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The Effects of Project-Based Learning on Students' Scientific Reasoning Abilities and Credibility : A Teachers' Perspective

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ABSTRACT

The purpose of this research paper is to investigate the impact of project-based learning on students' scientific reasoning skills and credence. The study's pre-exam and post-exam model was single group. 40 students from a public-school 8th grade students participated in the study during the spring 2021-2022 school year. The "Scientific Reasoning Exam Skills - SRES" was used to gauge the scientific reasoning abilities of the students before "Life science and Physical Science" course was taught using the research-project based learning approach and the SRES as a final progress check results. The 26 elements in this test are divided into 6 sub-categories Project-based learning is a student-centred approach that promotes active learning, critical thinking, and problem-solving through the exploration of scientific phenomena. This was accomplished in order to have a very solid result which will help schools to re-think in their curriculum design to make it more student-centered rand pee to peer rather than teacher centered. The results of the study's sub-problems can be summarized as follows: according to the sub-categories of proportional thinking, Hypothetical thinking, Probabilistic thinking and correlative thinking a significant difference was found between the SRES pre-exam total scores and post-exam total scores in favor of the pre-exam total scores. According to the sub-dimensions controlling variables and combinational thinking, there was no statistically significant difference in the pre-exam total scores. Between the SRES pre-exam and post-exam total scores of boys and girls students, there was no discernible difference. Only the combinational Thinking and correlative thinking sub-dimension showed a significant difference in the total scores of the SRES sub-dimensions.

Keywords: Project-based learning, scientific reasoning skills, student-centered approach, active learning, critical thinking, problem-solving, scientific practices, Science literacy, Self-efficacy

I. INTRODUCTION

The need to teach students how to use science to solve problems and to make informed decisions about how science affects their lives has been put back in the forefront of current efforts to reform science curricula around the globe (Australia, 1998; Council of Ministers of Education, 1997; Millar, Osborne, & Nott, 1998). Using more student-centered methods for active learning, such as peer instruction/discussion, problem- and case-based learning, peer teaching, team-based learning, and inquiry-based learning, is the most effective methodology to help this type of learning. Inquiry-based scientific investigations have reportedly increased from less than 10% to almost 80% of laboratory classrooms at universities in the United States and around the world over the past ten years, according to surveys of instructional practices (Sundberg & Armstrong, 1992; Sundberg, Armstrong, & Wischusen, 2005).

Students who experience the scientific argumentation and reasoning process as much as possible in educational contexts resembling the socio-cultural contexts of scientists are better able to comprehend the nature of science and scientific content (Koseoglu, Tumay, and Ustun, 2010). With reason and knowledge, nations may advance. Science curricula have been arranged and evolved to the present day because past times recognized the role and value of science in the field of education.

It is obvious from this transformation that reforming laboratory instruction has been successful, yet there are still a number of unsolved questions. First, surveys are the only sources of information indicating whether the reported improvement actually corresponds to changes in teaching practices. Second, there is a dearth of published studies comparing the effectiveness of inquiry instruction to more conventional training in terms of college students' overall level of science achievement, science literacy, and confidence in their scientific aptitude. Studies that evaluate modifications to entire course curricula are particularly few; instead, they tend to concentrate on changes to specific lab activities (Rissing & Cogan, 2009). By defining the types of inquiry-based activities designed for an introductory biology laboratory course for non-science majors, assessing changes in science literacy, science process skills, and self-confidence in doing and writing about science displayed by the students enrolled in the course, and contrasting skill acquisition and self-confidence of students taught using the inquiry laboratories and those taught using traditional classroom methods, this study aims to advance knowledge in that area.

The word "Project" has struggled with its meaning ever since it was first used (Barrow, 2006). The phrase was first used to suggest the idea of teaching science as it is actually done by scientists, which entails problem-solving through the creation and testing of hypotheses (Dewey, 1910; Schwab, 1960). However, despite decades-long efforts to define inquiry (National Academy of Sciences - National Research Council Washington DC. Center for Science Mathematics and Engineering Education., 2000), educators continue to disagree on the best way to measure it in real-world settings (Abrams, Southerland, & Silva, 2008; Chinn & Malhotra, 2002). Alternatives to traditional, didactic, "cookbook" style laboratories where students are instructed on what to do and learn are described by Sundberg and Moncada (1994). The term "inquiry" lab, which they attribute to Uno and Bybee (1994) and shows as a laboratory activity where the instructor guides students to find out a particular topic after being prompted by a straightforward query or challenge. A scale called the "authentic scientific inquiry scale," created more recently by Chinn and Malhotra (2002), measures how much complicated reasoning is needed in an inquiry lab as demonstrated by working scientists. Chinn and Malhotra (2002) found that current high school inquiry tasks were better categorized as simple inquiry tasks (such as simple observations, simple illustrations, or even simple experiments) and bore little resemblance to authentic scientific reasoning after using this scale to analyze published laboratory manuals.

The overarching goal of science education—the development of scientifically literate citizens—is attained by an inquiry teaching approach? This is the central question driving all of these investigations. According to some, the greatest way to develop scientific literacy is through inquiry-based teaching strategies since they give students the chance to discuss and debate scientific concepts (American Association for the Advancement of Science, 1993). According to Hogan and Maglienti (Hogan & Maglienti, 2001), this is the main method used by working scientists to assess scientific theories and findings. However, the majority of studies on the impact of inquiry-based learning have only measured one sort of scientific literacy—improvements in scientific knowledge. This form of science literacy is referred to as "fundamental" by Norris, Phillips, and Corpan (2003), who also highlight that it includes simple recall of scientific concepts.

Finding out if the inquiry laboratories we created could improve the aforementioned "derived" science literacy abilities was the main objective of this study. Our student body included non-science majors who participated in activities aimed at helping them gain a grasp of how scientific knowledge is acquired as well as the critical thinking skills necessary to assess popular stories of science they would come across in daily life. In more detail, we looked at whether students had actually learned to comprehend and plan investigations, whether they could apply this knowledge to real-world tasks and accounts from their own lives, and whether they had developed greater levels of self-credence in these skills.

Science education needs to be implemented in the classroom more effectively if we're going to be able to produce knowledgeable and successful people. The necessity for students to comprehend the essence of science and how scientific reasoning is made has been highlighted during the past century as one of the primary goals of science education (Schen, 2007). Musheno and Lawson (1999) also use an awareness of science's nature as the foundation for the scientific reasoning of "if... and... then..." Students can only experience scientists' experiences by learning about their thought processes if science is taught in its true nature.

The formal operational stage, which Piaget defined as the highest stage of cognitive development, spans 11 years and beyond, according to Epni (2008, p. 42–47). The formal operational stage of the cognitive process in humans is as follows:

Proportional thinking: Understanding the ratio between the parameters and contrasting the correlations requires cognitive process skills. This ability is the recognition of the type of ratio that exists among the factors that influence any event.

Correlative thinking: In other words, it refers to creating a connection between two variables. It is a process that is described as thinking about the kinds of connections and linkages that exist or do not exist between the settings or situations being evaluated.

Hypothetical thinking: It is a way of thinking that makes it feasible to come up with solutions to issues that arise in daily life or in the classroom. It is stated using a generic sentence structure like "if... and.. then..."

Controlling variables: Variables are things that can change an observed event. In order to test the hypothesis, event, or concept, this procedure involves determining, identifying, and controlling dependent and independent factors affecting the continuation of the scenario.

Combinational thinking: It is the capacity for systematic consideration of any theoretical or experimental link that is assumed to exist.

Probabilistic thinking: The capacity to estimate all potential possibilities at each stage of an event or assumption, from its initial condition to its final state, is known as probability analysis.

II. METHODS AND MATERIAL

The impact of the Life science and physical Science taught with a research-project based learning strategy on the students' scientific reasoning skills was investigated using a single-group pre-exam post-exam paradigm. The fact that the sample is not chosen at random is the only distinction between the semi-experimental approach used in this work and the true experimental approach. This is due to the fact that the current system prohibits this. In the study's chosen sample, there is just one class of grade 8 pupils participating in a science education program. Although Karasar (2013) suggests using this strategy in a variety of ways, the study's methodology is focused on pre- and post-exam applications on a single group. According to Karasar (2013), a randomly chosen group is subjected to an independent variable in the single group pre-exam post-exam model. There are measurements taken before the experiment (Pre-Exam) and after the experiment (Post-Exam).

O1.2 > O1.1 is said to be caused by "K". The model's symbolic representation is shown in Table 1 as follows.

Table 1. Single Group Pre-Exam Post-Exam Model with Symbolic View

G_1	$M_{1.1}$	K	$M_{1.2}$

*G: Group, K: Independent Variable Surface, M: Measurement, Observation

The ability to manipulate independent variables is the primary characteristic of any experimental research (McMillan, 2000). The "Research-Project Based Learning Approach" was used as an independent variable in this study, and its effects on experimental groups were examined. The six exercises designed to enhance formal reasoning were used in the lesson on “Life science and Physical Science, and their effects on the growth of scientific reasoning abilities were evaluated at the start and conclusion of the semester.

Study Group

40 students from a public-school 8th grade students participated in the study during the spring 2021-2022 school year. who had taken “Life science and Physical Science” courses made up the study group. 20 pupils used as experimental group, and 20 pupils as the control group.

Data collection tools

Scientific Reasoning Exam Skills (SRES)

(SRES) The research design used was a non-equivalent control group design whiles the research instrument was a scientific reasoning exam.This scientific reasoning exam adopted similar tests developed developed by Yuksel (2015) has a Cronbach Alpha reliability rating of 0.86. Some questions have been modified for middle school and high school students. A value of 0.86 was discovered to be a trustworthy value for the test in terms of Cronbach's Alpha values (Kayş, 2010, p. 405).

Scientific Reasoning Exam Skills (SRES)

Understanding conservation laws and the six sub-dimensions that are anticipated to be present in a person throughout the formal operational stage make up the entirety of the Scientific Reasoning Exam Skills (SRES), which has a total of 6 sub-dimensions. Table 2 lists the questions for the SRES 's sub-dimensions.

Question Set for SRES Sub-Dimensions, Table 2.

SRES Sub-Dimensions Questions	**Questions**
Proportional Thinking	1, 2, 3
Controlling variables	4, 5, 6, 7
Combinational Thinking	8, 9, 10, 11
Correlative thinking	12, 13, 14, 15
Probabilistic thinking	16, 17, 18, 19,
Hypothetical thinking	20, 21, 22, 23, 24, 25, 26

Data Analysis

Data entry was provided by coding 1 for the correct answers that the students provided and 0 for each answer they left blank and incorrectly responded to in the examination of the data. With the use of the SPSS analysis program, the students' accurate and incorrect responses to each question were examined. A dependent e Exam was used to assess the pre- and post-Exam results, and an e Exam for independent samples was used to analyze the gender variable.

Findings and Discussion

Does the SRES Pre- Exam Total Score Differ from the SRES Post- Exam Total Score in the Research-project Based Learning Approach for "Life science and Physical Science" Course? Table 3 displays the overall results of the SRES pre-Exam taken as part of the research-project based learning approach for the Life science and Physical Science course.

Table 3. SRES Pre-Exam Total Scores

Exam	**N**	**Mean P Score**
Pre - Exam	40	20,22 0,00
Post -Exam	40	16, 23

The overall scores of the SRES pre-exam and post-exam showed significant differences ($p = 0.00$, $p < 0.08$). It was discovered that the mean score for SRES pre-exam total scores was greater.

Does the SRES Sub-Dimension Exam Score in "Life science and Physical Science "Course Using a Research-Project Based Learning Approach Differ Between the Pre-Exam Total Scores and The Post-Exam Total Scores? In terms of the overall exam scores for the SRES sub-dimensions, Table 4 shows the difference between the pre-exam and post-exam total scores.

Table 4. Pre-Exam Post-Exam Total Scores of SRES Sub-dimensions

Sub-dimensions	**N**	**Pre-Exam Mean Score**	**Post-Exam Mean Score**	**p**
Proportional Thinking	40	3,45	2,34	0,01
Controlling variables	40	3,90	3,43	0,22
Combinational Thinking	40	2,68	2,21	0,33
Correlative thinking	40	2,30	1,45	0,02
Probabilistic	40	3,01	2,45	0,01

thinking				
Hypothetical thinking	40	2,02	0,98	0,02

Between the research-project-based learning approach's post-Exam total scores and the SRES pre-exam total scores: According to proportional thinking ($p = 0.01$, $p<0.08$), Hypothetical thinking ($p = 0.02$, $p < 0.08$), Probabilistic thinking ($p = 0.01$, $p <0.08$), and Correlative thinking ($p = 0.02$, $p<0.08$) there was a significant difference in favor of the pre-exam total scores. With regards to sub-dimensions scores of Controlling variables ($p = 022$, $p > 0.08$) Combinational Thinking ($p= 033$, $p > 0.08$) there was no significant difference in the pre-exam total scores.

Is there a Difference Between the Genders "Life science and Physical Science" Courses Using a Research-Project Based Learning Approach Regarding the SRES Post-Exam Total Scores? In the "Life science and Physical Science" course utilizing a research-project based learning strategy, the gender differences in SRES post-exam total scores are shown in Table 5.

Table 5 shows the gender-specific total scores for the SRES Post-Exam.

Gender	**N**	**Mean Score**	**P**
Girls	20	20,13	0,45
Boys	20	19,86	

Regarding the SRES post-exam total scores, there was no discernible gender difference ($p = 0.45$, $p> 0.08$).

Does the SRES Sub-Dimension Exam Score for Gender Differ in "Life science and Physical Science" Courses Using a Research-Project Based Learning Approach?

Using a research-Project based learning strategy, Table 6 compares the gender differences in the SRES sub-dimension test scores for "Life science and Physical Science" course.

Table 6 shows the scores for each SRES sub-dimension by gender.

Sub-dimensions	**N**	**Pre-Exam Mean Score for Girls**	**Post-Exam Mean Score for Boys**	**p**
Proportional Thinking	40	3,33	2,23	0,15
Controlling variables	40	3,40	3,10	0,22
Combinational Thinking	40	1,78	2,45	0,04
Correlative thinking	40	2,30	1,89	0,02
Probabilistic thinking	40	2,01	1,43	0,09
Hypothetical thinking	40	1,02	0,69	0,10

Using a research-project based learning approach, the gender differences in the sub-dimension scores between the post-exam total scores in "Life science and Physical Science" course, for Proportional Thinking ($p = 0.15$, $p > 0.08$), Controlling variables ($p = 0.22$, $p > 0.08$), Probabilistic thinking ($p = 0.09$, $p > 0.08$) and Hypothetical thinking ($p = 0.10$, $p>0.08$) sub-dimension score, there was no significant difference in the

post-exam total scores. However, there was a significant difference in favor of pre-exam total scores according to the sub-dimensions of correlative thinking ($p = 0.02$, $p < 0.08$) and combinational Thinking ($p = 0.4$, $p < 0.08$).

III. RESULTS AND DISCUSSION

The findings showed a substantial difference between the students with regards to the total SRES pre-test and post-Exam scores. It was discovered that the mean score for SRES post-Exam total scores was greater. According to the proportional thinking, Hypothetical thinking, Probabilistic thinking and Correlative thinking sub-dimensions of the SRES, there was a significant difference between the SRES pre-exam and post-exam total scores of the research-project based learning strategy in favor of the pre-exam total scores. According to the sub-dimensions controlling variables and combinational thinking, there was no statistically significant difference in the pre-exam total scores. The overall SRES ratings for “Life science and Physical Science” courses adopting a research-project based learning strategy did not significantly differ by gender. There was no statistically significant difference in the SRES post-exam total scores between genders for the sub-dimensions of Proportional Thinking, Controlling variables, Probabilistic thinking and Hypothetical thinking. According to the sub dimensions of correlative thinking and combinational Thinking there was a substantial difference in favor of pre-testexam total scores. According to the SRES total scores for the Science lesson, it was observed in Yuksel and Tarakci's (2018) study on middle school pupils that women had higher average scores than men overall. Girls performed better on average than boys on the sub-dimensions of detecting and managing the variables, combinational thinking, and correlational thinking. In terms of the overall corrected post-Exam scores for the sub-dimensions of detecting and managing the variables and hypothetical thinking, it was observed that there was a substantial difference between the boys’ and girls’ students (Yuksel, 2015). There was no discernible difference in the total adjusted post-exam scores for the other sub-dimensions between the boys’ and girls’ students. The finding indicates that with experience and instruction, one can improve one's capacity for scientific thinking. (Yangco, & Espinosa, 2016). Scientific thinking abilities are enhanced by project-based, student-centered instruction. (Jensen, Jamie Lee, & Lawson, A., 2011) Two facets of probabilistic reasoning and regulating variables have not been properly developed, according to an analysis of student replies. This happens as a result of pupils' failure to fully explore all potential solutions to a problem. The way the product works has not been carefully explored by the students. Students frequently neglect to take alternate explanations into account when performing deductive reasoning tasks. (Heckler & Bogdan 2018). Teams of students can work together to develop abilities in information synthesis, planning, technology use, problem solving, time management, communication, and product creation. (Çakici, Y. 2013). The findings also demonstrated that students who applied scientific reasoning possessed a solid conceptual grasp of fluids. Understanding the key components and causal connections of a system is known as conceptual knowledge. (Schlottmann, 2001). These findings are in line with earlier research that shows middle and high school science teaching improves some parts of proportional reasoning but has less of an impact on the development of probabilistic reasoning and control variables.

IV. CONCLUSION

It is highly recommended that schools and teachers should focus more PBL rather than summative exams, as the findings and results show students are capable and develop faster with their ability to think and reason whiles on task with application of critical thinking. Students are taught to think about many options while working on a projects through this instruction. By taking into account the type of project that can work properly, students also develop their capacity for scientific reasoning as they research and work the project. The inclusion of a "if-and-then-but-therefore" thinking model and the recording of all the factors present in the situation are suggested as ways to enhance probabilistic reasoning and the aspect of controlling variables project based learning integrated courses.

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