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Inquiry-Based Learning Practices for Science Teaching in Elementary Grades: A Literature Review of the Asian Countries

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Abstract: *Inquiry-based learning (IBL) is a student-centered approach of instruction that aims at increasing students' active engagement and their skills of investigation, reflection, and critical thinking within real-world expressions and practices. This literature review includes mostly those research studies in which a quasi-experimental approach was used, followed by a pretest-posttest design with random allocation of research participants. As per the aim of this literature review, those research studies were included where elementary grade students were selected as research participants to investigate the effects of IBL approaches on students' science literacy and skills. One of the engaging lessons from this review shows that IBL approach science skills are described as two sides of the same coin. Additionally, almost all reviewed studies defined IBL as students centered approach. Moreover, the effects of IBL are also discussed in detail.*

Key Words: Inquiry-based Learning, Science Literacy, Scientific Skills, Student-Centered Learning, Elementary Grade

Introduction

Traditional teaching methods, particularly in science, compel learners to cram the concepts as long as possible. On the other hand, student-centered teaching approaches like making models, simulations, doing experiments, and more importantly, conducting inquiry enable learners to develop conceptual understanding of science concepts, relate the science ideas with each other, and develop science process skills. Inquiry-based teaching is one of the best teaching approaches in the natural science discipline because it helps learners develop formal and informal research skills, challenge science concepts, and facilitate students to produce new ideas and processes. Likewise, this teaching method helps learners understand the natural and artificial world. In addition, it helps learners to enhance questioning skills, deepen conceptual understanding beyond the sub-matter knowledge. This paper reviews the relevant literature to highlight the importance of inquiry-based teaching and its impact on students' learning.

Criteria for Including Research Papers

Since the beginning of my doctoral studies in 2016, I have gathered, reviewed, and categorized the research studies on IBL under the umbrella of the science teaching-learning process. One of the primary aims of my research is to analyze the teaching practices of science teachers with the lens of IBL to advocate and improve IBL in my context, Sindh, Pakistan. It is, therefore, within the boundaries of the abovementioned aims, I have regularly searched empirical studies in EBSCO, ERIC, Google Scholar, Google, Education Research Complete, Tylor and Francis, Sage, ELSEVIER, and other search engines using the

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following key phrases: *inquiry-based learning*, *inquiry-based teaching*, *inquiry-based science teaching*, *project-based learning,* and *project-based teaching*. These terms were systematically linked with the following terms during the search: *in Asian countries, in elementary schools, in elementary grades*, *in primary schools*, *in middle grades*, *for elementary students*, and in *primary grades*. Moreover, for this review, inclusion criteria were: a) research studies in which intervention has occurred following IBL to examine effects on learning science concepts and science learning skills, b) students selected for examining effects of IBL should belong to elementary grades (≤ grade 8) of any Asian country, c) studies with clearly explained research questions/aims followed by clearly explained research methods and results of the study in line with the research questions/aims, and d) studies published between 2016 and 2019. In the result section, following literature review includes nine research studies.

Reviewed Literature and Discussion

The review of research articles includes three major areas. Research has mentioned that because of numerous IBL based initiatives in science, "the conceptual understanding of inquiry learning is still nebulous among educators and science teachers" (Ong et al., 2018, p. 350). So, in the first portion of this review, introductory parts of research studies were thoroughly read to see how IBL is defined and described, especially in line with the science teaching-learning process. In the second portion, limitations of IBL are mentioned, which were discussed in a few research studies of the reviewed research articles. Moreover, it has also been argued that the previous literature has shown that while implementing IBL, the science teachers have failed, let alone the effective implementation of IBL (Ong et al., 2018). Therefore, the third portion of this review, methodology, and subsequent sections were thoroughly read to understand IBL interventions and their impacts on elementary school students' achievement in science learning.

Defining inquiry-based learning

The review of research studies shows that the authors have chosen a different approach to define Inquiry-Based Learning (IBL). Some researchers have discussed IBL in detail (Duran & Dökme, 2016), and others have précised it (Hsiao, Hong, Chen, Lu & Chen, 2017). Those who have described IBL in detail have advocated IBL as a fundamental approach to the teaching-learning process and as a need of the current era. Like detailed discussion in a study (Duran & Dökme, 2016) described IBL as an instructive approach that is utilized in order to:

- Combining scientific knowledge and operations
- Use cause and effect, relational and critical thinking
- Find new ideas related to an event
- Use means of discovery and investigation in authentic settings

However, all the authors have described IBL according to their research objectives. For example, the study conducted in Turkey needed the description of IBL in line with technology and science literacy (Duran & Dökme, 2016). Moreover, the description of IBL in the reviewed articles can be divided into two major categories; a) a student-centered approach and b) the need for the science teaching-learning process. It is important to note that no particular research study in this review can be attributed to only one of the two categories. However, views by authors of the same research study can be attributed to both categories.

IBL: A Student-centered Approach

Interestingly, authors of the reviewed research studies have described IBL compared to traditional and/or teacher-centered approaches while advocating IBL as a student-centered approach. For example, authors in a study opened their discussion about IBL while mentioning it "in contrast to lecture methods" (Iqbal, Khalid & Khalid, 2017). Likewise, a study signified science and technology literacy. It then explained IBL as one of the student-centered approaches to learn science and technology, where the detailed table has been presented (p. 2890) in which the comparison has been discussed along with teachers' and students' roles, teaching methods, etc. across the two approaches (Duran & Dökme, 2016). Similarly, it has been mentioned in another research that

"The reality in the science learning in Pontianak Junior High School [research site] shows that many teachers use the teaching and learning method that is centered on the teacher (traditional). This is because the teachers [of the research site] consider the inquiry strategy [IBL] difficult to attempt" (Hairida, 2016, p. 210).

This view also indicates that IBL has been advocated compared to the teacher-centered approach. In the same way, authors of another research also advocated the importance of IBL as "a method in which learners process... knowledge by... critically reflecting" which is opposite "to traditional teaching approaches in which... learner is only restricted to knowing" (Ahmad, Samiullah & Khan, 2019, p. 424). Hence, it can be concluded from such descriptions in the reviewed research studies that IBL has been proposed as a solution to the existing teacher-centered approaches.

If we peep into the past practices of the science teaching-learning process in Pakistan, each researcher and educationist will propose IBL as the best possible approach to improve the science teaching-learning process. Mahmood (2007) indicated that Pakistani practicing science teachers' lower support for student involvement due to traditional teaching methods, including lecture-based teaching as one of the most popular teaching methodologies. Moreover, the development of the National Curriculum in 2006 by Ministry of Education [MoE] Pakistan was based on improving the quality of the science teaching-learning process in elementary grades (Government of Pakistan, 2006). The 'student-centeredness' and 'inquiry-based' approach to science teaching has been emphasized in this curriculum. Additionally, a study mentioned that the "role of a teacher is active and role of the student is passive in the transmission of [science] curriculum" in Pakistan (Ahmad, Shaheen & Gohar, 2007, p. 91). They argued for student-centered approaches in Pakistan.

Additionally, Ahmad et al. (2019) view that teaching is the second most important aspect, after the teacher, which must be carefully chosen for teaching science. They also pointed out that the "lecture method is prevailing in our [Pakistani] education system as the only method being used to teach almost all subjects of arts and sciences as well" (p. 424). Having discussed that, IBL has been advocated as an alternative approach to teacher-centered teaching approaches, including the lecture method, to increase students' active participation during science learning (Ahmad et al., 2019). Hence, it can be concluded here that traditional science teaching approaches have been confirmed in Pakistan; therefore, IBL should be promoted to improve the science teaching-learning process in Pakistan.

As discussed above, authors almost in every study have discussed the emergence of IBL, which is generally associated with 21st-century learning skills and, more specifically, IBL is associated with student-centered and constructivist approaches to the teaching-learning process. While describing IBL under the umbrella of student-centered approaches, the authors have mainly highlighted the development of 21st-century learning skills in students, including logical and creative thinking skills, reasoning, rational thinking, investigation, and experimenting scientific skills (Duran & Dökme, 2016; Hastuti, Tiarani & Nurita, 2018; Mulyeni, Jamaris & Supriyati, 2019).

Moreover, it is pertinent to note that authors of all reviewed research studies have chosen the literature to discuss IBL is leaned more towards proposing IBL as a student-centered approach. Moreover, the author's choice of words and descriptions also focuses more on students. Most of their definitions start from the point of a student, like "IBL engages students' analytic and critical-thinking skills" and "...in an IBL environment, students feel like a junior scientist..." (Duran & Dökme, 2016, p. 2888). Similarly, IBL has been described in a study as a process of asking questions and finding answers through conducting investigations to solve scientific problems (Mulyeni et al., 2019). In this study, authors have also discussed IBL from students who "use critical, logical and creative thinking" during IBL. Likewise, from the student point, they described IBL as an approach that "involves children in exploration activities which leads them to ask questions, test the ideas, and discover the answer" (Mulyeni et al., 2019, p. 189). Likewise, another research pointed out the importance of IBL in terms of "students' development of high-level thinking skills, discussion skills, investigation, and understanding of scientific facts" (Hastuti et al., 2018, p. 233). Their description of IBL as a student-centered approach can better be confirmed through their association of students' orientation of raising scientific questions with characteristics of IBL.

Likewise, the research studies conducted in Pakistan have also reported IBL as a student-centered approach. A study highlighted the need for 21st-century education that "demands the replacement of traditional methods of teaching and the outdated curriculum," and authors argued that there must be "...a shift in the instructional methodologies" while pointing out the need for student-centered teaching approaches (Ahmad et al., 2007, pp. 91-92). While pointing out the gap in Pakistan, this research study also presented IBL as a solution to the existing problems related to science teaching-learning in Pakistan. Then authors describe IBL as a way to 'encourage' and 'engage' students in the science teaching-learning process. In the same way, IBL has also been delineated from the students' standpoint and mentioned that IBL allows "learners to think about how to solve a problem critically" and makes them learn in addition to subject matter knowledge also acquire competencies and techniques that help them to solve problems (Ahmad et al., 2019, p. 424). Hence, this section can be concluded that the review of the research articles suggests that throughout their detailed discussions, the authors have maintained their positionality of considering IBL as a student-centered learning approach.

IBL and Science Learning are Two Sides of a Coin

In the reviewed research studies, authors' discussions have also depicted IBL and the science teaching-learning process as similar concepts. References Hairida (2016) directly opened the discussion while pointing out similar characteristics between IBL and science learning. The author, while referring to the curriculum, clearly asserted that "science learning and inquiry (here IBL) cannot be separated" (p. 209). In this research, IBL has been pointed out as a learning method that develops 'curiosity' and 'scientific and critical thinking in students and helps them "construct knowledge as if they [students] are real scientists" (p. 210). Similarly, in the rest of the reviewed research articles, IBL and science learning are also discussed.

Hsiao et al. (2017) opened their discussion while mentioning that "learning science advances...inquiry abilities and promotes the comprehension of inquiry" in students (p. 3394). This view intertwines science learning and IBL, which leads to a notion that IBL and science learning are two sides of a coin. These authors have précised IBL and defined it as a way to "combine scientific processes with scientific knowledge" in order to "reason and think critically about evidence and explanations" for developing scientific understanding and abilities to communicate scientific arguments (p. 3396). It must be noted that despite its precision, IBL is still defined from learners' standpoint. Moreover, another research also intertwined IBL and science learning and discussed that students' ideas could be strengthened through inquiry investigation (Mulyeni et al., 2019). For these authors, "scientific inquiry means incorporating the science process with other aspects such as scientific reasoning, scientific knowledge, and critical thinking" (p. 189).

Interestingly, their discussion includes four categories of inquiry, i.e., 1) Open-inquiry, ii) guided-inquiry, iii) structured-inquiry, and iv) confirmation-inquiry, which have been explained in some detail. Throughout this detailed discussion, the authors have maintained the intertwining of IBL and science learning. Similarly, Hastuti et al. (2018) discussed that IBL is interweaved in science learning, and authors take 'learned skills' as *juncture* that joins IBL and science learning. They asserted that IBL expects students to conduct investigations that help them grow practical 'skills,' which are basically the skills students use to discover scientific concepts through observation, experiment, and/or investigation. So, IBL discussed by the authors is interweaved in science learning in which authors mentioned that IBL gives "opportunity to apply the procedures used by scientists" (Hastuti et al., 2018). Moreover, their description also adds that IBL "does encourage not only the ability to think but also the ability to work and communicate scientifically" (Hastuti et al., 2018).

After my experiences as a science teacher and teacher educator, I am also of a view that abilities required in science learning and abilities advocated in IBL share similar characteristics. When a teacher helps students learn science practically, he/she is already following IBL. Likewise, if a teacher plans any learning experience following IBL, he/she is bringing a scientific learning style. Hence, it can be said that IBL and science learning are two sides of a coin.

Limitations of Inquiry-Based Learning

Some authors also discussed the limitations of IBL. One of the studies showed that the authors embarked on describing the limitations of IBL to pave the way for bringing in a new model that they

have implemented in their study (Hsiao et al., 2017). They target the very difficulties encountered by students. For example, as they highlighted, the student may face "...inability to judge the cause-and-effect relationships of scientific phenomena, organize and integrate scientific knowledge, and connect scientific theory and reality, which could result in the students not being successful in reaching the next step of inquiry" (Hsiao et al., 2017). They point out this gap and suggest their POE model for an active IBL process. Likewise, limited teaching material and learning resources as obstacles in implementing IBL have also been discussed in a study (Hairida, 2016). The author, to support this claim, pointed out the observations in the selected school in which the IBL approach was "rarely practiced because of the lacked supports especially the facilitation for the inquiry activities" including "teachers [with] are less skill[s] in applying inquiry learning strategy" (p. 210).
Similarly, Ahmad et al. (2007) highlighted that constructive paradigms, i.e., the IBL approach, are considered a significant problem in the current education system of Pakistan. They further added that most science teachers are unaware of "the demands and challenges posed by twenty-first century's for the individuals" (p. 92). Hence, only a few authors have pointed out this interesting notion, whereas the rest of the reviewed literature did not mention the hindering factors in the process of implementing IBL.

Effects of IBL-related Interventions on Elementary Grade Students

A study conducted experimental research on 90 students (n=45, in the experimental group) of 6^{th} grades, for which "a written material with activities based on the 6^{th}-grade unit known as *Particulate Structure of the Matter*" was systematically developed as guidance material (Duran & Dökme, 2016). Moreover, Demir's (2006) *critical thinking skills scale* was adapted to "elicit the extent to which critical thinking levels were affected by various variables" (p. 2891). The study reported that traditional classroom students' post-test critical thinking mean score was lower than their counterparts. While comparing adjusted mean scores of critical thinking skills between control and experimental groups, the study reports significant differences, and it favors the experimental group ($F(3-81)=28.21$, $p<0.05$). It means that the grade 6 students, who were taught with the IBL approach, have shown a higher level of critical thinking than their counterparts taught through traditional teaching methods. Thus, the IBL approach is more effective for developing critical thinking in grade 6 students. Based on these findings, authors argued that:

> ...science and technology classes taught with the IBL approach have a more positive effect on students' critical thinking level, and that science and technology lessons taught within the constraints of the coursebook do not significantly improve students' critical thinking levels (p. 2898).

Besides, following their observations, a study mentions that students' active participation has played a vital role in this process (Duran & Dökme, 2016). The critical attributes of students, which positively contributed to the development of critical thinking, were participating in activities, responding to researchers' questions during group discussions. The authors emphasized the role of 'discussions' in developing critical thinking skills in terms of helping students' abilities to make connections between claims and evidence. Moreover, the mean scores were also compared at the sub-dimension level of critical thinking skills, and findings favor the experimental group of grade 6 students across all dimensions.

Quasi-experimental pretest-posttest research was conducted where Tamil National-type schools were selected for the study (Ong et al., 2018). One of the two Year 5 classes were randomly selected as the experimental group (40 students) who received science education through the 5Es instructional model. Comparatively, the control group students (n=40) received instructions through traditional teaching methods. A standardized test with 20 MCQs was employed in pretest and in post-test, where the only change was a sequence of the MCQs. Analysis of covariance revealed an F value of 593.35 that is statistically significant (as $p < 0.001$), with an effect size of +1.87 that is educationally significant. The mean scores showed that the experimental group (m=90.32) was significantly higher than the control group (m=52.53). Hence the null hypothesis was not accepted. As a result, the authors discussed that using the 5Es IBL model of instruction led to a positive effect on selected students' science achievement. Authors presented that other essential aspects of IBL (i.e., higher-order thinking skills and problem-solving skills) were not explored in this study which could have added a better understanding of the 5Es model. Therefore, this literature review explored the use of IBL on science content and skills.

In a study, a five-week experimental process was planned for which 123 fourth-grade students were selected to improve their scientific learning performance (Hsiao et al., 2017). Researchers developed a five-stage prediction-observation-explanation (POE) inquiry-based learning model called FPOEIL. This model required students to complete three IBL activities that challenged them to think critically repeatedly. Students were provided with help in self-corrections in each activity while learning scientific concepts. An interesting thing about this intervention is applying the FPEOIL model in three different ways. After dividing students into experimental and control groups, the experimental group was further divided into three groups – A, B, and C. Group-A students were taught the selected science unit "using the FPOEIL model only. Each student had to finish the five stages of the model on their tablets" (p. 3401). In Group-B, students were taught the selected unit using FPOEIL with repertory grid technology-assisted learning (RGTL) "on their tablets to help them interpret, integrate, and organize scientific knowledge" during selected IBL activities. Group-C students were instructed IBL activities using FPOEIL with collaborative learning (CL) approach on students' tablets in which students discussed their learning with peers.

Findings revealed no significant difference (t = -0.18, p<0.05) between pretest and posttest scores of the control group. Comparatively, there was a significant difference between the pretest and post-test scores of the three experimental groups. In comparing post-test scores of the three experimental groups with control group students, it can be said that experimental approaches enriched students' science learning experiences. Moreover, the authors shared interesting findings after within experimental group comparisons. As discussed earlier, a notable addition was done in RGTL and CL for experimental groups B and C, respectively. When adjusted post-test scores of experimental groups A and B were compared, findings show that students in group B performed significantly better (p=0.009) for whom RGTL was used with the FPOEIL model. Similarly, when groups A and C were compared, group C students achieved significantly (p=0.036) better scores for whom CL was used with FPOEIL. However, findings report no significant difference (p=0.432) between post-test scores of students in groups B and C, which means that the use of RGTL and CL has somehow contributed similar improvement.

The results identified that using the FPOEIL model only improved the students learning performance in the selected area of science. Authors argued that using the 'cycle-mode POE method' could be a possible reason because it provided students with "more self-correction and self-adjustment opportunities" (p. 3409). Moreover, the authors also attributed the "feedback-correction learning process of the cycle-mode POE inquiry-based learning approach" to the FPOEIL model's effectiveness. Furthermore, students' use performed better when the FPOEIL model was used with RGTL than those who were instructed using the FPOEIL model only. Authors attributed the better improvement with opportunities to interpret, integrate and organize knowledge provided by the RGTL approach. Similarly, the better performance of students who were instructed under the umbrella of FPOEIL used with CL has also been attributed to characteristics of CL. Researchers argued that students' "discussion and interactions were effective, and…equal participation in the discussions helped" students solve problems and clarify scientific concepts (p. 3410).

This study also divided students based on their low and high prior knowledge and calculated the difference between them across all four groups. Results revealed that low prior knowledge students who received instructions under FPOEIL with RGTL performed significantly better (F=4.95, p=0.036) than those under the FPOEIL model only. The authors mentioned that students with low prior knowledge got distracted easily, and they were slower than students with high prior knowledge. So, the opportunity to interpret, integrate, and organize knowledge under the RGTL approach helped low prior knowledge students reduce their cognitive load and burden in the science learning process. Thus, they claimed that the "RGTL approach is an appropriate learning strategy for low prior knowledge students" to improve their scientific learning (p. 3410).

Similarly, low prior knowledge students under FPOEIL with CL showed significantly better learning performances (*F*=4.54, *p*=0.042) than a group where only FPOEIL was used. The authors claimed this learning effect resulted from 'interactive' and 'reciprocal' learning strategies provided under the CL approach. This helped low prior knowledge students in focusing "on the main points and understand the underlying themes of scientific concepts" and completing their learning targets "by discussing, listening, thinking, and criticizing the scientific concepts with their peers" (p. 3411).

Action research was conducted following two cycles (Mulyeni et al., 2019). The purpose of the study was to improve basic science process skills; *observing*, *classifying,* and *to measure*. As an intervention, ten lessons were taught to 23-second grade students (around seven years old) in each cycle, following the 5E model of IBL.

The pretest scores show that most students' basic science skills were under C and D categories – developing and beginning levels, respectively. Only a tiny portion of students scored under B category – proficient level, whereas no student scored under A category – advanced level. However, after the first cycle, most students' scores were under the B category, and the second majority was under the C category. A good number of students scored under the A category, and, interestingly, no student scored under the D category. Although the difference shows a significant improvement, the study reported that no students could secure a score of mastery learning set by the school, which was ≥ 78.

Moreover, after the second cycle, post-test results revealed that most students secured A category scores, the advanced level. Moreover, the second majority was of the B category, the proficient level. Interestingly, there were no students who scored under C and D categories, and these scores reached the minimum passing criteria (≥ 78) of the school. Hence, the overall results showed significant improvement in students' pretest and posttest scores across all three areas (i.e., observation, classification, and measurement) of science process skills.

The authors also discussed factors affecting basic science process skills through the IBL approach. They mentioned several other factors than science investigation through hands-on activities. Authors pointed out the use of "worksheets, singing a special song, and interacting with both peers and teacher" as the other factors (p. 196). Students, in the first cycle, were provided with worksheets following instructions. These instructions included 'written' and 'illustration' forms which enabled students' *classification* and *measurement skills*.

Similarly, they used songs where lyrics required students to *observe objects* properly. The song encouraged students "to use various senses and make quantitative observations," and some students "also sang the song during the investigation when they needed to recall the procedures" (p. 196). This clearly shows the practice of *observation skills* by students. Likewise, interaction with teachers also increased students' science process skills as they learned to observe, classify, and measure objects from teachers' demonstrations and explanations. For instance, some students asked teachers to demonstrate the *classification* of particular objects. In this way, students also learned science process skills through the other factors.

It has been investigated in a study that "whether or not there is any influence of the application of Inquiry-based science issues on Practical Skills of Junior High School students" in 2017 (Hastuti et al., 2018). The practical skills investigated in this study had four categories: a) *procedural and manipulative*, b) *observational*, c) *drawing,* and d) *reporting and interpretative*. All grade 7 students of the selected school were the study population, where two classes were taken for the control and experimental groups. The students in the experimental group were taught science through IBL, while control group students were taught through a scientific approach. The analysis of observation sheets shows that mastery of practical skills of experimental group students was better than their counterparts, where the "highest component in both [groups] was the observational skill aspect" (p. 235). Hence, based on observation sheets, this study concluded that the intervention of IBL was more effective for developing students' all four practical skills. The results of the tests were significant, indicating the considerable influence of inquiry-based science issues learning on the experimental group.

A research study aimed to determine the effectiveness of using an IBL intervention, inquiry-based science modules, with authentic assessment while following a quasi-experimental research method. All 7th-grade students of 11 Pontianak

Junior High School were the population of this study. Results of the study reveal that, in all inquiry aspects, the average 'skills of inquiry' within the experimental group was higher than the students in the control group. The inquiry aspects included "writing down the observations results in detail, the questions based on the data, the provisional assumptions based on facts, the observations result in the table, and the conclusion according to the problems" (Hairida, 2016). Based on these results, authors conclude that IBL in science class improved 'inquiry skills' as "average critical thinking skills" of the experimental group "was higher than the control class for all aspects of critical thinking" (pp. 211-212). Hence, the use of "authentic assessment was considered effective" for improving science students' critical thinking skills. Moreover, the exciting findings of the study suggest also that the experimental group students "felt motivated in learning because of the [interesting] activities" designed under IBL (p. 213). The IBL used with authentic assessment helped students participate enthusiastically at every stage of the designed IBL proceedings. The authors' reported that curiosity in the experimental group students was visible, and the students were excited to see the findings of their experiments.

IBL approach was used to investigate the effects of lab-based teaching methods on grade 8 students' ability of understanding and concept building in general science for elementary grades (Ahmad et al., 2019). The IBL used in this study was named an activity-based teaching approach. The sample of this study included 50 grade 8 students, where 25 students were allocated to the treatment group. Post-test was used to checking the ability of students to understand the concept. The average score obtained by the treatment group was 12.72, whereas the control group obtained 10.72, and the *t-test* comparison with value 5.06 at *df* 48 indicated the significant difference. So the treatment group students performed higher than control group students on the ability to understand the science concepts. Likewise, post-test scores for checking students' ability for rote memorization also indicated that control group students (m=4.52) performed higher than the treatment group students (m=3.56), where the *t-test* value with 2.26 at *df* 48 confirms a significant difference. Along with the significant difference, authors also reported that the treatment group students were not bored compared to the control group students, and the treatment group students posed fascinating queries and questions during IBL activities. Based on the above-discussed findings, authors argued that the better performance by treatment group students was because they "had a real-time chance of experiencing the activities ... [where] they accomplished all of the activities" and, comparatively, control group students "just listened passively" whatever was taught (p. 426).

The experimental research design was followed to conduct as research where the treatment group (n=26) was taught using the 5Es model of IBL, while the control group (n=26) was treated with the traditional lecture method (Ahmad et al., 2007). The research site was located in district Swat, and the research participants were students of grade 5. The treatment was given for six weeks, followed by pretest and post-test. As shown in Table I means, and p-value scores showed an insignificant difference between the control group and treatment group in all areas; knowledge ability, application ability, comprehension ability, skill development, and overall.

However, in the post-test scores, it was indicated that treatment group students (m=68.77) performed significantly higher than control group students (m=45.92). As per scores, the overall academic achievement of the treatment group, treated with the 5Es IBL instructional model, significantly increased students' performance. In *knowledgeability*, as the p-value (0.000) showed, the experimental group students (m=13.5) performed significantly higher than control group students (m=7.22). Similarly, the p=0.000 in *application ability* also indicates that students of the treatment group (m=15.76) performed significantly higher than the control group (m=9.01). In the same way, the treatment group students also performed significantly higher than the control group students in *comprehension ability* and *skill development ability*. Hence, according to these post-test results, it can be said that the use of the 5Es IBL instructional model has significantly increased the abilities of treatment group students in all areas. Therefore, it can be concluded that the IBL approach is more effective than the traditional approach.

Table 1. The Pretest Scores

Constructs	P-value	Mean Score (Treatment Group)	Mean Score (Control Group)
Knowledge ability	0.819	3.40	3.53
Application ability	0.376	2.26	2.17
Comprehension ability	0.472	4.65	4.08
Skill development ability	0.347	4.59	4.52
Overall	0.613	19.96	20.61

A researcher followed an experimental design to investigate the comparison between students' achievement in science between those who received instructions through the 5Es model and those who received instructions through regular classroom teaching (Parveen, 2017). The study population included grade 8 students with hearing impairment taught in a separate school system. Pretest scores from the independent sample t-test showed no significant difference between experimental and the control group students. However, post-test results showed a significant difference between the two groups.

Moreover, the author also analyzed students' performance for each level of Bloom's Taxonomy. Before the intervention, the performance of experimental and control group students was equal on three cognitive levels (knowledge, comprehension, and application). However, after the intervention, experimental group students performed better than their counterparts on comprehension and application levels of the cognitive domain. The author concluded that the 5E instructional model improved students' comprehension and application abilities, whereas the achievement in the knowledge component was identical in both groups even after different treatments.

A study used experimental design to compare the achievement level of students taught through traditional and problem-based learning as an IBL approach (Iqbal et al., 2017). In total, 70 grade 8 students were selected for the study, where odd and even number students were divided into control (n=35) and experimental groups. The experimental group was taught through the IBL approach, and the study followed the pretest and post-test research design.

Pretest scores showed no significant difference ($p > .05$) between the two groups. Hence students of experimental and control groups were at the same achievement level before intervention. However, the post-test results indicated a significant difference ($p < .05$) where experimental group students (m=20.00) performed better than control group students (m=20.80) in the achievement test.

Conclusion

The review clearly describes that inquiry-based learning (IBL), which has also been described as project-based learning, is a teaching approach used to increase students' active engagement and their skills of investigation, reflection, and critical thinking within real-world expressions and practices in learning science. The review shows that it has been defined as a student-centered teaching approach, and mostly it has been described as a solution to the existing traditional teaching methods used in science classrooms. Additionally, IBL and the science teaching-learning process are discussed as two similar concepts in the reviewed studies, where most of the authors have intertwined the characteristics of science learning and IBL. Moreover, since most of the studies are quasi-experimental, this review shows that almost all interventions have more positive effects on the group of students who have been treated with any type of IBL.

References

Ahmad, N., Shaheen, N., & Gohar, S. (2007). 5E Instructional Model: Enhancing Students Academic Achievement in the Subject of General Science at Primary Level. *Sir Syed Journal of Education & Social Research*, *1*(1), 91-100.

Ahmad, A., Samiullah, M., & Khan, A. M. (2019). Development of Scientific Knowledge and Science Comprehension through Activities at the Elementary Level Schools in Pakistan. *Global Regional Review*, *4*(4), 424-431.

Duran, M., & Dökme, İ. (2016). The effect of the inquiry-based learning approach on student's critical thinking skills. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(12), 2887- 2908.

Government of Pakistan. (2006). *National curriculum for general science grades IV-VIII,* Islamabad:
Ministry of Education.

Hastuti, P. W., Tiarani, V. A., & Nurita, T. (2018). The influence of inquiry-based science issues learning on practical skills of junior high school students in environmental pollution topic. *Journal Pendidikan IPA Indonesia*, *7*(2), 232-238.

Hairida, H. (2016). The effectiveness using inquiry based natural science module with authentic assessment to improve the critical thinking and inquiry skills of junior high school students. *Journal Pendidikan IPA Indonesia*, *5*(2), 209-215.

Hsiao, H. S., Hong, J. C., Chen, P. H., Lu, C. C., & Chen, S. Y. (2017). A five-stage prediction-Observation-explanation inquiry-based learning model to improve students' learning performance in science courses. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3393-3416.

Iqbal, S., Khalid, M. I., & Khalid, S. (2017). Effectiveness of Problem-Based Learning Approach on Students Achievement in Subject of Science at Elementary Level. *Journal of Elementary Education*, *27*(1), 95-105.

Mahmood, N. (2007). Elementary School Science Teachers' Belief about Science and Science Teaching in Constructivist Landscape. *Bulletin of Education & Research*, *29*(2), 59-72.

Mulyeni, T., Jamaris, M., & Supriyati, Y. (2019). Improving basic science process skills through inquiry based approach in learning science for early elementary students. *Journal of Turkish Science Education*, *16*(2), 187-201.

Ong, E. T., Arumugam, G., Sabri, M. S., Nor'ain, M. T., Nurulhuda, A. R., & Mohamad Termizi, B. (2018). 5E inquiry learning model: its effect on science achievement among Malaysian Year 5 Indian Students. *International Journal of Academic Research in Business and Social Sciences*, *8*(12), 348-360.

Parveen, Z. (2017). Educational effectiveness of the 5E model for scientific achievement of students with hearing impairment. *Journal of Baltic Science Education*, *16*(5), 723-732.