Inquiry Based Learning as an Instructional Strategy to Increase Student Achievement in Math and Science

Reza Chowdhury
Doctoral Student of Instructional Design and Technology
The University of Memphis
5998 Maher Valley Cove
Bartlett, TN 38135

Descriptors: Inquiry-based learning, teaching by asking

Abstract

Inquiry-based learning (IBL) is receiving a lot of attention and consideration as a modern instructional method. This paper defines IBL along with its constructivist paradigm. Inquiry-based learning could be best understood through its distinct phases, i.e., engage, explore, explain, expand, and evaluate. This survey of literature demonstrates the current trends of utilizing inquiry-based learning in the k-12 schools, influencing factors for successful implementation of IBL, and finally the benefits & challenges of inquiry-based learning. This survey of literature raised few critical questions, including: ‘Is there a universally accepted definition of Inquiry-based learning?’ and ‘Is Inquiry-based learning working for learners?’. Finally, this paper concludes with a discussion and recommendation for future research areas in Inquiry-based learning.

Introduction of the Problem

To break through the trend of stagnation and place it among the top five performers on the international stage in school level science and math achievements, the United States needs inquiry-based learning that promotes understanding over memorization and assessments, which are intentionally designed to measure student knowledge integration abilities over standardized tests (Liu, Lee, & Linn, 2010). The United States is not among the top five performers either in math or in science. To break this trend, the students of the United States must learn complex problem-solving techniques instead of memorizing algorithms or definitions (Marshall & Horton, 2011).

15-year-old students of the United States are participating in international testing since 1960’s with lackluster performance and consistently positioned on the bottom half of the participating countries (Hanushek, 2004). Two of the distinct and leading international assessment programs are: the program for International Student Assessment (PISA) under the umbrella of Organization for Economic Co-operation and Development (OECD) and the Trends in International Mathematics and Science Study (TIMSS). These assessments are the benchmark for comparing the outcome of the standardize test of math, science, and reading for 15-year-old participating students representing different countries. Though, over the last four decades, the United States has participated each of the last 15 international assessments, U.S. students failed neither to perform well nor to show any sign of improvement over the time. In 2012, among the 34 OECD countries, the United States ranked 27th in mathematics, 17th in reading, and 20th in Science (OECD, 2012). Though U.S. students demonstrated strengths in lower-order cognitive mathematical skills and abilities, U.S. students have tremendous weakness in modeling and solving higher-ordered cognitive activities related to mathematical models. U.S. has substantial economic advantage over most of the participating countries, spending the 5th highest amount of money per student and U.S. parents are better educated than the parents from most other participating countries (OECD, 2012). Considering the afore mentioned important elements of U.S. context, U.S. can and should do a much better job in preparing U.S. students to break through this stagnation and place its 15-year-olds among the top preforming nations.

These below average assessment results are the early warning sign for our nation’s future economic welfare and higher-order thinking skill workers. Research indicates, if U.S. can be positioned at the average level of European achievement distribution, U.S. economy will gain a one-half of one percent boost in per capita income, i.e., about an increase of $2,000 in per capita income after 10 years (Hanushek, 2004). Schools, teachers, administrators, educators, policy makers, and legislators can and should work hand on hand to help our students to develop higher-order cognitive thinking by introducing active, participative, and higher-order thinking teaching and learning approaches instead of simply transferring passive knowledge for rote memorization. While American
teachers are failing to promote and develop higher-order thinking skills among our students, a body of research suggests and promotes inquiry-based learning as a critical approach to boost students’ performance in international standard achievement tests (Marshall & Horton, 2011). The purpose of this literature review is to define IBL along with its epistemological paradigm, learn the current trends of utilizing IBL in the k-12 schools, identify the influencing factors for successful implementation of IBL, and understand the benefits & challenges of inquiry-based learning. Finally, this literature review attempts to address the eventual question, is inquiry-based learning working for our learners? The eventual goal of any successful instructional model is to help the learners accomplish new knowledge in an effective and efficient manner and promote higher order thinking. While there are challenges and limitations, analyzed data from 138 studies supports a strong and positive trend favoring inquiry-based learning practices, especially instruction that promotes student active thinking and develops decision-making capabilities based on explored data (Minner, Levy, & Century, 2010).

What is Inquiry-based Learning (IBL)?

Inquiry-based learning came into existence through a series of engaged dialogue regarding different approaches of learning and teaching, in particular from the work of Jean Piaget, Lev Vygotsky, and David Ausubel. The work of these theorists was blended into the philosophy of learning known as constructivism (Cakir, 2008), which was then used to shape instructional materials.

Inquiry-based learning is rooted in learning by discovery. Jerome S. Bruner, an American psychologist, made significant contributions in defining discovery learning. Bruner’s works focused on three distinct components while dealing with cognitive learning theory. Three key tenets are: the role of culture and structure in learning, the spiral curriculum, and discovery learning (Jiang & Perkins, 2013). Bruner described culture as the toolkit for sense-making and communication (Takaya, 2008). Learners make sense of the words, images, and concepts according to their own culture, beliefs, and shared views; while cultural values are not constant rather diverse and evolving in nature. Cultural aspect of the education directs the learners to think about alternative views and encourages the learners to explore multiple perspectives before coming to a conclusion (Takaya, 2008). The structural component demands that the learners understand the new concept by liking it with existing knowledge instead of simply memorizing in the vacuum (Jiang & Perkins, 2013). The structure component emphasizes on disciplined understanding by expanding and deepening a learner’s existing knowledge. The spiral curriculum concept encourages revisiting foundational concepts repeatedly until learns display mastery on those basic concepts. The third component, discovery learning, promises that learners utilize past knowledge and current experience to explore facts and relationships to develop new knowledge and understanding within themselves. The key idea here is to construct new knowledge by going beyond the presented facts and concepts. Constructivist approach of learning emphasizes the learners to go beyond something given. Vygotsky revealed a gap between a child’s “actual developmental level as determined by independent problem solving” and the higher level of “potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (1978, p.86). Vygotsky coined this term as the zone of proximal development. The concept of scaffolding is grounded in the theory of zone of proximal development (ZPD) (Vygotsky, 1978).

Fundamentally, constructivist designers view instruction as “a process of supporting [knowledge] construction rather than communicating knowledge” (Cunningham & Duffy, 1996, p.171). The constructivist classroom is an environment where learners actively inquire and originate new knowledge and ideas through engaged dialogue, interaction, presentation, sharing, and negotiation. In this setup, teachers’ role is to guide and moderate the discussion rather than passively passing information to the learners. Constructivist teachers provide direction to the learners by engaging them in inquiry activities and by stimulating student centered active discussion and knowledge sharing, i.e., promoting active learning in a social setup where learners construct new knowledge according to their prior knowledge, social realities, peers’ perspectives, and new findings (Bruner, 1986). Piaget, one of the most famous constructivist epistemological thinkers, argued that the learners’ new knowledge construction portrays the real world in which the learners lived through (Bruner, 1986). Based on the principles identified by Smith and Ragan in 2005, a new design theory has evolved with three basic principles: “Learning results from a personal interpretation of experience, Learning is an active process occurring in realistic and relevant situations, and Learning results from an exploration of multiple perspectives” (Richey, Klein, & Tracey, 2011, p.130).

According to Keller (1987), inquiry is a process of knowledge-seeking behavior. “A deeper level of curiosity may be activated by creating a problem situation which can be resolved only by knowledge-seeking behavior” (Keller, 1987, p. 2). So, the essential question is what are the key components of inquiry-based learning?
Key Components of Inquiry-based Learning Approach

Inquiry-based learning is structured around different inquiry phases, which work as an articulate group to build an inquiry cycle. However, it is evident from the literature that no single definition can include every possible phase of an inquiry cycle (Pedaste et al., 2015). Callison and Baker (2014) discovered five foundational elements of information inquiry learning that surprisingly remain constant in this evolving environment. These five foundational elements are: questioning, exploration, assimilation, inference, and reflection. Pedaste et al. (2015) reviewed 26 articles related to inquiry-based learning and suggested five distinct general inquiry phases: orientation, conceptualization, investigation, conclusion, and discussion (Pedaste et al., 2015). Marshall and Horton (2011) gathered more than 100 sets of classroom observational data of middle school science and math teachers to assess different components of inquiry-based instruction. They identified four common components of inquiry cycle: engage, explore, explain, and extend. Based on the research conducted by Luera, Killu, and O'Hagan (2003), the five key components or stages of inquiry-based learning are: engage, explore, explain, expand, and evaluate.

<table>
<thead>
<tr>
<th>Reference to the researchers</th>
<th>Number of components</th>
<th>Name of the components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedaste et al. (2015)</td>
<td>Five derived phases</td>
<td>Orientation, conceptualization, investigation, conclusion, and discussion</td>
</tr>
<tr>
<td>Callison and Baker (2014)</td>
<td>Five foundational elements</td>
<td>Questioning, exploration, assimilation, inference, and reflection</td>
</tr>
<tr>
<td>Li, Moorman, and Dyjur (2010)</td>
<td>Five key steps</td>
<td>Ask, investigate, create, discuss, and reflect</td>
</tr>
<tr>
<td>Marshall and Horton (2011)</td>
<td>Four common components</td>
<td>Engage, explore, explain, and extend</td>
</tr>
<tr>
<td>Luera, Killu, and O'Hagan (2003)</td>
<td>Five key components</td>
<td>Engage, explore, explain, expand, and evaluate</td>
</tr>
</tbody>
</table>

Table 1 summarizes different key components of inquiry-based learning as identified by diverse researchers between 2003 and 2015.

Pedaste et al. (2015) did a very thorough and detailed literature review of 30 peer reviewed journals to identify distinct phases in an inquiry-based learning process. An analysis of the articles resulted in the identification of five distinct general inquiry phases: orientation, conceptualization, investigation, conclusion, and discussion. According to this framework, inquiry-based learning begins with orientation and flows through conceptualization to investigation, where several cycles are possible. Inquiry-based learning usually ends with the conclusion phase. The discussion phase (which includes communication and reflection) is potentially present at every point during inquiry-based learning and connects to all the other phases, discussion may potentially occur at any time during (discussion in-action) or after inquiry-based learning when looking back (discussion on-action) (Pedaste et al., 2015).

According to Callison and Baker (2014), there are five foundational elements of information inquiry learning that are surprisingly constant in this evolving environment. These five foundational elements are questioning, exploration, assimilation, inference, and reflection. Questioning triggers thinking; thinking leads to greater understanding in resolving a problem at hand. In the exploration phase, students search for answers to the questions. Exploration is a discriminating process to find and organize information in an effort to answer the question. In the inference phase, students make a conclusion based on findings which they acquired during the exploration phase and personal prior knowledge. In the reflection phase, students contemplate to answer a few questions to solidify the inquiry learning. Though the inquiry learning approach is evolving at a fast pace, the five core elements of inquiry learning remain fundamentally unchanged (Callison & Baker, 2014).

According to Li, Moorman, and Dyjur (2010), the five key steps in an inquiry-based learning model are ask, investigate, create, discuss, and reflect. Li, Moorman, and Dyjur (2010) proposed an inquiry-based learning model with videoconferencing and e-mentoring for rural areas in Canada. According to this model, inquiry begins with student-inspired, natural questions and ends with new knowledge creation. After identifying the questions, learners investigate to acquire relevant facts and data. Based on the collected data, learners devise or create a solution to the problem or question at hand. Learners discuss and share their solutions and data with the other students. Finally, learners think and reflect utilizing higher order thinking to construct new knowledge to apply in a creative way for future uses.

Based on the research conducted by Luera, Killu, and O'Hagan (2003), the five key components or stages of inquiry-based learning are: engage, explore, explain, expand, and evaluate. This section will illustrate five
different components of IBL framework as championed by Luera, Killu, and O'Hagan (2003). Students learn most once they are engaged in the learning process. In the engage stage, the role of the teacher is to generate curiosity and interest in the topic. Engage phase is completed when a student forms a question for his or her inquiry. In exploration phase, students search for the answer to the question. Exploration is a discriminating process to find and organize information in an effort to answer the question (Callison, & Baker, 2014). In the explain stage, students share their findings and methods while explaining their hypothesis and results. At this stage, students ask relevant questions to each other to understand each other’s work. Callison and Baker (2014) suggested some of the critical questions for the students to ask: Did I answer my question successfully? Did I utilize the best possible resources at my disposal? Finally, the teacher explains the student’s questions and queries to link the information to the development of concepts (Luera, Killu, & O'Hagan, 2003). During the extend/expand stage, students apply the concepts and skills in the new problem to validate the knowledge (Luera, Killu, & O'Hagan, 2003). Knowledge expansion is best accomplished by associating new knowledge with real-world applications. The evaluation stage is the ongoing practice throughout the process. “At this point in a traditional lesson, students would often be asked to demonstrate their new understandings by completing an activity sheet or some other activity that would be turned in, graded, and later returned to the students.” (Luera, Killu, & O’Hagan, 2003, p. 7). Evaluation in the inquiry learning process is difficult but not impossible. One possible solution is a problem solving approach, in which students are challenged with problems based on newly learned concepts. In this process, immediate feedback is essential for quick identification of learning gaps and to reteach the concept (Luera, Killu, & O'Hagan, 2003).

Current Trends of Utilizing Inquiry-based Learning

There is a common belief that few teachers are teaching science and math utilizing an inquiry learning approach. Capps and Crawford (2013), found little to no practical evidence to support this claim. AASL’s (American Association of School Librarians) Standards for the 21st-Century Learner provides vision for teaching and learning by promoting inquiry framework of learning; i.e., to promote inquiry, critical thinking and eventually constructing new knowledge (Marriott, 2014). Students in the United States need to learn how to think critically in the class rooms and beyond the class room setup. To promote critical student thinking, commissions, studies, and reports continue to call for the adoption of inquiry-based learning approaches in science and math (Marshall & Horton, 2011).

There are different flavors of inquiry teaching practiced by teachers in classrooms. Banchi and Bell (2008) provided a framework for three different kinds of inquiry teaching methods—structured, guided and open. Structured inquiry method, developed and managed by the instructors, is a controlled and planned approach. In this approach, students investigate a prescribed question using a method provided by the teacher. This approach does not allow the students to come out with their own questions rather teachers provide a set of relevant and critical questions for the students to think and ponder on it. Teachers also provide a structured method of thinking through to solve the designated questions. This is the least creative and open thinking methods for inquiry learning for the students. In guided inquiry approach, teachers provide the structured inquiry questions but students come out with their own creative methods to investigate these questions. Whereas, in open inquiry, students investigate questions that they have posed using methods that they have designed (Banchi & Bell, 2008, p. 26 – p. 29). Though these three approaches offer different amount of teachers’ guidance and learners’ open thinking, at the center, all these approaches inspire critical think among the students to promote active learning.

Promoting “critical thinking” skills is taking center stage as a key objective in modern classrooms. Past researches have mostly examined the effectiveness of a single instructional approach in promoting critical thinking. Lately researchers began discussing mixed teaching approaches. Ku, Ho, Hau, and Lai (2014) suggested educators adopt more than one instructional approach of teaching critical thinking to optimize learning outcomes. Common Core State Standards (CCSS) requires educators to learn and teach how to ask essential questions to their students to encourage critical think and innovation (Wilhelm, 2014). On the other hand, despite the presence of a decade of rich literature promoting the need and importance of IBL, there is little evidence that it is widely used in science classrooms (Hermann & Miranda, 2010).

Table 2 summarizes Key current approaches of inquiry learning as identified by different researchers between 2008 and 2014.
Educators utilize IBL to promote active learning. In traditional learning setup, teachers actively pass the structured information to the students while students passively consume the delivered information. If teachers encourage and enforce knowledge exploration by the students before explaining new concepts and lessons, students construct better learning of the concept (Marshall & Horton, 2011). Marshall and Horton (2011) mentioned that there is a positive correlation between the amount of time spent on active learning by the learners on the new concepts and the amount of new knowledge construction in the learners.

While considering technology as a support for project-based science learning, Blumenfeld et al. (1991) identified six contributions that technology can make to the learning process: enhancing interest and motivation, providing access to information, allowing active, manipulative representations, structuring the process with tactical and strategic support, diagnosing and correcting errors, and managing complexity and aiding production. The Stanford Mobile Inquiry-based Learning Environment SMILE successfully inspired student questioning and changes student-teacher dynamics in class. Learners and learning environments influence students' initial abilities to adopt inquiry learning. SMILE, like advance technological integration in inquiry-learning, is more difficult to implement in learning environments where rote memorization is typical and deeply rooted (Buckner & Kim, 2014).

Another IBL based routine is to ask the students without giving the answer. The children in schools are better influenced by the teachers who most frequently ask, rather than teachers who usually tell (Marriott, 2014). Marshall and Horton (2011) gathered more than 100 sets of classroom observational data and separated the data set into two groups—students who explored basic concepts before receiving explanations and contributed to the explanations, and students who received explanations before exploration and did not contribute to the explanations. When teachers make students explore concepts before explanations, students construct better learning of the concept. There is a positive correlation between the amount of time spent on active learning by the learners on the new concepts and the amount of new knowledge construction in the learners. A negative correlation exists between the percent of time spent explaining concepts by the teachers and the cognitive enrichment of the students. According to Brown (2012), two important aspects of promoting inquiry teachings are asking essential questions and fostering focused conversation.

Teachers should initiate and engage the students in persuasive dialogue through essential questioning to challenge the students to discover, share, link, and apply what they are learning (Wilhelm, 2014). Wilhelm (2014) explained seven characteristics of essential questions: questions should matter to students now and in the future, questions should connect to students’ current lives, questions should force the students to make judgments, questions should get at the heart of the matter, questions should possess intellectual bite and challenges, questions should be open-ended in nature, questions should encourage the findings to link data, and questions should be concise and clearly stated (p. 3). Finally, carefully designed essential questions are imperative in engaging learners.
in persuasive dialogue to encourage discovery of knowledge without simply delivering the answer via traditional classroom lectures.

**Influencing Factors for Successful Implementation of Inquiry-based Learning**

Liu, Lee, and Linn (2010) suggested an inquiry-based science unit to promote knowledge integration. They developed assessments that measure student knowledge integration abilities. This science assessment tool was consisting of both proximal items that are related to the units and distal items that are published from standardized tests (e.g., Trends in International Mathematics and Science Study). They revealed that student, class, and teacher characteristics affect student inquiry science learning. Finally, several teacher-level characteristics including professional development showed a positive impact on science performance (Liu, Lee, & Linn, 2010). Teachers’ training is one of the common tools to provide professional development for the teachers to boost their confidence in inquiry-based teaching practices.

Teachers’ readiness and confidence in teaching inquiry-based learning has a direct correlation with attaining effective training. Teachers who received more training in inquiry are more comfortable with inquiry methods. Open-ended learning environments are especially challenging for teachers who do not have any training or exposure to inquiry-based learning and teaching challenges (Inoue & Buczynski, 2010). Teacher preparation programs make positive contributions in developing pedagogical stances towards inquiry-based teaching among the participating preservice teachers (PSTs). This program also helps boost confidence in PSTs with some variability across different groups (Truxaw, Casa, & Adelson, 2011).

Teachers view and their teaching practices play important roles in the successful implementation of any learning approach. According to Capps and Crawford (2013), teachers skipped inquiry based learning approaches half of the allocated classroom time due to lack of pedagogical knowledge and understanding of inquiry learning approach. Ireland, Watters, Brownlee, and Lupton (2012) suggested that teachers in the elementary schools neither think nor express inquiry learning in a pedagogical way. Teachers express their inquiry teaching and curriculum in general laymen terms; this is not conducive in promoting inquiry instruction.

Corder and Slykbius (2011) suggested teachers to take the lead in changing classroom culture of a school from a traditional cookbook lab into an inquiry driven science experience. This transformation is a difficult journey and the first attempt may fail. Teachers are encouraged to make multiple attempts to make it a success considering the enormous opportunities of learners’ new knowledge construction through an inquiry learning approach.

Implementing inquiry-based learning and changing the classroom culture is not an easy task. Though teachers play a central role in this important effort, their success largely depends on administrative support. School administration is in charge of determining school curriculum, instruction period, and assessment criteria. Teachers need more instruction time than a traditional instruction period to encourage active participation of every student to promote inquiry learning approach; this not the teachers rather the school administration who have the jurisdiction on allocation instruction period for each subject area. A supportive and knowledgeable school principal can play a vital role in guiding new teachers and in transforming classroom culture from the traditional lecture approach to an inquiry-learning approach (Towers, 2012).

Teachers and school librarians should work as a team to develop assignments which encourage to ask essential questions to foster creative thinking among students in an open learning environment (Wilhelm, 2014); these questions should not have an easy and simple answer rather should have the possibility of diverse and multiple potential correct answers. School librarians can play a critical role in collaboration with the teachers in scaffolding the students in the art of inquiry learning.

Ultimately this is the job of the teachers to develop and implement inquiry learning plans (ILP). Though inquiry learning is student centered, it is the teachers who are responsible for defining all the parameters of inquiry learning classrooms for the participating students (Donhauser, Hersey, Stutzman, & Zane, 2014). Teachers’ perceptions along with their professional development play a vital role in the successful implementation of inquiry-based teaching in the classroom (Ireland, Watters, Brownlee, & Lupton, 2012).

**Benefits and Challenges of Inquiry-based Learning**

Inquiry-based learning is gaining popularity all over the world. Traditional lecture based learning is passive and boring for learners. Teachers encourage and guide the students to develop their own questions, perform information search, develop hypothesis, test hypothesis, and share their findings in an inquiry-learning environment. This process helps learners to construct new knowledge in an actively participative classroom setup. Inquiry-based learning is essential to produce problem solvers instead of rote memorizers. The United States needs thinkers and
problem solvers to lead this great nation. Inquiry-learning has the potential to fulfill that promise. Inquiry-learning has its own challenges. The definition of inquiry-learning lacks conformity. Teachers are limited with no training in inquiry instruction. Inquiry-learning curriculums are neither easily available nor well-structured. Teachers are not supported by complimentary inquiry-learning resources. Classroom time is too short to promote inquiry-based learning. Finally, administrative support is rare to promote and support inquiry-based teaching and learning. Overall, school and classroom cultures are not conducive to inquiry learning.

Benefits

Inquiry-based teaching did not dramatically alter a student's overall achievement, as measured by North Carolina's standardized test in physical science. Nevertheless, “Inquiry-based instruction had other positive effects, such as a dramatic improvement in student participation and higher classroom grades earned by students. In additional Inquiry-based instruction resulted in more uniform achievement than did traditional instruction, both in classroom measures and in more objective standardized test measures” (Tretter & Jones, 2003, p. 350).

Inquiry-based learning is essential for math and science learning as traditional lecture based instruction is not producing the desired level of success. In addition, memorization based math and science learning failed to produce workforce ready employees (Li, Moorman, & Dyjur, 2010). In inquiry learning students develop explanations from the evidence and connect explanations to existing knowledge to construct new knowledge (Hermann & Miranda, 2010). New knowledge construction should not be the end of the inquiry learning cycle. The inquiry cycle should include knowledge sharing and learning for life (Marriott, 2014).

Teaching strategies that actively engage students in the learning process through scientific investigations are more likely to increase conceptual understanding than are strategies that rely on more passive techniques, which are often necessary in the current standardized-assessment laden educational environment (Minner, Levy, & Century, 2010). Brown (2012) suggested that teachers can provide genuine learning experiences by engaging active student discourse through inquiry learning approach. Schroeder, Scott, Tolson, Huang, & Lee (2007) discovered that alternative teaching strategies are more effective than that of traditional classroom lectures. According to Schroeder et al. (2007), eight categories of alternative teaching strategies are: questioning strategies; manipulation strategies; enhanced material strategies; assessment strategies; inquiry strategies; enhanced context strategies; instructional technology strategies; and collaborative learning strategies.

Challenges

Inquiry-based learning provides boundless opportunities for students to explore, explain, construct, and utilize science and math knowledge. Nevertheless, implementing inquiry learning in a classroom is not an easy task and often encounters a good number of challenges (Edelson, Gordin, & Pea, 1999). Settlage (2007) suggested that it is unrealistic for teachers to engage in inquiry learning on a day-to-day basis, he speculates open inquiry is difficult to utilize in the classroom. Edelson, Gordin, and Pea (1999) explored five significant challenges to implementing inquiry-based learning: lack of motivation, accessibility of investigating techniques, background knowledge, management of extended activities, and practical constrain of the learning context (p. 391).

Teachers find it extremely time consuming to take preparation for unknown and boundless peripheral open-questions by the students (Hermann & Miranda, 2010). If teachers lack understanding of inquiry-based learning, they will have little to no interest in introducing inquiry learning approach in their class rooms; these incompetent teachers will eventually skip inquiry learning approach in half of the allocated classroom time (Capps & Crawford, 2013).

Open-ended learning environments are specially challenging for the teachers who do not have any training or exposure to inquiry-based learning and teaching challenges (Inoue & Buczynski, 2010). In active learning environment, students ask creative questions without having any fear. Students also come out with varied and exotic responses in open learning environment. Pre-service teachers are often challenged to successfully respond and explain the responses in a simple, coherent, and meaningful way to the students. As a result of that these teachers failed to take the advantage of teachable moments in inquiry learning to support the students' meaning-making attempts (Inoue & Buczynski, 2010). Soprano and Yang (2013) confirmed that the pre-service teachers’ understanding of inquiry-based science teaching and learning along with their self-efficacy beliefs was developed and enhanced through the planning and teaching phases of the field experience. They recommended the use of
cooperative inquiry-based field experiences and pre-service teacher action research by teacher education programs to prepare the teachers who would be able to play positive roles in promoting inquiry instruction.

Fazio, Melville, and Bartley (2010) suggested that teacher development courses help improve teachers’ perception related to inquiry teaching but the role of practicum was problematic. Some of the key reasons, which work as a stumbling block for creating an inquiry-based environment, are: associate teacher subjugation, availability of resources, time constraints, and the need to address curriculum standards. Finally, while inquiry-based learning and instruction is promoted for K-12 education by both administration and educators, the educational industry lacks reliable assessment tools to measure the quality and quantity of effective and efficient blending of inquiry-based instruction (Marshall, Smart, & Horton, 2010).

In summary, inquiry-based learning is facing a lot of challenges as more and more educators are trying to adopt this evolving learning approach. The successful identification of challenges is the first step in developing successful solutions. For most of the identified challenges, the researchers came out with a set of proposed and validated solution.

Conclusion

One group of students was instructed through an inquiry-based learning method (5E instructional model) whereas another group was instructed through traditional methods. The 5E instructional model is composed of five distinct components: engagement, exploration, explanation, elaboration, and evaluation. The results showed that students who were instructed through inquiry-based learning achieved higher scores than the ones instructed through the traditional method (Abdi, 2014).

Luera, Killu, and O’Hagan (2003) designed an example of an inquiry-based mini unit for students to learn the concept of volume and how to measure the volume of a rectangular prism. The concept of volume has elements of lessons from both science and math. Their study validated that a carefully designed inquiry-based learning unit is a successful tool in promoting student knowledge construction. This well designed inquiry-based unit ensured minimum teacher’s intervention and promoted higher student engagement and learning achievement.

Marriott (2014) suggested that school librarians should work hand in hand with the teachers to develop complex assignment projects, which do not have a straight forward answer found in a single source or reference. This kind of project should encourage open-ended inquiry learning with many possible alternatives instead of a single right or wrong answer. This should encourage students to reach an evidence-based conclusion after exploring many diverse and relevant resources. The author also mentioned that children in schools are better influenced by teachers who most frequently ask question to promote active learners’ participation, rather than teachers who usually passively pass the knowledge (Marriott, 2014). The open-inquiry question template is a structured approach to practice and promote open inquiry that typically results in a rich and satisfying research experience for students and teachers (Hermann & Miranda, 2010).

In inquiry learning, teachers ask open-ended questions to ignite active discussion and participation among the students, students’ responses usually include different unexpected responses besides the usual one. Pre-service teachers are often intellectually and pedagogically challenged to successfully explaining these diverse unusual responses in an instructionally eloquent and meaningful way to the students. Instead, most of time, pre-service teachers over look and ignore these unusual responses. In this process by ignoring unfamiliar diverse responses, teachers failed to recognize and take the advantage of teachable moments in active inquiry learning approach, which enables the students to attempt and construct new meaning and knowledge (Inoue & Buczynski, 2010).

In conclusion, traditional lecture-based science instruction is not working to achieve optimal learning outcome in our schools. Traditional current textbooks are designed to teach segmented science concepts one at a time and fail to make connections for students and encourage thinking. This traditional approach promotes memorizing over understanding and open thinking. Liu, Lee, and Linn (2010) designed a science assessment consisting of both proximal items that are related to the units and distal items that are published from standardized tests (e.g., Trends in International Mathematics and Science Study). Their study compared the psychometric properties and instructional sensitivity of the proximal and distal items. The authors examined how student, class, and teacher characteristics affect student inquiry science learning. This study validated that an inquiry-based science unit is more successful in developing student knowledge integration. Teachers who have more than five years of experience teaching science have a positive impact in inquiry-based teaching. Teachers who have access to colleagues in the school implementing the same inquiry-based unit have a higher success rate in implementing inquiry-based learning. Teachers who participated in a workshop on designing inquiry-based units enjoy a higher rate of success in deploying inquiry-based learning.
Implications of the Literature

Over the past few decades, much has been written about what inquiry is and is not. Inquiry should not be considered as a singular construct, but rather a range of approaches that form a continuum (Hermann & Miranda, 2010). The National Research Council (NRC) provides one example; this continuum ranges from less to more learners’ self-direction with respect to different features of inquiry: confirmation inquiry, structured inquiry, guided inquiry, and open inquiry (NRC, 2000). Teachers, who do not have any training or exposure to inquiry-based learning, are specially challenged by the open-ended inquiry learning environment (Inoue & Buczynski, 2010).

Pedaste et al. (2015) conducted a literature review using 32 articles from the EBSCO host Library. The articles were selected based on specific search criteria describing inquiry phases or whole inquiry cycles. This analysis of the articles resulted in the identification of five distinct general inquiry phases: orientation, conceptualization, investigation, conclusion, and discussion. No single literature proposed all of these five phases, rather each proposed a different number of phases with many different descriptions and names. The authors synthesized the collected data and proposed a framework for inquiry-based learning processes with five distinct phases. In this framework, inquiry-based learning begins with orientation and flows through conceptualization to investigation, where several cycles are possible. Inquiry-based learning usually ends with the conclusion phase (Pedaste et al., 2015).

The next question is what are the key challenges and proposed solutions of inquiry-based learning? Many challenges are identified along with proposed solutions. It is a challenging task to implement inquiry-based learning in any learning environment, especially in the classrooms. Edelson, Gordin, and Pea (1999) have been exploring these challenges through a program of research on the use of scientific visualization technologies to support inquiry-based learning in the geosciences. They identified five significant challenges to implementing inquiry-based learning and present strategies for addressing them through the design of technology and curriculum. The five challenges are: motivation, accessibility of investigation techniques, background knowledge, management of extended activities, and the practical constraints of the learning context. The proposed solutions are a having meaningful problems with implications that matter to learners, staging activities that can be used to set the stage for open-ended inquiry activities and introduce learners to investigation techniques, bridging activities introducing practices that are familiar to students as a means of introducing unfamiliar scientific practices, embedding information sources that is a knowledge base directly connected to an inquiry tool, and record-keeping tools to facilitate management and organization of inquiry activities (Edelson, Gordin, & Pea, 1999).

The final question is, is inquiry-based learning working for our learners? Almost all the articles presented some evidence directly or indirectly supporting the positive impact of inquiry-based learning. Luera, Killu, and O’Hagan (2003) claimed that a carefully designed inquiry-based learning unit is a successful tool to promote student knowledge construction. In addition, a well-designed inquiry-based unit will ensure minimum teacher intervention and will promote higher student engagement and learning achievement (Luera, Killu, & O'Hagan, 2003). Minner, Levy, and Century (2010) conducted an inquiry Synthesis Project to synthesize findings from research conducted between 1984 and 2002 to address the research question, what is the impact of inquiry science instruction on K–12 students? Fifty-one percent of the 138 studies in the synthesis showed positive impacts of some level of inquiry science instruction on student content learning and retention.

In conclusion, while there are barriers to implementing inquiry-based instruction in the k-12 classroom, educators and administrators are aware of countless benefits of inquiry-based learning. Quality and creative inquiry-
based learning instruction, reliable inquiry learning assessment protocols and tools, trained instructors, mature technology, and involved students can optimize the benefit of inquiry learning. Successful implementation of inquiry-based learning will have a huge impact on our national pride by acquiring higher rankings in math and science tests at the international level. Inquiry-based learning positively impacts our learners, which could be further enhanced by establishing a globally accepted definition and framework. Blanchard, Osborne, Wallwork, and Harris (2013) suggested that to achieve success in implementing inquiry learning in classroom, first we need to ensure that our teachers feel comfortable with teaching inquiry science. Teachers need access to quality inquiry training and other supportive resources to boost their comfort level in teaching inquiry learning. Some of the best teachers are finding it difficult to implement inquiry learning in the classroom setup to help support reformed-based Common Core State Standards. Keys and Bryan (2001) emphasized that a teacher’s voice should be included when designing and implementing inquiry-based curriculum as teachers play a central role in the successful implementation of educational reform efforts. There is a tremendous opportunity to improve the teachers’ understanding of inquiry-based learning. Capps and Crawford (2013) teachers skipped the inquiry learning approach in half of the allocated classroom time due to their limited understanding of inquiry-based learning. The assessment aspect of inquiry-based learning needs improvement to generate enormous interest around inquiry learning. Overall, more investment is required to develop a successful and universal model for inquiry-based learning.

Discussion and Recommendation for Future Research

Lee (2011) suggested that existing literature is limited in providing clarity while defining inquiry-guided learning. Since the publication of The Boyer Commission Report (1998), inquiry-guided learning has acquired tremendous attention as a preferred solution for a teaching and learning method to overcome any learning ills. The Boyer Commission Report (1998) defined the inquiry-guided learning only generally or chiefly by anecdote (Lee, 2011). Although many years have passed, confusion still exists about what inquiry-guided learning really is and how to do it, whether in a single course or across the curriculum (Lee, 2011). There is very little research dedicated to developing assessment tools to validate the effectiveness of inquiry learning.

Chang and Wang (2009) suggested that the emergence of computer and internet technologies will continuously influence and challenge inquiry learning. They speculate that while inquiry-based learning has many known challenges, these challenges are not static and further investigation is needed to find current and future challenges. Open-ended learning environments are specially challenging for teachers who do not have any training or exposure to inquiry-based learning and teaching challenges (Inoue & Buczynski, 2010).

While inquiry-based learning and instruction is promoted for K-12 education by administration and educators, the education industry lacks reliable assessment tools to measure the quality and quantity of the effective and efficient blending of inquiry-based instruction (Marshall, Smart, & Horton, 2010). Keys and Bryan (2001) recommended that more research is needed in the areas of teachers’ beliefs, knowledge, and practices of inquiry-based science including the impact on student learning. Settlage (2007) suggested that it is unrealistic for teachers to engage in inquiry learning on a day to day basis, he speculates open inquiry is difficult to utilize in the classroom.

A final area for exploration is to master the art of asking medium questions to stimulate thinking among the learners. It is an easy task to either ask trivial questions to a learner or stimulate trivial questions in a learner’s mind. It is also an easy task to ask impossibly difficult questions to a learner. The challenging task for the educator is to present challenging but medium questions to stimulate and encourage thinking in the learners’ mind (Driscoll, 2005).

References


Organization for Economic Co-operation and Development (OECD), 2012. *PISA 2012 country-specific overviews-United States*


