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Impact of Inquiry-Based Learning on Biology Achievement: An Experimental Study of District Mardan

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Abstract

This study investigates whether inquiry-based teaching might improve biology pupil achievement compared to lecture-based methods. For this purpose a true experimental design—a Pre-test, Post-test equivalent group design was used. The study compared experimental and control groups to determine how different biology methods of teaching affect student performance. Government secondary school boys in District Mardan, Khyber Pakhtunkhwa, were the study's population registered in academic year 2020–2021. Eighty (80) students were randomly selected from these schools and assigned to experimental and control groups based on their prepared learning styles and academic achievement in Biology pre-test.

The study used the Learning Styles Test to categorize students by learning style and the Biology Achievement Test (BAT) for pre- and post-test evaluation. The experimental group used the 5E teaching paradigm for inquiry-based learning for eight weeks, while the control group got lecture-based training. Their biology topics were the same.

These results support the expanded use of inquiry-based teaching methodologies in secondary education to improve learning outcomes by showing that they improve Biology academic achievement across student demographics.

Introduction

Because of its varied terminology and practical features, biology is a particularly complex science subject. However, despite the subject's importance, many developing nations still have low levels of student accomplishment in biology (Adigun, 2020). A variety of factors have been cited to explain this poor performance, including the nature of the topics, the attitudes of the students, the lack of teaching resources, and the ineffective teaching methods. Teachers in secondary schools typically use traditional lecture-based teaching strategies, with a heavy emphasis on lectures and sporadic demonstrations to help students understand subjects. Yet, these approaches frequently restrict students' ability to participate, comprehend deeply, and be creative (Adigun, 2020).

In light of the shortcomings of conventional teaching techniques, academics support the use of more interactive pedagogical strategies to improve student comprehension and engagement (Adigun, 2020). Inquiry-based learning is such technique that is gaining popularity. It is a student-centered strategy that stresses active discovery, evidence-based reasoning, and the creation of scientific knowledge (MEB, 2013; Wood, 2003). Constructivist ideas are supported by inquiry-based learning, which encourages students to make connections between newly learned material and pre-existing cognitive processes in contexts that require social interaction (Anderson, 2007).

Not only do science students use inquiry to find out the truth about the world and the things that happen around them, but they also use it to come up with ideas and theories that will help them explain what they have seen with facts, just like scientists do (Harlen, 2004). The focus of science education has shifted from rote memorizing to the development of students' ability to critically analyze and apply scientific information (Zacharia, 2003). This is because inquiry-based science learning doesn't rely on passive observations of phenomena from books, but instead teaches the rules and laws of science through active understanding that requires students to do research. Students develop skills in areas such as critical thinking, questioning, research, and problem solving in inquiry-based scientific classes, in addition to learning scientific facts (Germann, 1994). According to Howe (2002), science classes at all levels should use an inquiry-based learning method. In his explanation, he outlined the goals of inquiry-based learning, which include teaching students to formulate questions, identify content areas, conduct research, and

draw conclusions. Furthermore, he said that letting students talk about the results makes learning more important and lasts longer.

Several studies have shown that implementing an inquiry-based learning strategy enhances students' higher-order thinking abilities and teaches them how to conduct scientific research like scientists. (Bransford, Brown, & Cocking, 2000; Carin & Bass, 2001; Wenk, 2000; Domjan, 2003; Keselman, 2003; Cuevas, Lee, Hart, & Deaktor, 2005; Bonner, 2005; Llewellyn, 2005; Tatar & Kuru, 2006; Walker & Zeidler, 2007; Çalışkan, 2008; Gordon & Brayshaw, 2008; Şaşmaz-Oren, Ormancı, Babacan, & Llewellyn (2010) said that using an inquiry-based learning method helps students learn the skills they need to be independent and keep learning throughout their lives. According to Martin, Sexton, Franklin, and Gerlovich (2005), examination, inquiry, and finding are all necessary for a good science education in inquiry-based learning. They also noted that when students structure their learnings via these methods, they mature into persons who know how to learn. Tatar (2006) posits that students acquire psychomotor skills through their interactions with instruments, whereas cognitive abilities are gained through process awareness and an understanding of cause-and-effect linkages. Lawson (2010) presented a number of study findings to support her claim that an inquiry-based learning approach not only improve academic performance and problem-solving skills, but also fosters critical thinking ability and definitely students' creativity. Inquiry-based learning improves scientific literacy, conceptual knowledge, critical thinking skills, and understanding of science (Lim, 2000; Domjan, 2003; Laipply, 2004; Alkan-Dilbaz, 2013). It also fosters a positive attitude towards science (Babadoğan & Gurkan, 2002; Bianchini & Colburn, 2000).

As a student-centered way of learning that emphasizes questioning, decision-making, problem-solving, critical thinking, and inquiry-based learning, inquiry-based learning teaches students skills that will serve them well throughout life. Thus, it assists pupils in dealing with challenges that arise (Branch & Solowan, 2003). The ability to think creatively is one of the talents used and cultivated during the inquiry-based learning process. Creative thinking is a skill for the 21st century that helps people see things from different points of view, understand them in new ways, and come up with new ideas. Inquiry-based learning requires creative thinking to build hypotheses about the research subject at hand. When striving to develop solutions, acquire data

in novel ways, and reach a conclusion through the interpretation of findings, it is necessary to employ creative thinking abilities (Lim, 2000; Hassard, 2005).

In inquiry-based activities, pupils independently or in groups analyze phenomena and events in order to formulate conclusions. By formulating inquiries, organizing novel assignments, deriving conclusions, and validating their knowledge, pupils direct their own research efforts (Bransford et al., 2000; Branch and Oberg, 2004). Students are encouraged to assume accountability, convey themselves, and develop self-assurance in this environment. The implementation of research experiences for students has the potential to enhance their cognitive frameworks and attitudes towards science. Individuals who actively engage in inquiry-based learning and derive enjoyment from the process will retain the information for an extended period of time. They would assume their societal roles as diligent, problem-solving individuals who fearlessly confront challenges. In essence, the objective of inquiry-based learning is to cultivate in students the abilities to think critically, generate their own interpretations, and conduct research (Spronken-Smith et al., 2008; Mui, 2010). Since scientific inquiry is a method that prioritizes investigation over the formation of definitive conclusions, instructors utilizing this method must assist students in concentrating on the research as opposed to forming absolute judgments (Lim, 2001). While it is indisputable that the most innovative scientific reasoning occurs when students generate their own inquiries, design experiments, and derive conclusions through data collection, learning environments that furnish questions and data and encourage active student participation in analysis and drawing conclusions are also grounded in scientific inquiry when students' age groups and levels are considered.

Within the framework of constructivism, inquiry-based learning can be executed through an assortment of learning methodologies. These encompass cooperative learning, example-based learning, project-based learning, and problem-based learning. These approaches commence by identifying a problem and prioritize the student-generated information process. All of these strategies involve various sorts of inquiry. These inquiry-based methodologies and constructivist approaches help children understand science in a meaningful way (Eick & Reed, 2002). Similarly, Kinyota (2020) described inquiry-based science instruction as the teaching process that includes the methodologies used by scientists when doing their research. According to Blyth (2010), inquiry-based learning is a technique in which students learn via exploration, facilitating

a thorough knowledge of biology topics and allowing students to participate actively in the learning process. Furthermore, Ghumdia and Adams (2017) defined inquiry as a teaching technique in which students seek information or understanding about specific phenomena with minimal teacher guidance. From these views, inquiry-based teaching can be defined as a kind of teaching in which students actively participate in the process of acquiring or looking for specific planned knowledge or information via various methods employed by scientists or inquiry-based activities. Kinyota (2020) and Şimşek and Kabapinar (2010) suggest many methods for conducting research, such as asking questions, developing hypotheses, observing, collecting data, interpreting, and reporting findings.

Five essential elements of inquiry-based science education are outlined in "Inquiry and the National Science Education Standards" (NRC, 2000; Tatar, 2006; Ulu, 2011). These elements include formulating explanations, evaluating explanations, communicating proposed explanations, and engaging students through scientifically oriented questions. Students gain scientific and critical thinking abilities in addition to conceptual comprehension through inquiry-based learning (Jorgenson et al., 2004).

In the context of science education, it is crucial to encourage scientific thinking from an early age [Poon & Tan, 2009]. However, the traditional lecture methods that are prevalent in Pakistani science classrooms usually lead to rote memorization rather than developing conceptual knowledge (Safdar, 2013). In response, educational frameworks such as the Biological Science Curriculum Study (BSCS) support inquiry-based approaches such as the 5Es (Engagement, Exploration, Explanation, Elaboration, Evaluation) to foster conceptual comprehension and active learning (Bybee et al., 2006).

In the experimental group of the present study, inquiry-based teaching was implemented utilizing the 5E instructional approach. The model, according to Bybee (2006), comprises five consecutively significant components. Before encouraging student participation, instructors must inquire about students' prior knowledge via discussions and activities designed to arouse their curiosity. By means of investigation, pupils are presented with actual problems from the real world, wherein they can independently gain fresh insights and skills under the supervision of the instructor. The explanation phase entails students elucidating their discoveries while the

instructor imparts fresh definitions and vocabulary. By elaborating, students are compelled to apply their knowledge to novel contexts, thereby enhancing their comprehension. In evaluation, tests are utilized to determine if predetermined objectives have been attained. The aforementioned phases formed the cornerstone of the inquiry-based biology curriculum.

This study compares the effectiveness of traditional lecture methods with inquiry-based methods in improving the academic achievement of secondary biology students in District Mardan, Pakistan. By exploring and integrating past research work and theoretical framework, this paper aims to shed light on the capacity of inquiry-based teaching methods to revolutionize scientific education and enable students to access more intensive learning avenues. The study intended to formulate novel pedagogical methods that could effectively and directly engage students during the learning process was conceptualized from the need to bridge the current gap of information through standard lecturers and class instruction. This study also intended to fill in the existing gap of knowledge; this paper also investigates the influence of inquiry-based teaching approaches on biology student performance at the senior secondary level in Mardan District, Pakistan. By aligning with the educational dimension of constructivist learning and stressing educational stakeholder empowerment and improved secondary school biology performance, this study is justified.

Methodology

For the purpose of this study, an equivalent group design called a pre-test and post-test was utilized. The natural sciences, including physics, chemistry, and biology, particularly benefit greatly from the application of this kind of design. Using this strategy, it is feasible to compare the performance of the experimental group and the control group in terms of their achievement in biology. This is made possible by controlling extraneous variables and other causes of variance. For the purpose of determining the researchers' baseline knowledge, pre-tests were administered to both the experimental and control groups in the study. As a means of assessing the pupils' development following the session, a post-test was administered to them. It was determined that this design was necessary in order to evaluate the efficacy of inquiry-based teaching approaches

in comparison to traditional teaching methods in terms of enhancing learning outcomes in biology.

Population and Sample of the Study

Secondary school pupils who were enrolled in boys' government schools in District Mardan, Khyber Pakhtunkhwa, for the academic year 2020–2021 were included in the research population. Eighty pupils were chosen as a purposeful sample from this population. Following that, 40 pupils from each of the experimental and control groups were formed, guaranteeing random assignments of students based on their learning styles and academic performance in the pre-test.

Data Collection Instruments

The study used the Biology Achievement Test (BAT) and the Learning Styles Test as its two main instruments. The Biology curriculum was carefully followed in the development of the BAT, which consists of multiple-choice questions, short answers, and diagram identification tasks. It also includes a post-test. Students' preferred learning styles were determined by administering the Learning Styles Test; this information, combined with their pre-test results, guided the random assignment of the students to the control or experimental groups.

Data collection process

All participants were given the Learning Styles Test and the pre-test at the start of the process. Students were randomized to the experimental and control groups according to their pre-test scores and learning preferences based on the findings. While the control group was taught by traditional lecture-based method, the experimental group used the 5E instructional approach to engage in inquiry-based learning. During this eight-week term, both groups were given the same Biology content.

Following the intervention, the students were given post-test evaluations to assess their academic development in biology. The necessary educational authorities provided consent for data collection, ensuring that ethical concerns were addressed.

The experimental and control groups' academic performance was compared using the independent samples t-test in SPSS version 16. The goal of this investigation was to determine how inquiry-based teaching practices influence student learning outcomes while taking individual learning styles into account.

Results

The study's findings are as follows:

Table 1

Comparative analysis of academic achievement of experimental and control groups

Groups	N	Mean	S.D	t-value	df	p-value
RCG	40	62.10	12.11	0.257	78	0.035
REG	40	65.33	10.13			

According to Table 1, the experimental group, which received inquiry-based instruction, had statistically significant differences (0.035< 0.05) in academic achievement from the control group, which received just lectures. The study indicated that inquiry-based biology instruction improved student performance more than lecture-based instruction. Inquiry-based teaching improved topic scores, showing that it can increase learning outcomes.

Table 2

Comparison of low-achieving students in experimental and control groups' biology

Groups	N	Mean	S.D	t-value	df	p-value
RCG	12	12.50	3.66	0.238	22	0.039
REG	12	19.88	7.46			

The results presented in Table 2 demonstrate a statistically significant difference in academic achievement among those with low academic performance in the experimental group, who received inquiry-based training, and those with low academic performance in the control group,

who received lecture-based instruction, within the subject matter of biology. Based on the obtained p-value of less than 0.05, it may be inferred that the teaching approach employed has a statistically significant influence on the academic performance of students who are classified as low-achieving.

More precisely, students with lower academic performance who underwent inquiry-based training had superior academic performance in comparison to their peers who got conventional lecture-based education. This suggests that the utilization of an inquiry-based approach may yield greater efficacy in addressing the educational requirements of students with lower academic performance in the field of biology.

Table 3. Comparison of experimental and control high-achiever student academic achievement

Groups	N	Mean	S.D	t-value	df	p-value
RCG	12	33.09	4.37	0.622	22	0.04
REG	12	37.02	9.65			

According to Table 3, there is a statistically significant difference ($p = 0.04<0.05$) between the inquiry-based education experimental group and the lecture-based instruction control group in the academic performance of high achievers in Biology. This indicates that high achievers' academic performance is significantly impacted by the teaching methodology. Academic performance was higher for high achievers who got inquiry-based instruction as opposed to standard lecture-based training. Thus, it would seem that improving the academic achievement of biology students who achieve high standards would benefit more from an inquiry-based approach.

Conclusions and discussion

The study's conclusions, which highlight the ways in which inquiry-based teaching strategies can raise secondary biology students' academic achievement, provide strong justification for increasing their application in the classroom. The experimental group, which used inquiry-based learning methods, scored significantly better academically than the control group, which

received instruction using conventional lecture-based methods. This finding aligns with research conducted in 2018 by Hashmi, Hussain, and Shoaib and in 2013 by Ozgelen, Yilmaz-Tuzun, and Hanuscin, which found that students performed better when inquiry-based learning was used instead of traditional teaching methods.

This study also looks closely at how inquiry-based teaching approaches affect students' performance across a range of achievement levels. This result is consistent with studies by Yager and Simmons (2013) and suggests that children who perform less well academically can benefit from inquiry-based methods by providing a dynamic and supportive learning environment. Inquiry-based teaching approaches significantly improved the academic performance of students who were not high achievers. In a setting like this, the children might be able to engage with the material more thoroughly, which might lead to improved understanding and performance.

However, the inquiry-based method also proved beneficial for top performers. This demonstrates how inquiry-based learning benefits students who find it difficult to learn using traditional methods and enables high achievers do better academically. This study supports the findings of Savery (2015), Zareen and Kayani (2014), and Manishimwe, Shivoga, and Nsengimana (2023) that inquiry-based learning approaches can raise high achievers' academic levels. Because inquiry-based learning fosters critical thinking, active involvement, and discovery while presenting obstacles that support ongoing intellectual advancement, these kids might be especially drawn to it.

Inquiry-based learning techniques have been shown to significantly raise academic achievement in both high and low performers. This implies that these strategies can be advantageous for a range of educational environments and student demographics. The results align with previous research, such as a meta-analysis conducted by Aktamiş et al. (2016) and a study conducted by Bayram et al. (2013) that demonstrate the enhancement of students' motivation and attitudes towards science through inquiry-based learning.

Thus, the idea that biology teaching should shift to a more inquiry-based approach is supported by this research. By creating a more stimulating, demanding, and encouraging learning environment, these strategies not only improve students' attitudes and overall academic achievement, but they also increase their motivation to learn. Inquiry-based learning approaches

can be included into the curriculum to improve student learning results and get them ready for scientific possibilities and problems in the future. Authorities and educators should take this into account. To fully grasp these methodologies' potential and constraints, as well as how to apply them in a variety of scientific and educational contexts, more research is required.

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