedagogical strategies and methods.

Existing Studies

Research focusing on "Using Inquiry-Based Laboratory Instruction to Improve Critical Thinking and Scientific Process Skills among Preservice Elementary Teachers" was conducted by Irwanto Irwanto, Anip Dwi Saputro, Eli Rohaeti, and Anti Kolonial Prodjosantoso in 2018. Participants of this study were randomly divided into two subgroups; a control group of 22 students, and an experimental group of 21 students. 53% of the participants were female and 46% were male. The instruments used in this study were the Oliver-Hoyo Rubric for Critical Thinking (Oliver-Hoyo, 2003) and the Observation Checklist for Scientific Process Skills (Irwanto et al., 2018). These assessments were conducted individually at the beginning and end of the study, as a pre-test and a post-test. Baseline data were gathered through the administered pre-test. The location of the study occurred at the Muhammadiyah University of Ponorogo in Indonesia.

In the 2015 study titled "Effects of 7E Learning Cycle Model and Case-Based Learning Strategy on Secondary School Students' Learning Outcomes in Chemistry," Francis Adewunmi Adesoji and Mabel Ihuoma Idika examined the effects of IBL on student learning outcomes and understandings. Participants for this study included 208 senior secondary students from two schools in Ibadan, Oyo state, Nigeria and were separated into an experimental group or control group. The instruments used in this study were the Teachers' Instructional Guide for 7E Learning Cycle Model, Teachers' Instructional Guide for Case-Based Learning Strategy, Chemistry Achievement Test, Students' Attitude to Chemistry Questionnaire, Evaluation Sheet for Research Assistants. For baseline data, the Chemistry Achievement Test and the Students' Attitude to Chemistry Questionnaire were administered as a pre-test. The experimental and control groups received instruction for four weeks and at the conclusion of the treatment, the Students' Attitude to Chemistry Questionnaire was administered a second time and a rearranged Chemistry Achievement Test was assigned at conclusion of the last lesson presentation.

In 2020, Beth Archer-Kuhn, Yeonjung Lee, Savannah Finnessey, and Jacky Liu conducted a study to examine the student engagement levels in learning by implementing IBL in higher education courses. Participants for the sample size included 157 students who were enrolled in social work courses with IBL methods incorporated throughout the course. Among the total participants, 69 students participated in the study and completed the pre-course survey and 52 students participated in the study and completed the post-course survey. 36 students of the total sample size completed both the pre-course and post-course survey. Of the group of 52 students, six partially structured focus group interviews were conducted with 19 students. To gather baseline data, the researchers distributed a survey to assess the student engagement and experiences using IBL. Several instruments were used to analyze data including the National

Survey of Student Engagement survey, the higher-order learning subscale, and the reflective and integrative learning subscale. Focus groups were also used to measure and understand the students' perspectives and explain results of the quantitative data from the surveys using qualitative methods.

Lia Yuliati, Cycin Riantoni, and Nandang, Mufti explored the effects of students' problem-solving skills through IBL with online PhET simulations in 2018. Participants within the sample size included first-year Physics Education students at the State University of Jambi, Indonesia. Data were obtained using instruments of a multiple-choice questionnaire about Determining and Interpreting Resistive Electric Circuit Concept (Engelhardt & Beichner, 2004) and interviews of unstructured techniques for answer confirmation and problem-solving skills for exploration. Baseline data for initial problem-solving skills were collected through a pre-test and student interview. Data collection was obtained through implementation of IBL with online PhET simulations through IBL questions and procedures and results were reassessed through a post-test and student interview.

All four research studies had thematic sections dedicated to determining and analyzing the relationship between IBL and student motivation, achievement, and long-term knowledge recall and retention. Each research study used formal analysis assessments to consider the effect of IBL on student achievement, motivation, and long-term knowledge recall and retention.

Findings and Conclusions

A systematic review and meta-analysis of the four research studies chosen for analysis and evaluation showed strong support and evidence IBL positively impacts and effects student achievement, motivation and long-term knowledge retention and recall.

As Francis Adewunmi Adesoji and Mabel Ihuoma Idika (2015) determined through their study, self-directed learning is a successful strategy where the teacher is a facilitator and the student discovers knowledge and demonstrates ability to apply to real-life circumstances through structured learning activities.

Irwanto Irwanto, Anip Dwi Saputro, Eli Rohaeti, and Anti Kolonial Prodjosantoso's (2018) discovered through their research, students are becoming trained to critically think and problem solve ideas and are capable of succeeding higher learning achievements when using IBL and conducting experiments of their preference through experimental and discovery learning, rather than being limited to a set of guidelines.

Beth Archer-Kuhn, Yeonjung Lee, Savannah Finnessey, and Jacky Liu (2020) demonstrated through their experiment, IBL allows for students to reflect and integrate content knowledge toward real-world scenarios by increasing their higher-order learning skills, permitting students to engage and interact with their learning and content material.

Lia Yuliati, Cycin Riantoni, and Nandang, Mufti (2018) presented through their study results, IBL permits students to solve for viable solutions, organize conceptual knowledge, form deeper understandings of procedural and experimental knowledge, and formulate strategies to apply and implement problem-solving and critical-thinking skills, while activating memory recall and retention of content material.

Recommendations for Further Study

Based on the data and findings, it is recommended that science teachers should implement, employ and incorporate IBL into the classroom for students to construct and develop their own understandings of knowledge and actively learn and interact with curriculum content. Educators should be equipped and prepared for the classroom environment to promote effective IBL for meaningful and deeper instruction and learning. Establishing an inclusive classroom and help promote further IBL with the sense of ownership of learning upon the students. It is also recommended for teachers to research and understand the necessary components, materials, and planning time needed to implement IBL to present effective active learning among lessons. Further research is needed to examine the influence of educational policy makers in terms of funding for scientific learning materials and laboratory supplies. Science educators should be morally encouraged to introduce IBL strategies and methods into the science classroom to promote deeper and active learning.

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