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Improving spatial reasoning and self-regulated learning among students through project-based instruction in geography

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ABSTRACT

The study examined the effectiveness of project-based learning (PBL) in developing spatial perception and self-learning skills among tenth-grade geography students. A quasi-experimental design was employed. The researcher developed a teacher›s guide based on PBL, a Spatial Perception Test, and a Self-Learning Skills Scale, all of which were validated for reliability and validity. The sample consisted of 60 tenth-grade female students from Al-Mazar Comprehensive Mixed Secondary School during the first semester of the 2025/2026 academic year. Students were randomly assigned to an experimental group (n = 30) and a control group (n = 30). Data were analyzed using SPSS.

The findings revealed statistically significant differences in favor of the experimental group in both spatial perception and self-learning skills. PBL produced a large effect on spatial perception (69%) and a substantial effect on self-learning skills (57.1%), demonstrating its effectiveness in enhancing students› learning outcomes in geography.

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Introduction

The educational process has recently undergone radical transformations, as the methods of memorization are no longer able to meet the requirements of the 21st century and the imposed skills of critical thinking, communication, and creativity. With the development of knowledge and technology, the need for modern teaching strategies has emerged that focus on the role of the active learner instead of being a passive recipient of knowledge. Project-based learning is one of the most prominent of these strategies, especially in the teaching of geography because of its Applied and investigative nature, which enhances the skills of Planning, Research, Collaborative Work and the development of geographical awareness among learners.

Yahya (2005) believes that the basic function of geography is to provide information and facts about the World, enhance understanding of location, place and the relationship

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between places, realize and understand the nature of society, test values and attitudes towards the environment, as well as enhance research and investigation, sharpen mental and applied skills, and its role in the geographical Organization of the basics and skills is not hidden, and these basics and skills are needed for individual and group decision-making, problem solving, and the teacher should take advantage of this information and skills, and employ them in his teaching of geography. He adds (al-Duwairi, 2014) that geography has a prominent role in the formation of an individual's personality and his value system; this is because geography examines the relationship between man and the environment and the influences reflected on human behaviors.

Al-Masoudi (2013) pointed out that teaching geography is related to Broad and complex topics, starting from the local environment to outer space, and from natural phenomena to humans; it calls for strategies and methods of education, as well as the acquisition of various skills, and that some topics require the application of certain teaching methods that may not fit with other geographical topics, so teaching climate and weather topics, for example, other than migration and population distribution, and this requires developing the student's ability to accurately observe, and help him explore and analyze phenomena and infer their occurrence, as well as research, investigation, information collection, and problem solving facing the community.

Project-based learning is one of the most important strategies, the most effective and appropriate in teaching geography, it links theory with practice, and works to consolidate a learner-centered learning culture, in which the educational project is built around a problem or question that raises the learner's challenge; it makes him practice several skills, such as problem solving, decision-making, collaborative work, communication and communication to find a solution to the problem of the project or its question posed, and also Solutions, which expands the circle of knowledge from the abstract to the application, thereby deepening understanding and connecting learning It encourages the spirit of cooperation between learners to carry out assignments.

(Al-far and Wahba, 2017), and (Al-Zahrani, 2017) defined project-based learning as the set of activities carried out by students to perform educational tasks, individually or in groups in order to achieve specific goals, and adds that it is of great importance, by instilling a spirit of enthusiasm, competition and active participation among team members, and through project-based learning, imagination and creativity are developed, it also makes the vocabulary of measurement, performance, results, success, failure, patience and attempt present in the learner's mind, and also develops his sense of responsibility and tolerance.

The idea of project-based learning dates back to the eighteenth and nineteenth centuries, where there was a trend for the freedom of the learner, replacing him with the appropriate place in the education process, and making him the center of effectiveness around which the teacher's efforts revolve, and John Dewey had a role in the emergence of new trends, in changing the stereotypical relationship between school and society, he saw that the school is no longer some dry materials and abstract facts, but that the school has become a place where students learn practical social life).

(Thomas, 2000) identified five elements of project-based learning: projects should be the core of the curriculum and not an additional activity, and the project should be based on an original problem that pushes the learner and challenges his thinking, then students conduct an organized survey in terms of collecting, analyzing and interpreting information and evidence, and give independence to the learner, guiding him to make decisions and choose ways and roles, and finally to simulate reality so that it connects with reality and connects knowledge to life.

(Hyenk, 2017) presents a conceptual framework in which he shows the nature of project-based learning in geography, where students are involved in problems related to authentic

and realistic problems, and constructively builds learning, through investigative and collaborative work, and projects produce products that can be displayed, this builds deeper understanding, increases geographical skills, and also makes geography more fun, but the teacher must carefully design his activities and integrate them into real geographical contexts.

Project-based learning in geography requires steps that can be explained by the following : choosing the steps of the project, which are the most important stages, and it must be in line with the students' inclinations, taking into account the conditions of the environment and the possibilities of work, and then planning the project; developing a plan and discussing it under the supervision of the teacher, so that it addresses the goals, activities, knowledge and their sources, roles and dividing groups, followed by implementation; so that the plan, proposals and imagination need, and learning ends with a calendar, so that students judge their project with questions such as: The extent to which the project provided us with an opportunity to grow our expertise, the extent to which we were able to think collectively and individually, and the extent to which the project was able to provide students with the required inclinations and trends, and the evaluation process is continuous at the stages of project-based learning in geography, and ensures course correction and correction of errors. (Omar, 2010)

(Brisini, 2018) explains the importance of project-based learning, that the assessment of education should not be limited only to memorizing knowledge, but it must measure the application of what they have learned, and use it in their lives inside and outside school, and this is the required knowledge economy, in addition to its appropriateness teaching complex and complex topics in geography based on self-directed inquiry, and all this requires a focus on project-based learning, because it helps students succeed in their lives, and, 2009) that the project-based learning method exceeded students ' understanding of their environment,and gave a positive impact in applying what they learned in their daily lives by solving problems and relying on their previous experiences, in addition to its role in developing and building knowledge and stimulating their motivation to learn, Zimmerman (2010) adds that project-based learning contributes to preparing students for the after-school stage, because it contributes to the development of skills, increases learning pleasure and motivation, and it also helps in adapting and changing education according to student needs.

Geographical awareness is closely related to spatial perception, and Al-Kholy (1999) defined spatial perception as the process by which an individual becomes aware of the surrounding environment by interpreting and organizing the information obtained by the senses, and it is also one of the patterns of multiple intelligence as reported (Gardner), and (Catling, 1979) referred to in the study of Abdul Basit (2008) explains three stages of the development of spatial perception, namely : The topographic stage, where the learner realizes simple associations between the parts of the figure in an abstract way, and then the projective stage, where he understands the reality of the connection between places, and here his ability to represent in an accurate way and show accurate spatial relationships appears, and finally the stage (Euclid) where spatial understanding develops to the level of the exact concept of relationships : Since Project-Based Learning in geography focuses on studying problems in the surrounding environment, it must develop the learner's spatial perception by linking the project to reality and developing critical, creative and deductive thinking, and increasing the perception of locations through geographical tools such as maps of all kinds, they provide spatial data and real descriptions of reality.

Since Project-Based Learning in geography involves the student in exploratory activities in problems from their reality, the learner must determine the goals of the project, planning and organizing, data collection, decision-making, and these are all self-learning

skills, Zaghloul (2003) defined self-learning by the ability that the learner has to manage his education himself, by setting goals, choosing appropriate strategies and resources, monitoring his progress and evaluating his work without total dependence on the teacher, he thereby prepares the learner for life and after school and establishes for sustainable learning.

Geography topics are very suitable for project-based learning, especially as they deal with natural and Human Problems and their potential effects, hence the importance of project-based learning.it deals with these problems according to an investigative approach, and by studying according to a scientific approach to reach a solution to these problems and innovative ways to deal with them. by accessing and presenting the project product, the learner feels that he was actually an element in the classroom situations, and not just listening to what the teacher offers. Due to the great importance of project-based learning in geography teaching, this study came to identify the effectiveness of project-based learning during geography teaching in the development of spatial perception and self-learning skills.

Study Problem

This study is based on new global trends in the educational context, which focus on the quality of Education, which indicate that success is measured not only by school exams, but in real exams; namely, facing real problems, managing crises and time, rotating experience, mental flexibility and success in real ways of life (Obaid, 2011), and in the global framework as well, the National Council for social studies (2016) pointed out that one of the goals of teaching geography is to recognize spatial relationships and understand the natural and human system and the relationships between them, through survey and teamwork discussions, projects, community service, as well as while working independently Through self-directed learning.

At the Jordanian national level, the special framework for Social Studies Research, its standards, learning outcomes and performance indicators, issued by the National Center for Curriculum Development (2024), has emphasized the learning outcomes that enable the learner to understand natural phenomena and processes, the human system and the interaction between them, and the role of geography of place in understanding issues of diversity and spatial variation, and provides creative solutions to environmental problems, and the use of individualization methods of education, such as individual instructional learning.

This study also came in line with the Royal vision of economic modernization by 2033, which was directed by His Majesty King Abdullah II – may God protect him - for the basic and Secondary Education stage by graduating knowledgeable and skilled Jordanians, who have the ability to think critically, solve problems and learn permanently.

In a study for (Zimmerman, 2010) confirmed that students who learned by projects acquired the skills of communication, cooperation, problem solving, time management and self-learning, better than the group that studied by the traditional method in geography and social studies, the study recommended the need to provide resources and training for the success of project-based learning, and a study (al-Jali, 2024) concluded that E-project-based learning in geography contributed to improving and increasing self-orientation, self-motivation and self-esteem; this is because students innovate and solve In a study (Supriyanto, 2025) that dealt with Project-Based Learning using of Google Maps, where it was found that the group studied in this way had better results, and also recommended the adoption of project-based learning in geography teaching showed a clear improvement in spatial thinking, and students' involvement in the method of web-based learning by

geographic information systems, than in the traditional way .

The current study will answer the following questions:

- *Are there any significant differences at the level of significance (α=0.05) between the average scores of the experimental group and the average scores of the control group in the Spatial Perception Test attributable to the teaching method (project-based learning, the usual method).*
- *Are there any significant differences at the level of significance (α=0.05) between the average scores of the experimental group and the average scores of the control group in the measure of self-learning skills attributable to the teaching method (project-based learning, the usual method).*

Objectives of the study

- Detection of statistically significant differences at the level of significance (α = 0.05) between the average scores of students of the experimental group and the control group in the Spatial Perception Test attributed to the teaching method (project-based learning versus the usual method).
- Detection of statistically significant differences at the level of significance (α = 0.05) between the average scores of students of the experimental group and the control group in the measure of self-learning skills attributed to the teaching method (project-based learning versus the usual method).

Importance of the study:

The theoretical importance of the study is manifested in its reliance on the use of project-based learning in an integrative format that combines traditional paper projects such as the preparation of thematic maps, reports and leaflets, and digital projects such as virtual tours and presentations, improving understanding of the nature of this educational portal. The study also provides a teacher's guide entitled" Project-based learning while teaching geography to basic tenth grade students", which can be used to develop students ' spatial perception and self-learning skills. As for the applied importance, the study's contribution is to guide those responsible for developing geography curricula in Jordan to the need to include project-based learning activities mainly within textbooks.

Boundaries and limitations of the study

1. Objective determinants: the objective determinants were limited to a unit of the geography textbook for the tenth grade, so that it will examine the effectiveness of project-based learning in the geographical techniques unit on spatial perception and self-learning skills.
2. Time limits: this study was conducted in the academic year 2025/2026 first semester.
3. Spatial boundaries: Al-Mazar comprehensive mixed secondary school affiliated to the Directorate of education of the northern Mazar brigade.
4. Human boundaries: this study was conducted on a sample of tenth grade female students at Al Mazar comprehensive Mixed Secondary School .
5. Study determinants: the results of the study are determined by the conditions provided in the selection of the study sample, its size and tools, and the results of this study are determined by the method adopted in the application of study tools, the extent of cooperation of the teacher and the school administration with the researcher, as well as the nature of the statistical analysis used in analyzing the results of the study.

Method and procedure

To achieve the objectives of the study, which is to reveal the impact of using project-based learning in the development of spatial perception and self-learning skills in the subject of geography among the students of the tenth grade, the researcher used the experimental curriculum with a semi-experimental design; due to its relevance to the nature of the study. Accordingly, the study subjects were randomly divided into two groups (experimental and control), and the effectiveness of the independent variable represented by the use of Project-Based Learning was investigated in the two dependent variables (spatial perception and self-learning skills).

Study personnel:

The members of the study are female students of the tenth basic grade in all its branches for the academic year 2025/2026 at Al-Mazar comprehensive Mixed Secondary School, numbering (105). the reason for choosing the school by intentional appointment is due to the cooperation of the subject teacher with the researcher, and her readiness to cooperate fully when applying the study procedures. the study sample was selected in a simple random way, with two divisions, one of which is experimental and has a number of (30) female students, the other is a female officer and has a number of (30) female students from the same school, the experimental group studied the unit the third of the geography textbook for the basic tenth grade (geographical techniques) using a project-based learning strategy، The control group studied the third module of the geography textbook for the basic tenth grade (geographical techniques) in the usual way without processing as shown in Table 1

Table 1. Distribution of basic tenth grade students on the study sample

SCHOOL	DIVISIONS	GRADE	GROUP	NO. OF STUDENTS
Almazar Secondary School	2	10th grade	The experimental group	30
			The control group	30

Study tools

To achieve the study objectives of revealing the impact of using project-based learning in the development of spatial perception and enhancing self-learning skills in the subject of geography among the basic tenth grade students, the following tools were used:

First: Spatial Perception Test

1. Determining the goal of the test: the test aims to measure the extent to which tenth-grade students possess spatial perception skills, contained in the unit (geographical techniques) in the geography textbook for the tenth grade for the first semester of the academic year 2025/2026.
2. Formulation of Objective Multiple-Choice questions that measure spatial perception skills, after analyzing the content of the topics contained in the module (geographical techniques) of the geography textbook for the tenth grade, and after referring to the educational literature and previous studies that dealt with spatial perception as my study (Lee & Bednarz, 2012) (Ibrahim, 2014), the test may be in its initial form of (30) paragraphs per paragraph, of which four alternatives, one of these alternatives represents the correct answer, so that the student gets a mark for each one for each

correct answer and zero for each wrong answer, the questions were divided into four areas:

- Observation: it measures the learner's ability to acquire and understand geographical information by directing his attention to maps, photos and drawings.
- Comparison: it measures the learner's ability to identify similarities and differences between two phenomena, representations, two forms or two maps, and other information that can be compared in geography.
- Perception of relationships: it measures the learner's ability to distinguish links between geographical phenomena, describe relationships between geographical information, and determine the type of relationship.
- Explanation: it measures the learner's ability to understand geographical phenomena by identifying the causes and factors behind them.

Honesty of the content to test spatial perception:

To verify the truthfulness of the content of the spatial perception test, the test in its initial form consisting of (30) questions was presented to a group of arbitrators with experience and competence in social studies curricula and teaching methods from faculty members at Jordanian universities, and supervisors of the geography research (appendix), in order to express their opinions about the clarity of the questions, their belonging to the skill you are measuring, their linguistic integrity, the nature of maps and attached images, the suitability of the content for the tenth grade, and any other observations they deem appropriate. The judges made a set of pedagogical and linguistic observations on the test in its initial form, which consisted in reformulating some of the questions to become clearer and more accurate in measuring the target skill, such as simplifying the formulation of observation questions, improving the formulation of comparison questions and perception of relationships and interpretation, and suggesting adjustments to maps and accompanying images to be more clear and appropriate to the age level of students. Redundant Phrases were also deleted, some questions similar in content were combined, and the questions were rearranged in terms of difficulty and gradation. After taking the observations, the test took its final form consisting of (30) questions, distributed among four main skills as shown in Table 2.

Table 2. The number of paragraphs for each area of the Spatial Perception Test

SKILL	PARAGRAPHS IN THE TEST	PARAGRAPHS	RELATIVE WEIGHT
Observation	1-9	9	30%
Comparison	10-18	9	30%
Perception of relationships	19-24	6	20%
Explanation	25-30	6	20%

Test correction method

- If the answer is correct, the student gets one mark, but if the answer is wrong, he gets (zero).
- The key to correcting the test and evaluating students ' grades has been set
- The maximum mark for the test (30).

Second: self-learning skills scale

The scale of self-learning skills was built through a review of educational literature,

measurement tools and previous studies that dealt with self-learning skills in school laboratories, most notably the study (Liu & Laxman, 2009) and the Obeikan study (2022), in order to determine the main skills that should be measured among students of the tenth grade basic. In light of this, five areas of the scale were identified, namely: planning, time management, the use of technology and learning resources, taking responsibility for learning, and self-evaluation, then indicators and paragraphs representing these areas were formulated, where the initial picture of the scale consisted of (36) paragraphs according to the triple Likert scale (large, medium, weak). To verify the apparent truthfulness, the scale was presented to a group of arbitrators specializing in social studies curricula and teaching methods, geography, educational psychology, along with a number of educational supervisors with doctoral and master's degrees, as well as to a specialist in the Arabic language to ensure the correctness of the linguistic and grammatical wording. In light of the arbitrators ' remarks, the necessary amendments were made, which included rewriting some paragraphs and correcting them linguistically, so that the scale came out in its final form consisting of (36) paragraphs distributed over its five areas, and gradually the same three (high, medium, weak).

Correction of the scale of self-learning skills

The researcher adopted the Likert triple ladder to correct the study tool, giving each of his paragraphs one of his three grades (large, medium, weak), and the paragraphs were given correction as follows: High (3), Medium (2), weak(1).

Results

First: the results related to the first question: which stated: "are there any statistically significant differences at the level of significance (α=0.05) between the averages of the experimental group's scores and the averages of the control group's scores in the Spatial Perception Test attributable to the teaching method (project-based learning, the usual method)?"

To answer the first study question, the first null hypothesis emanating from it was examined, which states that:

There are no significant differences at the level of significance (α=0.05) between the average scores of the experimental group and the average scores of the control group in the Spatial Perception Test attributable to the teaching method (project-based learning, habitual method).

This question was answered and the hypothesis related to it was tested by extracting the arithmetic averages and standard deviations of the members of the experimental and control groups on the Spatial Perception Test and table (3) shows this.

Table 3. Arithmetic circles and standard deviations of the performance of study personnel in testing spatial perception skills combined according to the teaching strategy

Group	PRE-TEST		POST-TEST	
	Arithmetic mean*	Standard deviation	Arithmetic mean*	Standard deviation
Control	7.77	2.56	18.80	2.86
Experimental	7.30	3.95	25.93	2.48
Sum	7.53	3.31	22.37	4.47

* Maximum test score (30)

Table 3 shows that there is an apparent difference between the averages of the

dimensional performance of the experimental and control groups in the combined spatial perception skills test in favor of the experimental group; the arithmetic mean of the dimensional performance of the control group members was (18.80), while the arithmetic mean of the performance of the experimental group members was (25.93). To test the statistical significance of this apparent difference in dimensional performance in the combined spatial perception skills test, after adjusting the effect of tribal performance according to the teaching strategy, the accompanying unilateral variation analysis (an-Way ANCOVA) was performed, in order to reveal the effect of the project-based learning strategy compared to the usual method, and Table (4) shows this.

Table 4. Analysis of the accompanying unilateral variation (One - Way ANCOVA) to test the statistical significance of the apparent difference in the performance of the study's dimensional individuals in the test of combined spatial perception skills after adjusting the effect of tribal performance according to the teaching strategy.

SOURCE OF VARIABILITY	TOTAL SQUARES	DEGREES OF FREEDOM	AVERAGE SQUARES	F VALUE	STATISTICAL SIGNIFICANCE	ETA SQUARE (H^2)
Pre- performance	59.991	1	59.991	9.641	0.003	0.145
Teaching strategy	790.086	1	790.086	126.975	0.000	0.690
Error	354.675	57	6.222			
Sum	1177.933	59				

Table 4 shows that there is a statistically significant difference between the average performance of the experimental and control group in the combined spatial cognition skills test, in favor of the experimental group, and the value of the ETA square (0.690) indicates that the teaching strategy explains (69%) of the variation in performance in the combined spatial cognition skills. To compare the average performance of the experimental and control group in the combined spatial perception skills test, according to the adjusted arithmetic averages, the two standard deviations, and the two standard errors according to the teaching strategy before and after adjusting the tribal differences, and Table (5) shows this.

Table 5. The arithmetic mean, standard deviation and standard errors of the experimental and control group in the combined spatial perception skills test before and after adjusting for pre- and post-differences.

THE DEPENDENT VARIABLE	GROUP	BEFORE ADJUSTMENT		AFTER ADJUSTMENT	
		Arithmetic mean	Standard deviation	Arithmetic mean	Standard error
Combined spatial perception skills	Control	18.80	2.86	18.73	0.46
	Experimental	25.93	2.48	26.01	0.46

Table 5 shows that there is a difference between the performance of the experimental and control group in the combined spatial perception skills test, in favor of the experimental group. Thus, the strategy of the project-based learning strategy has a statistically significant effect on improving spatial perception skills in basic tenth grade students.

The arithmetic mean and standard deviations of the performance of the pre-and post-study subjects in the test of spatial perception skills were also calculated individually according to the teaching strategy (project-based learning strategy, normativity), and Table 6 shows this.

Table 6. Arithmetic circles and standard deviations of the tribal and dimensional performance of study personnel in testing spatial perception skills individually according to the teaching strategy

SKILL	GROUP	PRE-TEST		POST-TEST	
		Arithmetic mean	Standard deviation	Arithmetic mean	Standard deviation
Observation	Experimental	2.52	1.28	5.30	1.74
	Group	2.53	1.48	7.73	1.28
	Sum	2.53	1.37	6.52	1.95
Comparison	Experimental	2.63	0.81	6.00	1.70
	Group	2.17	1.39	8.17	1.21
	Sum	2.40	1.15	7.08	1.83
Perception of relationships	Experimental	1.27	0.94	4.00	1.11
	Group	1.17	1.05	5.20	0.66
	Sum	1.22	0.99	4.60	1.09
Explanation	Experimental	1.33	1.06	3.50	1.20
	Group	1.43	0.90	4.83	0.75
	Sum	1.38	0.98	4.17	1.20

Table 6 shows that there are apparent differences between the computational circles of the dimensional performance of the experimental and control groups in testing spatial perception skills (individually) according to the teaching strategy, in favor of the experimental group; the average performance of the experimental group members in the observation skill (7.73), in the comparison skill (8.17), in the perception of relationships skill (5.20), in the interpretation skill (4.83), while the average performance of the control group members in the observation skill (5.30), in the comparison skill (6.00), and in the skill of perception of relationships (4.00), and in the skill of interpretation (3.50).

Table 7. Multivariate univariate variance analysis (One - Way MANCOVA) to test the statistical significance of the differences in the performance of the study subjects in the dimensional spatial perception skills test (singly) after adjusting the effect of tribal performance

SOURCE OF VARIABILITY	THE VALUE OF HOTELLING TRACE AND ITS SIGNIFICANCE	SKILL	TOTAL SQUARES	AVERAGE SQUARES	F VALUE	STATISTICAL SIGNIFICANCE	ETA SQUARE (η^2)
Pre		Observation	4.778	4.778	2.737	0.104	0.048
		Comparison	15.719	15.719	11.606	0.001	0.177
		Perception of relationships	1.702	1.702	2.083	0.155	0.037
		Explanation	5.422	5.422	5.732	0.020	0.096

Teaching strategy	F=38.074	Observation	102.600	102.600	58.767	0.000	0.521
	Sig=0.000	Comparison	83.013	83.013	61.292	0.000	0.532
	η^2=0.749	Perception of relationships	22.414	22.414	27.431	0.000	0.337
		Explanation	21.816	21.816	23.066	0.000	0.299
Error		Observation	94.277	1.746			
		Comparison	73.137	1.354			
		Perception of relationships	44.123	0.817			
		Explanation	51.074	0.946			
Total adjusted		Observation	224.983				
		Comparison	196.583				
		Perception of relationships	70.400				
		Explanation	84.333				

Table 7 shows that there are statistically significant differences between the computational circles of the experimental and control group's performance in testing the four spatial perception skills (individually) in favor of the experimental group. The ETA (N2) square values of the teaching strategy indicate that the percentage of explanation for the difference in performance was 52.1% for the observation skill, 53.2% for the comparison skill, 33.7% for the perception of relationships skill, and 29.9% for the interpretation skill. Overall, the project-based learning strategy explains 74.9% of the variation in performance in the combined spatial perception skills. Therefore, the size of the impact of the teaching strategy on the development of spatial perception skills for all of them is high, and it is consistent with what was indicated in Al-Kilani and Al-sharifin (2016) that the size of the impact is considered high if it exceeds 16%. To compare the average performance of the experimental and control groups on each of the four spatial perception skills (individually), the adjusted arithmetic mean, standard deviations, and standard errors were calculated according to the teaching strategy before and after adjusting for tribal differences, and Table 8 shows this.

Table 8. Adjusted arithmetic mean, standard deviations and standard errors of the experimental and control group on the four spatial perception skills (individually) before and after adjusting for tribal differences

SPATIAL PERCEPTION SKILLS	GROUP	BEFORE ADJUSTMENT		AFTER ADJUSTMENT	
		Arithmetic mean	Standard deviation	Arithmetic mean	Standard error
Observation	Control	5.30	1.74	5.13	0.25
	Experimental	7.73	1.28	7.91	0.25
Comparison	Control	6.00	1.70	5.84	0.22
	Experimental	8.17	1.21	8.33	0.22
Perception of relationships	Control	4.00	1.11	3.95	0.17
	Experimental	5.20	0.66	5.25	0.17
Explanation	Control	3.50	1.20	3.53	0.18
	Experimental	4.83	0.75	4.81	0.18

Table 8 shows that there are differences between the performance of the experimental and control group on each spatial perception skill (individually) in favor of the experimental group. Thus, the strategy of the project-based learning strategy has a statistically significant effect on improving spatial perception skills in basic tenth grade students.

The researcher attributes this result to the fact that project-based learning provided an active learning environment that enhanced students ' awareness of spatial relationships through the implementation of projects based on cooperation, research, and analysis of geographical phenomena, which contributed to the development of observation and spatial reasoning and increased learning motivation. The use of geographical techniques, such as ArcGIS Earth, and satellite imagery, helped students to understand the locations, directions, and relationships between natural and human phenomena more accurately and realistically, and to link theoretical knowledge to the surrounding environment. In turn, traditional methods were limited to memorization and memorization, which limited the development of spatial perception skills. This result is consistent with the results of the studies of Supriyanto (2025), Gali (2024), sofiasa and Pierrakeas (2021), Rosyida et al. (2019), and Mabrouk (2017), which confirmed the effectiveness of project-based learning in the development of thinking, spatial perception and improvement of geographical skills.

Second: the results related to the second question: which stated: "Are there any statistically significant differences at the level of significance (α=0.05) between the averages of the experimental group's scores and the averages of the control group's scores in self-learning skills attributable to the teaching method (project-based learning, the usual method)?"

To answer the second study question, the second null hypothesis emanating from it was examined, which states that.

There are no significant differences at the level of significance (α=0.05) between the average scores of the experimental group and the average scores of the control group in self-learning skills attributable to the teaching method (project-based learning, habitual method).

This question was answered and the hypothesis related to it was tested by extracting the arithmetic averages and standard deviations of the members of the experimental and control groups on self-learning skills and Table 9 shows this.

Table 9. Arithmetic circles and standard deviations of the performance of study personnel in the scale of self-learning skills combined according to the teaching strategy

GROUP	PRE-TEST		POST-TEST	
	Arithmetic mean*	Standard deviation	Arithmetic mean*	Standard deviation
Control	1.21	0.11	1.84	0.14
Experimental	1.18	0.12	2.64	0.48
Sum	1.19	0.12	2.24	0.53

* Maximum mark of the scale (5)

Table 9 shows that there is an apparent difference between the averages of the dimensional performance of the experimental and control groups in the combined self-learning skills in favor of the experimental group; the arithmetic mean of the dimensional performance of the control group members was (1.84), while the arithmetic mean of the performance of the experimental group members was (2.64). To test the statistical significance of this apparent difference in dimensional performance in the combined spatial perception skills test, after adjusting the effect of tribal performance in accordance with the

teaching strategy, the accompanying unilateral variation analysis (One-Way ANCOVA) was performed, in order to reveal the effect of the project-based learning strategy compared to the usual method, and table (10) shows this.

Table 10. Analysis of the accompanying unilateral variation (an - Way ANCOVA) to test the statistical significance of the apparent difference in the performance of the study individuals after the combined self-learning skills scale after adjusting the effect of tribal performance according to the teaching strategy.

SOURCE OF VARIABILITY	TOTAL SQUARES	DEGREES OF FREEDOM	AVERAGE SQUARES	F VALUE	STATISTICAL SIGNIFICANCE	ETA SQUARE (η^2)
Pre-Performance	0.046	1	0.046	0.363	0.549	0.006
Teaching strategy	9.591	1	9.591	75.839	0.000	0.571
Error	7.209	57	0.126			
Adjusted sum	16.855	59				

Table 10 shows that there is a statistically significant difference between the average performance of the experimental and control group in combined self-learning skills in favor of the experimental group, and the value of the ETA square (N2 = 0.571) indicates that the teaching strategy explains 57.1% of the variation in performance in combined self-learning skills. To compare the average performance of the experimental and control group in combined self-learning skills, according to the two Adjusted arithmetic averages, the two standard deviations, and the two standard errors according to the teaching strategy after adjusting for tribal differences, Table 11 shows this.

Table 11. The arithmetic mean, standard deviation and standard errors of the experimental and control group in combined self-learning skills before and after adjusting for tribal differences

THE DEPENDENT VARIABLE	GROUP	BEFORE ADJUSTMENT		AFTER ADJUSTMENT	
		Arithmetic mean	Standard deviation	Arithmetic mean	Standard error
Combined self-learning skills	Control	1.83	0.13	1.83	0.07
	Experimental	2.64	0.48	2.65	0.07

Table 11 shows that there is a difference between the performance of the experimental and control group in the combined self-learning skills, in favor of the experimental group. Thus, the strategy of the project-based learning strategy has a statistically significant impact on improving the self-learning skills of basic tenth-grade students.

The arithmetic mean and standard deviations of the performance of the pre-and post-study personnel in self-learning skills were also calculated individually according to the teaching strategy (project-based learning strategy, normativity), and table (12) shows this.

Table 12. Arithmetic circles and standard deviations of the tribal and dimensional performance of study personnel in individual self-learning skills according to the teaching strategy

SKILL	GROUP	PRE-TEST		POST-TEST	
		Arithmetic mean	Standard deviation	Arithmetic mean	Standard deviation
Planning	Control	1.27	0.19	1.87	0.16
	Experimental	1.29	0.19	2.54	0.52
	Sum	1.28	0.19	2.20	0.51
Use of technology and learning resources	Control	1.20	0.10	1.81	0.15
	Experimental	1.15	0.15	2.61	0.44
	Sum	1.18	0.13	2.21	0.52
Time management and learning responsibility	Control	1.17	0.22	1.84	0.19
	Experimental	1.14	0.17	2.71	0.59
	Sum	1.15	0.20	2.28	0.61
Self-evaluation	Control	1.22	0.21	1.87	0.23
	Experimental	1.15	0.20	2.70	0.66
	Sum	1.19	0.21	2.29	0.65

Table 12 shows that there are apparent differences between the computational circles of the dimensional performance of the experimental and control groups in the skills of self-learning (individually) according to the teaching strategy, in favor of the experimental group; the average performance of the experimental group members in the skill of planning (2.54), compared to (1.87) among the control group members, and their average performance in the skill of using technology and learning resources (2.61) versus (1.81) 2.71) versus (1.84) in the control group, and their average performance in the self-assessment skill was (2.70) versus (1.87) in the control group.

To test the statistical significance of these apparent differences in the dimensional performance of study subjects in self-learning skills (individually) in accordance with the teaching strategy, and after adjusting the effect of tribal performance, a multivariate concomitant unilateral variation analysis was performed (One-Way MANCOVA), the results of which are shown in Table (13).

Table 13. Multivariate univariate variance analysis (One - Way MANCOVA) to test the statistical significance of the differences in the performance of the study subjects after self-learning skills (singly) after adjusting the effect of tribal performance

VARIABLE SOURCE	THE VALUE OF HOTELLING TRACE AND ITS SIGNIFICANCE	SKILL	TOTAL SQUARES	AVERAGE SQUARES	F VALUE	STATISTICAL SIGNIFICANCE	ETA SQUARE (η^2)
Pre-		Planning	0.224	0.224	1.527	0.222	0.027
		Use of technology and learning resources	0.153	0.153	1.847	0.180	0.033
		Time management and learning responsibility	0.199	0.199	1.103	0.298	0.020
		Self-evaluation	0.116	0.116	0.475	0.494	0.009

Teaching strategy	F=26.295 Sig=0.000 η^2=0.673	Planning	6.775	6.775	46.220	0.000	0.461
		Use of technology and learning resources	8.115	8.115	98.232	0.000	0.645
		Time management and learning responsibility	10.435	10.435	57.775	0.000	0.517
		Self-evaluation	9.928	9.928	40.487	0.000	0.428
Error		Planning	7.915	0.147			
		Use of technology and learning resources	4.461	0.083			
		Time management and learning responsibility	9.753	0.181			
		Self-evaluation	13.241	0.245			
Adjusted sum		Planning	15.400				
		Use of technology and learning resources	15.793				
		Time management and learning responsibility	22.307				
		Self-evaluation	24.634				

Table 13 shows that there are statistically significant differences between the computational circles of the experimental and control group performance in the four self-learning skills (individually) in favor of the experimental group. The values of the ETA (N2) Square for the teaching strategy indicate that the percentage of explanation for the discrepancy in performance was: planning (46.1%), the use of technology and learning resources (64.5%), time management and learning responsibility (51.7%), and self-evaluation (42.8%). Overall, the project-based learning strategy explains about 67.3% of the variation in performance in self-learning skills combined. Therefore, the size of the impact of the teaching strategy on the development of self-learning skills for all of them is considered high, and it is consistent with what Al-Kilani and Al-sharifeen (2016) indicated that the size of the impact is considered high if it exceeds 16%.. To compare the average performance of the experimental and control groups on each of the four self-learning skills (individually), the adjusted arithmetic mean, standard deviations, and standard errors were calculated according to the teaching strategy before and after adjusting for tribal differences, and table (14) shows this.

Table 14. Adjusted arithmetic mean, standard deviations and standard errors of the experimental and control group on the four self-learning skills (solo) before and after adjusting for tribal differences

SELF-LEARNING SKILLS	GROUP	BEFORE ADJUSTMENT		AFTER ADJUSTMENT	
		Arithmetic mean	Standard deviation	Arithmetic mean	Standard deviation
Planning	Control	1.87	0.16	1.86	0.07
	Experimental	2.54	0.52	2.55	0.07

Use of technology and learning resources	Control	1.81	0.15	1.83	0.05
	Experimental	2.61	0.44	2.59	0.05
Time management and learning responsibility	Control	1.84	0.19	1.85	0.08
	Experimental	2.71	0.59	2.71	0.08
Self-evaluation	Control	1.87	0.23	1.87	0.09
	Experimental	2.70	0.66	2.71	0.09

Table 14 shows that there are differences between the performance of the experimental and control group on each of the self-learning skills (individually) in favor of the experimental group. Therefore, the strategy of the project-based learning strategy has a statistically significant impact on improving the self-learning skills of basic tenth grade students.

The researcher attributes this result to the fact that project-based learning provided students with greater opportunities to plan, organize work, share roles, and take responsibility for learning, which contributed to the development of self-learning skills. The implementation of projects, such as the preparation of thematic maps, brochures, virtual trips, presentations, required research into various knowledge sources, paper and digital, and the use of geographical applications and techniques, which enhanced the skills of using technology, time management, self-evaluation, as well as raising motivation towards learning through the presentation and evaluation of products in an environment based on competition and cooperation. In contrast, the traditional method did not provide similar opportunities to practice these skills in practice. This finding is consistent with the results of the AL-Jali study (2024), the Al-Khayat and Al-Barbari study (2023), and the Zimmerman study (2010), which confirmed that project-based learning contributes to the development of self-learning, planning, time management, communication, and problem solving skills better than traditional teaching methods.

Results discussion

This result indicates that the project-based learning strategy has effectively contributed to the development of students ' spatial perception, as it provided an active learning environment that makes the student the focus of the educational process, and moves him from the role of the recipient to the role of researcher and explorer of knowledge. This is explained by the fact that project learning is based on addressing real-world problems, Research, investigation and interaction with the surrounding environment, which is consistent with the constructivist foundations that affirm that learning becomes more profound when the learner builds his own knowledge through direct experience. The implementation of geographical projects also provided students with opportunities for discussion, exchange of ideas, and analysis of spatial phenomena, which enhanced their ability to perceive and understand spatial relationships more accurately compared to the traditional method of indoctrination. This finding is consistent with what was pointed out by Ibrahim (2018), Abu sherikh (2008), al-Asadi and Al-Massoudi (2015), Obaid (2011), Meri and Al-Hilla (2015), Thomas (2000), and Krajcik and Shin (2014), who confirmed that project-based learning is one of the most capable learning strategies for developing deep thinking, building knowledge, linking concepts to reality, and providing students with higher mental skills.

This result can also be explained in light of the nature of the projects that relied on the use of geographical techniques, digital maps and satellite images, which provided realistic visual representations of spatial phenomena, and helped students to realize the locations,

directions, distances and relationships between natural and human phenomena. Interactive digital environments allow the learner to dynamically explore the place and make spatial and temporal comparisons, which contributes to building mental perceptions of the place more clearly than traditional maps. The use of applications such as Arc GIS Earth has enhanced the ability of students to analyze spatial data and link it to the surrounding geographical reality. This finding is consistent with the findings of Ibrahim (2014), Khamis (2015), Abdul Hakim (2016), Abdul Rahman (2020), fares (2020), bloom and Palmer-Moloney (2004), and Kerski (2008), who confirmed that the use of geospatial technologies and electronic maps directly contributes to the development of spatial cognition and thinking in learners.

The researchers also believe that the connection of projects with the local environment contributed to increasing the effectiveness of learning; students were asked to implement thematic maps, prepare reports, conduct virtual trips, and analyze geographical phenomena related to their reality, which made learning meaningful for them, and enhanced their ability to link theoretical knowledge with practical application. These activities also stimulated students to carefully observe, collect data, analyze, and interpret spatial relationships between different phenomena, all of which are cognitive processes that are closely related to the development of spatial perception. This result is in line with what was confirmed by Suleiman (2015), al-Omari (2004), Suleiman (2004), Saleh Idris (2011), the National Center for Curriculum Development (2024), the National Council for the Social Studies (2016), Solis (2017), which explained that geography education should be linked to realistic situations, and focus on the use of geographical knowledge in interpreting the surrounding environment, thus enhancing awareness and perception the students have space.

This result is also due to the fact that project-based learning provided a collaborative learning environment that allowed students to exchange experiences, discuss ideas, distribute roles, and take collective responsibility during the implementation of the project, which positively reflected on the processes of thinking, analysis, and spatial reasoning. Working in collaborative teams also strengthened students ' motivation towards achievement, encouraged them to constantly review their ideas and defend their geographical interpretations, which contributed to building a deeper understanding of spatial relationships. This finding is consistent with the findings of Al-Tarhouni (2023), Al-Jali (2024), Al-Khayat and Al-berberi (2023), Al-Humaidan (2017), and warisanty et al. (2020), bell (2010), and Larmer, Mergendoller, and Boss (2015), who confirmed that project-based learning raises the level of active participation, enhances collaboration skills, and leads to improved outcomes of geography learning and spatial thinking.

This result also reinforces the findings of many previous studies that have proven the effectiveness of project-based learning in the development of thinking and spatial perception skills in geography, as it is consistent with the study of Al-Jali (2024), Al-Tarhuni (2023), Khayat and Berber (2023), and Mabrouk (2017), as well as consistent with the results of foreign studies such as Putra et al. (2021), sofiasa and Pierrakeas (2021), Supriyanto (2025), Putri (2020), Hynek (2017), Hasmita (2024), Azizah et al. (2025), which showed that integrating project-based learning with geographical techniques contributes to the development of spatial thinking, improving performance in geography, and increasing students ' ability to interpret spatial phenomena and link them to reality. This consensus confirms that project-based learning represents an effective educational input for the development of geography learning, and the development of spatial perception as one of the most important outputs of its learning.

Recommendations

- Directing geography teachers to employ project-based learning, because of its effectiveness in developing students ' spatial perception and self-learning skills.

- Directing the supervision and training department at the Ministry of education to hold training courses for geography teachers to employ project-based learning, and to take advantage of the teacher's guide in training geography teachers on the mechanisms of using project-based learning while teaching geography.
- Directing universities and teacher training centers to the need to provide a curriculum and a scheduled training material for geography teachers entitled" Project-Based Learning, and the mechanisms of its application in teaching geography, "whether before service, or during service.
- Directing the authors of geography books to the need to further include and diversify learning projects.

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