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Improving Science Education via Inquiry Oriented Curriculum: (A Systematic Review)

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Abstract:
Students' understanding of science in Pakistan is not up to at standard. The main **purpose** of this study is to see that science education can be improved through inquiry-oriented curriculum among Pakistani schools. A systematic review of related literature and Meta-analysis has been done for this purpose. Literature leads to a conclusion that there is a need to study utility of inquiry-oriented curriculum model.
Findings show that inquiry-oriented curriculum is more effective than routine methods of teaching. It helps in development of creativity and academic achievement. It is further **recommended** that teachers and students become acquainted with inquiry-oriented curriculum and also implement this approach into teacher training institutes for quality science education.
Key Words: **Inquiry Oriented Curriculum**, Meta-analysis, **SR Approach**, quality education.

INTRODUCTION:

The plan of educational activities carried out inside or outside of the school to identify educational goals is known as the curriculum (Tala, 2012). Effective markers of successful curriculum implementation are teaching strategies. The adoption of effective teaching techniques allows for the transmission of the subject's philosophy into the classroom (Nehru, 2015).

Because of the constructivist pedagogy's foundations, Martin (2000) highlighted that inquiry-oriented curricula are "corporate in inquiry-based science instruction." At elementary and secondary levels, the inquiry technique is thought to be more beneficial and appropriate in the study of science. In reality, teaching through inquiry involves using tools to help students learn. It also entails the growth of investigative abilities, like capacity to (1) detect and describe problem, (2) articulate a hypothesis, (3) plan an experiment, (4) collect and analyze data, (5) infer data and draw significant inferences. Science is considered as inquiry is not only a repository for facts; rather, it is a process by which facts can be discovered (Eltinge, Roberts, 1993).

Instead of receiving clear instructions from the teacher on how to address an issue, pedagogics and curriculum require students to work independently to find solutions. N. Aceska (2016). Through use of inquiry-oriented teaching techniques, inquiry-oriented curriculum are employed in science classrooms. The purpose of inquiry-based education is to advance students' development of critical thinking abilities while they learn science. It is a method of instruction that combines students' natural curiosity and scientific methodology.

With an analytical attitude towards teaching and learning, inquiry-oriented science gives learners the chance to explore any topic, search for workable answers, create annotations, pose questions, check out concepts, and think creatively and innovatively while applying their insight. As a result, inquiry-based science involves pupils learning by doing. They themselves assess their perceptions in the context of available information. In this kind of instruction, teachers identify significant issues before presenting them to the students, who then attempt to resolve the issues on the basis of the evidence presented. According to Chang and Mao (1999), who was cited by Hansen & Buczynsk (2013), students who are taught using an inquiry-based technique exhibit improved achievement and a positive attitude toward science?

Controlled, directed, and free are the three categories of student inquiry described by Mackenzie (2016). In addition, he outlines how teachers typically begin with controlled inquiry, go on to guided inquiry, and if all goes good, complete year through free inquiry. An example of one of Mackenzie's three styles of inquiry is as follows:

- **Controlled Inquiry:** The themes are chosen by the instructors, who then specify the sources that the students will utilize to respond to the questions.
- **Guided Inquiry:** Students plan the product or come up with solutions while the teacher chooses the themes and questions.
- **Free Inquiry:** Without taking into consideration any required results, the students independently select their themes.

How inquiry-based science teaching is helpful for students? With this approach, the students learn to prioritize evidence, evaluate the results based on the evidence, articulate and explain their findings after being prodded by scientific questions. To put it briefly, it necessitates the use of reasoning, judgment, and evidence while developing explanations for the naturally existent universe (Abell, Hubbard, Martini, McDonald, Newman & Ottaala, 2004, p.258).

To help students develop their capacity for creative thought, inquiry-based teaching is one of teaching strategies that can provide a dynamic and real scientific knowledge learning process. Asking questions, looking for answers, and coming up with fresh ideas in relation to an event are all part of inquiry-based education. That is to say, in inquiry-based learning, students gain knowledge by combining scientific knowledge and processes with cause-and-effect, interpersonal, and critical thinking (Parim, 2009).

Difference between Traditional Teaching Method and Inquiry-Oriented Teaching:

Traditional Teaching Method		**Inquiry-Oriented Teaching**
Teacher	Facts, principles, concepts, and generalizations are presented.	Advisor, leader, and guide.
Student	Passive information receiver.	A person who approaches things scientifically.
Area of Interest	Pertaining to the teaching of concepts, abilities, and phenomena. Concentrations on what should be taught.	Pertaining to choosing the approach that will best solve the issue. On what and how to teach.
Learning environment	Class, teacher, and common classroom supplies; set class time.	Learning is a creative practice that doesn't depend on any one particular person, place, or time.
Method/Techniq ue	Delivering lectures, reciting, dictating, and repeating.	Project, experiment, and problem-solving.
Communication	Communication is based on rivalry.	Communication focused on collaboration.
Creativity	It's crucial that kids carry out the tasks they are supposed to do while watching their teacher practice them.	Children have the chance to experiment with novel approaches to achieving the behaviors and abilities that are expected of them.
Expectation - motivation	Every youngster is expected to succeed in the subject they are studying. Perfectionism is emphasized.	It is encouraged when kids try to find their own solutions to challenges. All endeavors are encouraged.
Purpose	Learning is necessary because it is necessary.	By resolving issues, students gain knowledge. Understanding is what learning is all about.
Measurement - evaluation	Standard testing for evaluation that is one-dimensional and product-focused.	Evaluation that is multifaceted and process-oriented using tools like performance tests and portfolios.

A variety of theoretical, curricular, and instructional teaching techniques are explained by inquiry-oriented learning and inquiry-oriented science education. Its core ideas involve the requirement that learning would be based on student inquiries. Instead of accepting the teacher's direct orders, inquiry-oriented curricula challenge students to work independently to solve difficulties. Teachers are more often seen as learning facilitators than as knowledge dispensers. Therefore, in an inquiry-based learning environment, the teacher's main responsibility is to support students in their quest for information rather than just impart it to them. Its guiding concepts include the necessity for instruction to be built around student inquiries.

According to a study, inquiry-based science training promotes students' interest in science and their understanding of scientific concepts (Hoftsein, Mamlok, Naaman, 2007). Students benefit from inquiry-based learning understandings in that they acquire critical thinking abilities and feel a feeling of accomplishment. When developing and implementing STEM instruction, you can use 5E Inquiry-oriented Instructional Model. The 5E Instructional Model

functions as learning cycle to help designers of curriculum, classroom teachers, and institute librarians create classes that showcase constructivist, reform based, finest teaching practices.

Engagement

The teacher assesses students' past knowledge and/or looks for potential misconceptions during this first stage of the 5E Learning Cycle (Duran, Duran 2004). This student centered phase ought to arouse curiosity about the upcoming subject.

Exploration

Students are given a standard set of practical assignments throughout the discovery phase. These exercises will assist students in using prior information to research, come up with fresh ideas, and carry out a preliminary study (Bybee 2009). Typically, the primary inquiry-based experience that fosters students' understanding occurs at this stage of learning cycle (Duran and Duran, 2004).

Explanation

Explanation stage is more instructor directed and informed by learners' prior-phase experiences (Duran and Duran 2004). The teacher corrects pupils' misconceptions after the students explain how they comprehend certain subjects (Bybee 2009). The instructor could offer formal definitions, explanations, and labels throughout the stage (Duran and Duran, 2004).

Elaboration

Learners are counseled to use their new conceptual understandings while restating new capabilities through elaboration level (Duran, Duran, 2004). Students "might perform extra investigation, build products, link information and ideas, or apply their knowledge and abilities to other areas," according to Duran and Duran (2004). (p. 53). Chances for teacher are here to syndicate science with other subject areas throughout this stage of learning cycle (Duran and Duran 2004).

Evaluation

"Evaluation phase enables apprentices to evaluate their understanding and skills and gives opportunity for instructors to assess student improvement toward reaching learning objectives," stated by Bybee (2009, p. 5). In this phase, formative and summative both evaluations are suitable. A list of non-traditional assessment methods recommended by Duran and Duran (2004) for gauging students' comprehension and performance includes portfolios, performance-based evaluations, concept maps, physical models, and journal records.

Literature Review from World Perspective:

Inquiry in science, according to Lee and Songer (2003), is a deep integration of scientific thinking processes and an understanding of scientific concepts to support student learning. According to the findings of their study, kids exposed to an inquiry-oriented science curriculum during a two-week summer camp showed positive attitudes toward science subjects and a greater level of interest in trailing a career in the field. Tassanee Bunterm et al. (2014) identify the effects of inquiry learning on learners in a study conducted in Thailand. They discovered that kids benefit more from the open-ended inquiry. The common activities that scientists enjoy and engage in are called inquiries, and they give beginning scientists rich conceptual frameworks from which to generate investigative questions (Chinn and Malhotra 2002).

The Chinese Ministry of Education's Chemistry Curriculum Standard for Junior High School argues that "science inquiry is a major content and also an important strategy of learning." One of the five core subject areas in the standard is scientific inquiry. Other four topics includes chemistry materials in everyday life, construction of substances, chemical reactions, and link between chemistry and society. According to standard, the purpose of the chemistry curriculum is to build students' competency in scientific inquiry as well as their comprehension of the processes and methods used in a scientific investigation. It states that the eight steps of scientific inquiry are: asking a question, formulating a hypothesis, creating a plan, carrying out an experiment, gathering data, drawing a conclusion, reproducing, and collaborating.

Beginning in 2000, the Chinese Ministry of Education began new period of general education reforms across country. Ministry of Education announced new science curriculum requirements for Class 1 to 9 within a year (Chinese Ministry of Education, 2001). The goal of curriculum revision in science education was to place more focus on developing students' scientific literacy through inquiry-based instruction than on knowledge transmission in the classroom (Liu et al. 2012). According to the reform plan, all across the nation's elementary schools implemented integrated science curricula, while the majority of provinces adopted divided science courses for Elementary school and Secondary school students, including chemistry, physics, biology, and geography.

Hu and Adey (2002) have suggested a model that involves challenging scientific imagination, diverse thinking, and other foundational elements of inquiry and novelty. A thorough model was also anticipated by Cheng (2006) for the physics curriculum. Not only had that but Kind and Kind (2007) also pioneered another movement toward creative learning from the standpoint of science education. Open inquiry, creative writing, creative problem-solving, metaphor, and analogy are all included in this. According to (Gholam, 2019), students can benefit from inquiry in the classroom

by engaging in ongoing professional development, working with skilled educators who use IBL, and carefully planning and introducing IBL units over time. This results in a classroom that fosters curiosity, fosters a culture of deep learning and produces motivated and engaged students. When made comparison between Inquiry-oriented and traditional methods of science teaching to students in 8th class.

According to BouJaoude's (2002) study of scientific inquiry from Lebanese science curriculum, it is clear that the curriculum's creators made an effort to address the topic of scientific inquiry. This curriculum appears to be an improvement over the previous one in that it places a greater emphasis on particular goals and activities that promote inquiry. According to Aceska, Natalija (2016), Macedonia's educational system promotes the growth of students' critical thinking skills as well as their ability to reason through and apply evidence. Instead of receiving clear instructions from the teacher on how to address an issue, pedagogy and curriculum require students to work independently to find solutions.

According to (Yager & Akçay, 2010), the inquiry is a teaching strategy that mimics the actions scientists take when conducting research. It may be very effective teaching strategy that helps learners in grasping concepts and use of science process skills. As a result, inquiry-based scientific instruction promotes students' interest in science by encouraging them to participate in more science-related activities and exercises (Olson & Louks-Horsley, 2000).

Through inquiry that emphasizes critical thinking, problem-solving, and logical reasoning, students learn physics more effectively (Dayal et al., 2007; Wheeler, 2000). According to Anderson (2002), prior research suggests using inquiry-oriented science teaching in science education has some favorable impacts on cognitive achievement, process skills, and attitude toward science, but these results are reliant on the individual.

Inquiry-based teaching and learning methodologies, per Ketpichainarong et al. (2009), have an impact on students' abilities to solve issues, reflect on their work, draw conclusions, and make predictions. It is expected that inquiry will play a significant role in science instruction since, as stated above, "inquiry is key to science learning" (p. 2). However, despite its significance, "pursuing a consistent strategy to teaching science by all teachers does not entail" (p. 2). As opposed to this, the NSES asserts that "the core technique for teaching science" is an inquiry into "genuine questions derived from learner experiences" (p. 31). In addition to this extensive definition of inquiry teaching that is more process-oriented, the NSES also discusses inquiry as a learning activity (p. 13). It "states to activities that apprentices engage in to acquire knowledge of and appreciation for scientific concepts along with a grasp of how scientists do research on the natural world" (p. 23). By defining a "complete investigation" and a "partial inquiry," the NSES admits that not all inquiries are completely deserving of the label (p. 143). Any distinction between assessment and instruction is erased when inquiries are employed as a method of evaluation (p. 202).

The inquiry appears to be employed in a variety of ways in the context of education without careful differentiation as to the distinctions. It is regarded as a trait of a preferred mode of instruction as well as a specific type of activity. In any scenario, there is no clear operative definition, and the student is allowed to build his or her own ideas of what this type of teaching looks like even if the NSES provides some precise instructional examples. According to findings of their study, kids exposed to an inquiry-oriented science curriculum during a two-week summer camp showed positive attitudes toward science subjects and a greater level of interest in pursuing a career in the field. If an inquiry is to be a scaffolder, it is also vital to continually relate inquiry to classroom activities since doing so successfully illustrates how theory and practice are linked throughout the entire process. This modeling must be founded on the science teacher educator's real-world experiences in order to be effective. The first and second authors both worked closely with classroom teachers who used inquiry when they taught in secondary schools from an inquiry approach (Melville & Bartley, 2010).

Due to limitations like instructors' shortage of time, poor understanding of the nature of science, inappropriate curricula, and scarcity of pedagogical skills, scientific inquiry teaching characterized as being challenging to implement and narrow in its applicability. This has led to an acuity of scientific inquiry as an unstructured teaching strategy that is challenging to apply (Roehrig, 2004). The word "scientific inquiry" itself has been given numerous meanings by researchers and politicians alike, which may limit the reform efforts associated with it and cause confusion in teachers' own identifications of the modification (Wallace & Kang, 2004).

Literature Review from Pakistani Perspective:

According to the National Curriculum created by the Government of Pakistan in 2006, "Student-centered" and "Inquiry-based" are considered as two major concepts of General Science for Grades IV–8. "The Curriculum in 2006 is envisioned to promote a paradigm move from traditional methodologies to inquiry-based methods," (Pakistani government, 2006). Considering General Science Curriculum (2006), M. Y. Mustafa et al. (2022), sought to foster an awareness of scientific literacy can be achieved through inquiry-oriented, learner-centered methods, and an outcome-focused curriculum. However, difficulty in Pakistani context always lay in the execution level.

Through inquiry-based teaching and learning, Pakistani science curricula aims to foster students' scientific literacy as well as their feeling of wonder and curiosity about the world of science and technology. (Pakistani government, 2020). Every single choice we made is based on inquiry and scientific method, so they are essential for science education and practice. People have a built-in need for knowledge, which drives them to ask questions based on their observations,

form hypotheses, test them with data, assess the findings, and base decisions on them. Teaching techniques should be utilized to develop students into scientific thinkers and problem solvers who are able to study and comprehend complicated problems and provide new knowledge, information, and answers.

When elementary school pupils are exposed to an inquiry-based curriculum, Ali (2007) found that "Science process abilities are well established." The advent of inquiry-based education in mathematics classrooms, according to Khan, A. W. (2012), gave pupils the chance to have physical, social, and intellectual space during the learning process. The practice of treating pupils as passive consumers of knowledge in poor nations like Pakistan stood in stark contrast to this reality. In their comparison of curriculum implementation in urban and rural schools, Haq and Akbar (2021) came to the conclusion that, when it came to the implementation of the physics curriculum, teachers in urban schools used small group discussions, project work, inquiry-based learning, and debate more frequently than teachers in rural public sector secondary schools.

Inquiry-based pedagogy could be a useful place to start when developing pedagogy and could enhance instructors' professional teaching practices as well as student teachers' learning, according to Nasrin and Khalid's (2015) research on the development of such skills in pre-service teachers (ITE). The findings of a different study on the impact of inquiry-oriented learning on learners' performance demonstrate that middle-level inquiry-based learning supports improving students' performance (Nazir, 2006). Inquiry-oriented teaching approaches, according to Zahid and Misbah (2021), have also been found to be effective in helping secondary-level biology students develop a deep concept-based learning with long retention, energetic contribution, problem-solving abilities, power of decision-making, confidence in their own abilities, and the ability to achieve goals quickly. Additionally, they suggested that biology teachers be taught to use the inquiry group learning method when instructing biology at the secondary school level. Similarly, Khan (2004) came to the conclusion that the achievement-level of learners showing to the Inquiry-oriented approach is considerably higher than that of the students exposed to the traditional method.

Inquiry-based instruction has a favorable effect on secondary students' learning, according to Siraj, S. (2002). He added that the inquiry-based teaching strategy is a good technique to improve students' science learning. Changes to the physical classroom environment, the roles of teachers and students in learning process, a focus on autonomy rather than efficiency in the classroom, and changes to the current exam system could all be used to introduce inquiry-based teaching in mathematics classrooms in lower secondary schools in Pakistan. According to Kalsoom and Afifa (2017) and Khan, A. W. (2012), teacher education programs may use inquiry-oriented learning as a means of raising undergraduate students' awareness of sustainability.

In their research, Khalid, Qaisera, and Muhammad (2019) proposed that students' personal questions be effectively used to engage mathematics students and that both teachers and students should be encouraged to make better inquiries. Additionally, they suggested that a training program be supported in order to aid mathematics instructors in the proper and efficient implementation of inquiry-based curriculum and that instructors of mathematics be stimulated to apply the inquiry-oriented 5-E model in their classroom. It was determined that innovative teaching techniques like IBL should be used to teach primary school pupils in order to improve their understanding of scientific ideas. The use of this approach was strongly advised for improved learning. (Shaheen, N. Alam, T. Mushtaq, M. Bukhari, and A. M. 2015)

Objective of study:

The main objective of study is to review previous researches on Inquiry oriented curriculum analytically.

Research Questions:

- How students can well comprehend science through inquiry oriented approach in under-developed countries?
- How students can comprehend science well through inquiry approach in developed countries?

Significance of Study:

This study may be significant for:

Teachers Inquiry based teaching provides an interesting systemic approach. So use of this model drive to enhance quality of instruction. This approach will help teachers to coherent new solutions of a problem.

Students This model will improve students' learning towards concepts for the subject of science. Also, this approach Benefiting Science Students with inquiry. This might enrich the academic performance of students and will make them more confident towards science learning.

Curriculum Developer and Training Institutes Findings of this study will be helpful for curriculum developers in the curriculum. They will be able to select proper instructional material and contents for a course. It will also helpful for the training institutes so that this approach will be implemented in teachers' training.

Research Methodology:

This research is classified as a review of literature. Systematic review is done via meta-analysis approach. Regarding this technique, the miles considered as qualitative, because it pursues to create meanings and importance to the object of study.

Analysis of Results:(Developed Countries/World Perspective)

S	Year	Country	Author	Findings
1	2003	USA	Lee and Songer	Inquiry in science develop positive attitudes toward science subjects
2	2014	Thailand	Tassanee, Bunterm, et. al.	Kids benefit more from the open-ended inquiry.
3	2002	USA	Chinn and Malhotra	Inquiry based teaching gives beginning scientists rich conceptual frameworks from which to generate investigative questions
4	2001	China	Chinese Ministry of Education	Purpose of the inquiry-oriented chemistry curriculum is to build inquiry and comprehension skills.
5	2012	Taiwan	Liu et al.	Inquiry-based instruction is used to develop students' scientific literacy.
6	2002	Unknown	Hu and Adey	Scientific imagination, diverse thinking developed through Inquiry based teaching.
7	2007	USA	Kind and Kind	Pioneered another movement toward creative learning through Inquiry teaching.
8	2002	USA	BouJaoude	Emphasis on specific goals and activities that promote inquiry through inquiry-oriented curricula.
10	2016	Macedonia	Aceska, Natalija	Macedonia curriculum focusses on growth of students' critical thinking skills.
11	2010	Turkey	Yager & Akçay	Inquiry is a teaching strategy helping learners in grasping concepts.
12	2000	USA	Olson & Louks-Horsley	Inquiry-based instruction promotes students' interest in science
13	2007	India	Dayal et al.	Inquiry emphasizes critical thinking, problem-solving, and logical reasoning.
14	2000	USA	Wheeler	Through inquiry approach students can learn physics more effectively.
15	2002	USA	Anderson	Inquiry teaching impacts on cognitive achievement.
16	2009	Thailand	Ketpichainarong et al.	Inquiry teaching impact on students' abilities to solve issues
17	2007	Israel	Hoftsein and Mamlok-Naaman	Inquiry-based training develops students' understanding of scientific concepts
18	2019	UAE	Gholam	Students can benefit from inquiry in the classroom by engaging in ongoing professional development.

Pakistani Perspective (Developing):

S	Year	Country	Author	Findings
1	2006	Pakistan	Govt. of Pakistan	The Curriculum (2006) is envisioned a paradigm move from traditional methodologies to inquiry-based methods.
2	2020	Pakistan	Govt. of Pakistan	Through inquiry-oriented teaching and learning, Pakistani science curricula aims to nurture feelings of wonder and curiosity about the world of science.
3	2022	Pakistan	M. Y. Mustafa et al	Scientific literacy can be achieved through inquiry-oriented teaching

4	2004	Pakistan	Khan	Made a conclusion that the achievement-level of learner through Inquiry-oriented approach is higher than that the traditional method.
5	2007	Pakistan	Ali	Science process abilities are well established through inquiry-oriented curriculum.
6	2012	Pakistan	Khan, A. W.	Inquiry oriented education in Mathematics gave pupils the chance to have physical, social, and rational space during a learning process.
7	2021	Pakistan	Haq and Akbar	Implementation of the physics curriculum, teachers in urban schools used inquiry-based learning more frequently than teachers in rural schools.
8	2015	Pakistan	Nasrin and Khalid	Inquiry-based pedagogy enhances instructors' professional teaching practices
9	2006	Pakistan	Nazir	inquiry-based learning supports improving students' performance
10	2021	Pakistan	Zahid and Misbah	Inquiry-based teaching develops a deep concept-based learning with long retention.
11	2002	Pakistan	Siraj, S.	Inquiry approach improves students' science learning with focus on autonomy
12	2017	Pakistan	Kalsoom and Afifa	Inquiry-oriented learning is used as a means of raising undergraduate students' awareness of sustainability.
13	2019	Pakistan	Khalid, Qaisera, and Muhammad	Training program can be used to aid mathematics instructors in the proper and efficient implementation of inquiry-based curriculum
14	2015	Pakistan	Shaheen, N. Alam, T. Mushtaq, M. Bukhari, and A. M.	Inquiry teaching should be used to teach primary school pupils in order to improve their understanding of scientific ideas.

DISCUSSION:

Inquiry-based curricula use inquiry methods, which are instructional approaches that motivate students to probe academic topics through queries, research, and answers. These approaches prioritize students' inquiries and give research component skills the same importance as subject knowledge and comprehension. By doing this, a learning atmosphere that emphasizes hands-on, open-ended activities is created in the classroom. It involves posing difficult questions.

It is also concluded from the discussion above that inquiry-based courses have a stronger influence on conceptual comprehension and scientific literacy. Inquiry-based strategies are more effective than the traditional lecture method for teaching science at all levels. Inquiry-based teaching and learning strategies are beneficial for learners at primary and secondary levels in a number of learning domains, such as the growth of critical thinking and science process skills, along with knowledge, comprehension, application, and skill development abilities.

CONCLUSION:

This study performed literature review on effectiveness of inquiry-oriented curriculum at elementary and secondary levels of different developing and developed countries. The inquiry-oriented curriculum is applied in both developing and developed countries and there is no major difference between effectiveness of inquiry-based approach in both categories. Therefore, it is concluded from under developing countries that inquiry-oriented approach is very useful at different levels of science educational activities and developed countries are also in favor of inquiry approach to employ in education sector. It is suggested for future work that teacher must use inquiry approach in any subject of science at any level of education that can increase student’s ability to perform better and develop thinking abilities that can be heightened up during educational activities.

Recommendation:

It is recommended that for proper implementation of inquiry-oriented curriculum teachers should be trained to employ inquiry in their classes and future educators are taught inquiry as a basic technique of curriculum delivery.

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