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THE EFFECTIVENESS OF A TEACHING STRATEGY BASED ON THE PERKINS AND BLYTHE MODEL IN ACQUIRING BIOLOGICAL CONCEPTS AND SCIENTIFIC VALUES AMONG ELEVENTH GRADE SCIENTIFIC STUDENTS

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ABSTRACT. This study aimed to investigate the effectiveness of a teaching strategy based on the Perkins and Blythe model in acquiring biological concepts and developing scientific values among eleventh-grade scientific students. The researcher employed a quasi-experimental methodology with partial control design on a sample of 69 students deliberately selected from eleventh-grade students at Zakho Preparatory School for Boys for the academic year 2024-2025. The sample was randomly distributed into two groups: an experimental group consisting of 33 students who studied using the Perkins and Blythe model-based teaching strategy, and a control group consisting of 36 students who studied according to the traditional method. After ensuring equivalence across several variables, the researcher determined the scientific material for the first unit, which represents the first three chapters of the eleventh-grade biology textbook (Internal Balance and Transport, Photosynthesis, Cellular Respiration). To verify the research objectives, the researcher prepared 24 actual lesson plans for each group, and developed a biological concepts acquisition test consisting of 30 questions in its final form, and adopted the scientific values scale prepared by Al-Mohtaseb (2018) consisting of 45 items distributed across 8 domains with both positive and negative items. After verifying validity and reliability indicators for the test items and scientific values scale, data were analyzed using the t-test for two independent samples. Results showed a statistically significant difference between the mean scores of students in the experimental and control groups on both the biological concepts acquisition test and the scientific values scale in favor of the experimental group. Based on the findings, the researcher made several recommendations and suggestions for future research studies.

Keywords: Perkins and Blythe Model, Biological Concepts Acquisition, Scientific Values

INTRODUCTION

Educational systems across the globe are witnessing transformative changes as traditional teaching methods give way to innovative pedagogical approaches that prioritize deep understanding over superficial learning. The movement toward learner-centered education has gained significant momentum in recent years, challenging educators to move beyond conventional knowledge transmission models toward frameworks that actively engage students in constructing their own understanding. This shift represents more than just a methodological change; it reflects a fundamental reconceptualization of what it means to learn and understand in the 21st century (Zhao et al., 2020).

Modern educational research emphasizes the critical importance of helping students develop genuine understanding rather than merely accumulating factual information. Deep learning requires students to actively construct knowledge through meaningful engagement with content, concepts, and real-world applications. This constructivist approach to education recognizes that learners are not passive recipients of information but active participants who bring their prior experiences, cultural backgrounds, and individual perspectives to the learning process (Cooperstein & Kocevar-Weidinger, 2004).

The Teaching for Understanding framework, developed through extensive research at Harvard University's Project Zero, represents one of the most significant contributions to this educational paradigm shift. David Perkins, Tina Blythe, and their research team created a comprehensive framework that fundamentally reimagines how teachers can design and implement instruction that promotes genuine understanding among students. This framework moves beyond traditional approaches by establishing clear pathways for students to develop transferable knowledge and skills that can be applied flexibly across diverse contexts and situations (Allen & Tanner, 2005).

Contemporary biology education faces unique challenges as the field continues to expand rapidly with new discoveries and technological advances. Students must not only master fundamental biological concepts but also develop the scientific thinking skills necessary to navigate an increasingly complex world of biological knowledge. Recent research indicates that traditional lecture-based approaches often fail to help students develop the deep conceptual understanding necessary for success in advanced biology courses and careers. Instead, students need learning experiences that actively engage them in scientific reasoning, hypothesis formation, and evidence-based thinking (Freeman et al., 2014).

The acquisition of biological concepts requires sophisticated cognitive processes that go far beyond simple memorization of facts and terminology. Modern research in biology education emphasizes that conceptual understanding develops through iterative cycles of exploration, reflection, and application. Students must construct coherent mental models that connect molecular, cellular, organismal, and ecological levels of biological organization. This process requires instructional approaches that provide multiple opportunities for students to examine biological phenomena from different perspectives while making explicit connections between related concepts (Theobald et al., 2020).

Scientific values and attitudes play an equally important role in quality biology education. These values encompass the intellectual virtues and ethical commitments that characterize scientific inquiry, including curiosity, intellectual honesty, respect for evidence, and appreciation for the collaborative nature of scientific knowledge construction. Research demonstrates that students who develop strong scientific values are more likely to engage meaningfully with scientific content and pursue further study in scientific fields. Moreover, these values prepare students to function as informed citizens capable of making evidence-based decisions about scientific and technological issues that affect their lives and communities (Wright & Boggs, 2002).

The constructivist learning theory that underlies the Perkins and Blythe model emphasizes several key principles that align with contemporary understanding of how students learn science most effectively. Learning is viewed as an active process in which students must engage intellectually with content to develop genuine understanding. Prior knowledge and experience significantly influence how students interpret and integrate new information, suggesting that effective instruction must acknowledge and build upon students' existing cognitive frameworks. Social interaction and collaborative learning environments provide crucial opportunities for students to articulate their thinking, consider alternative perspectives, and refine their understanding through dialogue and negotiation (Bada, 2015).

Recent developments in educational technology have created new possibilities for implementing constructivist pedagogical approaches in secondary education. Digital tools and platforms can provide powerful support for collaborative learning, authentic assessment, and personalized instruction that aligns with the principles underlying the Perkins and Blythe framework. However, successful integration of technology requires careful attention to pedagogical principles rather than simply adopting new tools without considering their educational purposes and effects (Kumar & Owston, 2016).

Secondary education represents a critical period for developing students' conceptual understanding and scientific thinking skills. Adolescent learners are developing increasingly sophisticated cognitive capabilities while simultaneously navigating complex social and emotional developmental processes. Research indicates that secondary students benefit from learning environments that engage them as active participants in their own learning while providing appropriate scaffolding and support. The Perkins and Blythe framework offers particular promise in this context by emphasizing student agency, collaborative inquiry, and authentic assessment practices that align with adolescent developmental needs (Weimer, 2002).

Contemporary assessment practices in biology education have evolved significantly from traditional approaches that emphasized memorization and recall toward more authentic forms of evaluation that measure students' ability to apply knowledge in novel contexts. The ongoing assessment component of the Perkins and Blythe framework reflects this shift by emphasizing formative assessment practices that provide timely feedback to both students and teachers about learning progress. This approach to assessment not only measures student achievement but also serves as a powerful tool for enhancing learning by helping students monitor their own understanding and adjust their learning strategies accordingly (Angelo & Cross, 1993).

The global emphasis on scientific literacy and STEM education has heightened attention to the quality of science instruction at all educational levels. International assessments and research studies consistently demonstrate significant variation in student achievement across different educational systems and instructional approaches. Countries and educational systems that emphasize deep conceptual understanding and scientific reasoning tend to produce students who perform better on measures of scientific literacy and are more likely to pursue advanced study in scientific fields. These findings underscore the importance of implementing pedagogical approaches that promote genuine understanding rather than superficial learning (National Research Council, 2007).

The current research aims to investigate the effectiveness of a teaching strategy based on the Perkins and Blythe model in acquiring biological concepts and developing scientific values among eleventh-grade scientific students.

To achieve the research objective, two null hypotheses were formulated. The first hypothesis states that there is no statistically significant difference at the 0.05 level between the mean scores of students in the experimental group who studied according to the Perkins and Blythe model and the mean scores of the control group who studied according to the traditional method in the post-application of the biological concepts test. The second hypothesis states that there is no statistically significant difference at the 0.05 level between the mean scores of students in the experimental group who studied according to the Perkins and Blythe model and the mean scores of the control group who studied according to the traditional method in the post-application of the scientific values scale.

This research is bounded by several specific parameters that define its scope and applicability. The human boundaries encompass eleventh-grade students enrolled in morning preparatory schools for boys within the specified geographical region. The spatial boundaries are limited to Zakho Preparatory School for Boys, which operates under the administrative jurisdiction of the secondary education system in the independent Zakho administration center. The temporal boundaries cover the first semester of the academic year 2024-2025, providing a focused timeframe for data collection and analysis. The cognitive boundaries are restricted to the first unit of the biology curriculum, which encompasses the first three chapters covering Internal Balance and Transport, Photosynthesis, and Cellular Respiration.

Theoretical Framework

Contemporary educational research has established constructivist learning theory as a foundational framework for understanding how students develop deep conceptual understanding in science education. This theoretical perspective fundamentally reconceptualizes learning as an active process of knowledge construction rather than passive information absorption. Students are viewed as active participants who bring their prior experiences, cultural backgrounds, and individual perspectives to the learning process, requiring instructional approaches that acknowledge and build upon these existing foundations (Oliver, 2024).

The constructivist approach to learning emphasizes that knowledge is not simply transmitted from teacher to student but is actively constructed through meaningful interactions with content, peers, and instructional materials. This perspective has profound implications for biology education, where students must develop sophisticated understanding of complex biological systems and processes. Constructivist learning environments provide multiple opportunities for students to examine biological phenomena from different perspectives while making explicit connections between related concepts and real-world applications (Baviskar et al., 2023).

Social constructivist theory extends these principles by emphasizing the crucial role of social interaction and collaborative learning in knowledge construction. Students develop understanding not only through individual cognitive processes but also through dialogue, negotiation, and shared inquiry with peers and teachers. This perspective suggests that effective biology instruction should provide rich opportunities for collaborative investigation, peer discussion, and group problem-solving activities that engage students in authentic scientific practices (Nyamekye et al., 2023).

The Perkins and Blythe Teaching for Understanding framework represents a sophisticated synthesis of constructivist learning principles with practical pedagogical strategies designed to promote deep conceptual understanding. This framework was developed through extensive research involving over 60 teachers and 30 university-based researchers across diverse educational contexts. The framework consists of four interconnected elements that work together to create learning environments focused on understanding rather than mere information acquisition (Project Zero, 2024).

Generative topics serve as the foundation of the Teaching for Understanding framework by providing rich, engaging content that connects to students' interests and experiences while offering multiple pathways for exploration and investigation. These topics are carefully selected to be central to the discipline, accessible to students, and rich enough to support sustained inquiry. In biology education, generative topics might include complex biological systems or processes that can be examined from multiple perspectives and scales of organization (Central Coast Grammar School, 2023).

Understanding goals provide clear targets for student learning by identifying the specific aspects of generative topics that students should understand deeply. These goals go beyond factual knowledge to emphasize the big ideas, concepts, and principles that students should be able to apply flexibly in new situations. Effective understanding goals in biology focus on fundamental concepts that transcend specific content areas and can be applied across diverse biological contexts (Annenberg Learner, 2024).

Understanding performances represent the heart of the Teaching for Understanding framework by providing authentic opportunities for students to demonstrate and develop their understanding through meaningful activities and assessments. These performances are carefully designed to require students to use knowledge and skills in novel ways while receiving ongoing feedback and support. In biology education, understanding performances might include designing experiments, analyzing data, constructing explanations, or developing models that demonstrate conceptual understanding (Simply Psychology, 2025).

Ongoing assessment serves as the mechanism for monitoring and supporting student learning throughout the instructional process rather than simply evaluating achievement at the end of a unit or course. This approach to assessment emphasizes formative feedback that helps students understand their current level of performance and identify specific areas for improvement. Ongoing assessment in biology education includes both formal and informal strategies for gathering evidence of student understanding and providing timely, specific feedback (Buffalo University, 2024).

Contemporary research on conceptual change in science education has identified several key factors that influence how students develop scientific understanding. Students often enter biology classrooms with alternative conceptions or misconceptions that can interfere with their ability to construct scientifically accurate understanding. Effective instruction must acknowledge these pre-existing ideas and provide learning experiences that help students recognize inconsistencies between their initial conceptions and scientific explanations while supporting the construction of more accurate understanding (Sana et al., 2024).

The development of scientific thinking skills represents another crucial dimension of quality biology education that is addressed through constructivist pedagogical approaches. Scientific thinking involves the ability to formulate hypotheses, design investigations, analyze data, draw evidence-based conclusions, and communicate findings effectively. These skills develop through authentic engagement with scientific practices rather than through abstract instruction about scientific methods (Barnard et al., 2021).

Motivation and engagement play critical roles in determining the effectiveness of any instructional approach. Research consistently demonstrates that students are more likely to develop deep understanding when they are actively engaged in learning activities that they find meaningful and relevant. The Perkins and Blythe framework addresses motivational factors by emphasizing student choice and agency, connecting learning to real-world applications, and providing opportunities for collaborative inquiry and peer interaction (Orr et al., 2022).

Assessment practices in constructivist learning environments differ significantly from traditional approaches that emphasize recall and recognition of factual information. Authentic assessment focuses on measuring students' ability to apply knowledge and skills in meaningful contexts rather than simply demonstrating memorization of isolated facts. This approach requires multiple forms of evidence gathered over time through diverse assessment strategies that capture the complexity and depth of student understanding (Fata-Hartley, 2023).

The role of technology in supporting constructivist learning environments has become increasingly important as digital tools and platforms offer new possibilities for collaborative learning, authentic assessment, and personalized instruction. However, successful integration of technology requires careful attention to pedagogical principles and learning objectives rather than simply adopting new tools for their own sake. Technology should enhance rather than replace the fundamental human interactions that characterize effective constructivist learning environments (Richter et al., 2024).

Professional development and teacher preparation represent crucial factors in the successful implementation of constructivist pedagogical approaches. Teachers need both theoretical understanding of constructivist learning principles and practical knowledge of how to design and facilitate learning experiences that embody these principles. This requires ongoing support and collaboration among educators as they develop expertise in implementing innovative instructional approaches (Mbise & Lekule, 2023).

The multicultural and multilingual contexts that characterize many contemporary educational settings present both challenges and opportunities for implementing constructivist pedagogical approaches. Effective instruction must acknowledge and build upon students' diverse cultural backgrounds, linguistic resources, and ways of knowing while helping all students access rigorous academic content. The Perkins and Blythe framework's emphasis on connecting learning to students' experiences and interests makes it particularly well-suited for implementation in diverse educational contexts (Telore & Damtew, 2023).

Educational equity and social justice considerations have become increasingly important in discussions of pedagogical innovation and reform. All students deserve access to high-quality educational experiences that support their academic, social, and personal development regardless of their background or circumstances. Constructivist pedagogical approaches can contribute to educational equity by providing multiple pathways for student success and recognizing diverse forms of knowledge and expertise (Makoa & Segalo, 2021).

The assessment and evaluation of instructional innovations requires sophisticated research designs and methodologies that can capture the complexity and multidimensional nature of educational outcomes. Quasi-experimental designs, such as the one employed in this study, provide valuable evidence about the effectiveness of pedagogical interventions while acknowledging the practical constraints of educational research. Mixed-methods approaches that combine quantitative and qualitative data collection strategies offer particularly rich insights into how and why different instructional approaches affect student learning (Semerci & Batdi, 2022).

Contemporary discussions about the future of education emphasize the need for pedagogical approaches that prepare students for an uncertain and rapidly changing world. Students need not only subject-matter knowledge but also the skills, dispositions, and ways of thinking that will enable them to continue learning throughout their lives. The Perkins and Blythe framework addresses these concerns by emphasizing transferable understanding and the development of intellectual habits that support lifelong learning (Kim, 2023).

Quality science education must address both cognitive and affective dimensions of learning by helping students develop not only conceptual understanding but also positive attitudes, values, and dispositions toward science. Students who develop appreciation for the beauty and elegance of scientific knowledge while understanding its limitations and provisional nature are more likely to remain engaged with science throughout their lives. The Teaching for Understanding framework supports both cognitive and affective learning goals through its emphasis on meaningful engagement and authentic assessment (Cetin-Dindar, 2024).

The global nature of contemporary scientific challenges requires educational approaches that help students understand the interconnectedness of scientific, social, and environmental issues. Climate change, biodiversity loss, public health challenges, and other complex problems require citizens who can think scientifically about multifaceted issues while considering ethical, social, and political dimensions. Biology education that emphasizes deep understanding and scientific thinking skills can contribute to preparing students for engaged citizenship in a complex world (Ayaz & Sekerci, 2021).

Recent research on learning and instruction has highlighted the importance of metacognitive skills in supporting student success across diverse academic contexts. Students who develop awareness of their own learning processes and strategies are better able to monitor their understanding, identify areas needing additional attention, and adjust their approaches as needed. The ongoing assessment component of the Perkins and Blythe framework specifically supports metacognitive development by providing regular opportunities for reflection and self-evaluation (Abbott & Fouts, 2020).

METHOD

This study employed a quasi-experimental research design to investigate the effectiveness of the independent variable, which is the teaching strategy based on the Perkins and Blythe model, on the dependent variables of biological concepts acquisition and scientific values development among eleventh-grade scientific students. The quasi-experimental approach was selected as the most appropriate methodology for addressing the research questions while accommodating the practical constraints of conducting educational research in authentic classroom settings.

Experimental Design

The research utilized a quasi-experimental design with partial control, featuring two equivalent groups designated as experimental and control conditions. This design was chosen for its suitability in achieving the research objectives while maintaining scientific rigor within the constraints of the educational environment. The experimental group received instruction based on the Perkins and Blythe model, while the control group received traditional instruction methods.

Figure (1) illustrates the experimental design of the research

Group	Group Equivalence	Independent Variable	Dependent Variable (Post-test)
Experimental	Established through statistical analysis	Teaching strategy based on Perkins and Blythe model	Biological concepts acquisition test; Scientific values scale
Control		Traditional teaching method	

Population and Sample Determination

The research population consisted of all eleventh-grade scientific students enrolled in preparatory schools within the Zakho Education Directorate system. This population totaled 2,544 students distributed across 21 preparatory schools for boys, all of whom were continuing their studies in morning preparatory programs during the 2024-2025 academic year. Through purposive sampling methodology, Zakho Preparatory School for Boys was selected as the research site due to its representative characteristics and administrative accessibility for conducting the experimental intervention.

The sample selection process involved random assignment of two eleventh-grade scientific sections, with section B designated as the experimental group and section D serving as the control group. Following the exclusion of students who had failed previous courses or demonstrated frequent absence patterns, the final sample composition was determined as shown in the following distribution table.

Table (1) Distribution of Research Sample Groups

Group	Teaching Method	Section	Number of Students		
			Before Exclusion	Excluded	After Exclusion
Experimental	Teaching strategy according to Perkins and Blythe model	B	36	3	33
Control	Traditional method	D	38	2	36
	Total		**74**	**5**	**69**

Group Equivalence Verification

Prior to implementing the experimental intervention, comprehensive equivalence testing was conducted across multiple variables known to influence educational outcomes and experimental validity. Data for these variables were systematically collected from official student academic records and through standardized assessment instruments administered specifically for this research.

Intelligence assessment was conducted using Raven's Progressive Matrices test, which had been previously standardized for the Iraqi educational context. This assessment was administered on September 24, 2024, to all participants in both experimental and control groups. General academic achievement was measured using students' overall grade point averages from their tenth-grade scientific track completion during the 2023-2024 academic year. Subject-specific prior achievement was assessed through students' biology course grades from their tenth-grade scientific studies.

Chronological age was calculated in months for all participants as of September 1, 2024, to ensure age-related developmental factors were equivalent across groups. Prior knowledge assessment was conducted through a researcher-developed instrument consisting of 15 items covering scientific topics relevant to the biology curriculum but not specifically included in the experimental content.

Statistical analysis of group equivalence was performed using independent samples t-tests for all measured variables. The results of this analysis are presented in the following comprehensive equivalence table.

Table (2) showing equivalence results for a number of variables for the two research groups

Equivalence Variables	Experimental Group N = (33)		Control Group N = (36)		Calculated (t) Value	Tabulated (t) Value	Significance Level
	Mean	Standard Deviation	Mean	Standard Deviation			
Intelligence Score	16.636	2.391	16.720	2.010	0.241	2.000 Significance level = (0.05), Degree of Freedom = (67)	Statistically Significant
General Average	68.53	9.821	67.53	7.078	0.460		Statistically Significant
Mathematics Grade	69.41	8.512	67.83	5.713	0.796		Statistically Significant
Chronological Age	195.17	6.218	196.46	8.257	1.259		Statistically Significant
Prior Knowledge	11.18	2.235	10.72	2.061	0.945		Statistically Significant

The statistical analysis revealed that all calculated t-values fell below the critical value of 2.000 at the 0.05 significance level with 67 degrees of freedom. These results confirm the absence of statistically significant differences between the experimental and control groups across all measured variables, thereby establishing the equivalence necessary for valid experimental comparison.

Research Materials and Instruments Development

The research required systematic development of multiple components including curricular materials, instructional plans, and assessment instruments. The scientific content was carefully selected to represent the first unit of the eleventh-grade biology curriculum, encompassing three distinct but interconnected chapters that provide comprehensive coverage of fundamental biological processes.

Chapter One Addresses Internal Balance and Transport, including detailed examination of passive transport mechanisms and active transport processes. Chapter Two Covers Photosynthesis, with specific focus on light-dependent reactions and the Calvin cycle. Chapter Three examines Cellular Respiration, incorporating glycolysis, fermentation pathways, and aerobic respiratory processes. This content selection provides substantial scope for implementing the Perkins and Blythe model while maintaining curricular alignment.

Educational content analysis was conducted systematically according to established taxonomic categories including concepts, symbols, characteristics, functions, classifications, and equations. This comprehensive analysis facilitated the development of specific behavioral objectives and detailed lesson plans that align with curricular standards while supporting the implementation of the experimental teaching strategy.

Behavioral objectives were formulated according to Bloom's revised taxonomy for the cognitive domain, encompassing remembering, understanding, applying, analyzing, evaluating, and creating levels. The validity of these objectives was established through expert review by a panel of experienced science education specialists. Based on their feedback and recommendations, comprehensive lesson plans were developed for both experimental and control group instruction.

Table (3) Distribution of Behavioral Objectives According to Bloom's Taxonomy across Four Chapters of the Study Material

Chapter	Remember	Understand	Apply	Analyze	Synthesize	Evaluate	Total
First	6	8	4	4	1	2	25
Second	9	11	4	5	3	3	35
Third	10	12	6	3	3	3	37
Total	**25**	**31**	**14**	**12**	**7**	**8**	**97**

Lesson plan development involved creating two distinct instructional models corresponding to the experimental and control conditions. The experimental group lesson plans incorporated the four key elements of the Perkins and Blythe framework: generative topics, understanding goals, understanding performances, and ongoing assessment. The control group lesson plans followed traditional instructional approaches consistent with standard educational practices in the research context.

Both sets of lesson plans were subjected to expert validation through review by experienced science education specialists who confirmed their appropriateness and comprehensiveness. Following this validation process, a total of 27 detailed lesson plans were prepared for each group, providing complete instructional guidance for the entire experimental period.

Assessment Instrument Development

Biological Concepts Acquisition Test

The development of a reliable and valid instrument for measuring biological concepts acquisition required systematic attention to test construction principles and psychometric properties. The test was designed specifically to assess student understanding of biological concepts covered in the experimental curriculum while maintaining alignment with established assessment standards.

The primary objective of this assessment instrument was to measure the depth and breadth of students' acquisition of biological concepts as operationally defined through the three levels of conceptual understanding: definition, discrimination, and application. This multi-level approach ensures comprehensive assessment of conceptual mastery rather than superficial recall of factual information.

Content determination was based on systematic analysis of the first three chapters of the eleventh-grade biology curriculum, yielding identification of 54 distinct biological concepts at various levels of specificity and complexity. From this comprehensive list, 10 fundamental concepts were selected for inclusion in the assessment instrument based on their centrality to biological understanding and their representativeness of the broader conceptual domain.

A detailed test specification table was constructed to ensure appropriate distribution of assessment items across content areas and cognitive levels. This table provides a systematic framework for item development while maintaining content validity and instructional alignment.

Table (4) Test Specification Chart for the Biological Concepts Test

Chapter	Total Concepts	Focus Percentage	Number of Concepts for Testing	Definition	Discrimination	Application	Total
First	17	30%	3	3	3	3	9
Second	22	41%	5	5	5	5	15
Third	16	29%	2	2	2	2	6
Total	**54**	**100%**	**10**	**10**	**10**	**10**	**30**

Test item development resulted in a 30-item instrument incorporating both multiple-choice and matching formats to assess different aspects of conceptual understanding. The assessment is organized into three distinct sections, each targeting a specific level of conceptual mastery. The first section consists of 10 matching items designed to assess concept definition capabilities. The second section includes 10 multiple-choice items focused on concept discrimination skills. The third section contains 10 multiple-choice items measuring concept application abilities.

Comprehensive test instructions were developed to provide clear guidance regarding assessment objectives, response procedures, and scoring criteria. A detailed answer key was prepared to ensure consistent and objective scoring procedures. The scoring system assigns one point for each correct response and zero points for incorrect or omitted responses, yielding total scores ranging from 0 to 30 points.

Test validity was established through multiple approaches including face validity and content validity verification. Face validity was confirmed through expert review by a panel of specialists in biology education and science pedagogy who evaluated item clarity, appropriateness, and alignment with stated objectives. Content validity was established through systematic evaluation of the test specification table and its correspondence with curricular content and learning objectives.

Statistical analysis of test items was conducted using data from a pilot administration involving 46 students from a comparable educational context. This analysis yielded psychometric information regarding item difficulty, discrimination, and alternative effectiveness. Item difficulty coefficients ranged from 0.38 to 0.71, indicating appropriate challenge levels. Discrimination coefficients ranged from 0.29 to 0.61, meeting established criteria for effective assessment items.

Test reliability was assessed using the Kuder-Richardson Formula 20 (KR-20), which is appropriate for assessments employing binary scoring procedures. The calculated reliability coefficient of 0.84 indicates strong internal consistency and supports the use of this instrument for research purposes.

Scientific Values Scale

Assessment of scientific values required adoption of a previously validated instrument that demonstrates appropriate psychometric properties for the target population. The scale developed by Al-Mohtaseb (2018) was selected based on its comprehensive coverage of scientific values domains and its established validity and reliability in similar educational contexts.

This instrument consists of 45 items distributed across eight distinct domains that encompass the breadth of scientific values relevant to biology education. These domains include respect for scientists and their contributions, appreciation of scientific knowledge, intellectual open-mindedness, scientific honesty, acceptance of criticism, scientific thinking patterns, intellectual curiosity, and deliberate judgment processes.

The scale employs a five-point Likert response format ranging from "strongly agree" to "strongly disagree," with a neutral "uncertain" option. The instrument includes both positively worded items (n=32) and negatively worded items (n=13) to control for response bias and ensure thoughtful consideration of each statement. Total scores can range from 45 to 225 points, providing substantial score variability for research analysis.

Scale validity was confirmed through expert review by specialists in science education who evaluated item clarity, domain coverage, and appropriateness for the target population. Minor revisions were made based on expert feedback to ensure optimal item functioning within the specific research context.

Statistical analysis of scale items was conducted using data from the same pilot sample employed for the biological concepts test. Item discrimination analysis was performed using independent samples t-tests comparing responses from upper and lower scoring groups. All items demonstrated significant discriminative power with t-values ranging from 2.120 to 6.698, indicating effective differentiation between high and low scorers on the overall scale.

Scale reliability was assessed through two complementary approaches. Test-retest reliability was established through administration to a subset of 28 participants with a two-week interval between assessments, yielding a correlation coefficient of 0.82. Internal consistency reliability was assessed using Cronbach's alpha, which yielded a coefficient of 0.79 for the overall scale and comparable values for individual domains.

Table (5) Scientific Values Scale Reliability by Domain

Domain	Respect for Scientists	Science Appreciation	Open-mindedness	Scientific Honesty	Accepting Criticism	Scientific Thinking	Curiosity	Deliberate Judgment	Total Scale
Cronbach's Alpha	0.80	0.76	0.77	0.82	0.81	0.79	0.78	0.81	0.79
Number of Items	6	6	5	6	7	5	6	4	45

Experimental Implementation

The experimental intervention was implemented during the first semester of the 2024-2025 academic year, extending from October 14, 2024, through December 19, 2024. This nine-week implementation period provided sufficient time for meaningful exposure to the experimental treatment while maintaining alignment with institutional academic calendars. The intervention schedule consisted of three lessons per week, accounting for official holidays, special events, and regularly scheduled examination periods.

Experimental group instruction was implemented according to the five-stage Perkins and Blythe model framework. The first stage involved establishing clear understanding goals that identify fundamental concepts and skills students should master through deep comprehension rather than superficial familiarity. The second stage focused on designing understanding-generating performances that challenge students to think critically and apply knowledge in innovative ways across diverse contexts and situations.

The third stage emphasized continuous guidance and feedback provision, with teachers offering ongoing assessment and support while encouraging student self-reflection and self-assessment. The fourth stage involved systematic revisiting and expansion of understanding through connecting previous learning with new concepts and real-world applications. The fifth stage culminated in comprehensive assessment of understanding through authentic performance tasks that demonstrate students' ability to apply knowledge effectively in meaningful contexts.

Control group instruction followed traditional pedagogical approaches consistent with standard educational practices in the research setting. These lessons were structured according to conventional presentation-implementation-evaluation sequences that emphasize teacher-directed information transmission and student reception of predetermined content.

Post-Intervention Assessment

Comprehensive post-intervention assessment was conducted through administration of both the biological concepts acquisition test and the scientific values scale. The biological concepts test was administered on December 22, 2024, followed by the scientific values scale on December 23, 2024. Both assessments were administered to all participants in both experimental and control groups under standardized conditions to ensure data quality and comparability.

During assessment administration, clear instructions were provided regarding response procedures and expectations. Students were explicitly directed to respond to all items without omitting any questions to ensure complete data collection. Assessment sessions were conducted in regular classroom environments to minimize anxiety and maintain ecological validity.

Statistical Analysis Procedures

Data analysis was conducted using the Statistical Package for Social Sciences (SPSS), which provides comprehensive statistical capabilities for educational research. This software platform was selected for its reliability, extensive functionality, and widespread acceptance in educational research contexts. Supplementary calculations were performed using Microsoft Excel to verify computational accuracy and provide additional analytical perspectives.

The primary statistical procedure employed was the independent samples t-test, which is appropriate for comparing mean scores between two independent groups on continuous dependent variables. This analytical approach directly addresses the research hypotheses by testing for statistically significant differences between experimental and control group performance on both assessment instruments.

Additional statistical procedures included Pearson product-moment correlations for examining relationships between variables, Cronbach's alpha for reliability assessment, and Kuder-Richardson Formula 20 for internal consistency evaluation of the biological concepts test. These supplementary analyses provide comprehensive psychometric information supporting the validity and reliability of research findings.

RESULT AND DISCUSSION

Research findings are presented in accordance with the stated research hypotheses, providing systematic evaluation of the experimental intervention's effectiveness on both dependent variables.

First Hypothesis Results

The first research hypothesis stated that there would be no statistically significant difference at the 0.05 level between mean scores of students in the experimental group who received instruction based on the Perkins and Blythe model and students in the control group who received traditional instruction on the biological concepts acquisition test.

Statistical analysis was conducted using independent samples t-test procedures after confirming appropriate assumptions. Descriptive statistics and inferential test results are presented in the following comprehensive table.

Table (6) t-value between Mean Scores of Biological Concepts Test for Research Groups

Variable	Group	N	Mean	Standard Deviation	Calculated t-value	Significance Level
Biological Concepts	Experimental	33	25.515	2.538	11.242	Significant favoring experimental
	Control	36	17.388	3.366		

The statistical analysis revealed a calculated t-value of 11.242, which substantially exceeds the critical value of 2.000 at the 0.05 significance level with 67 degrees of freedom. This result indicates a statistically significant difference between group means, with the experimental group demonstrating markedly superior performance on the biological concepts acquisition test. The effect size calculation indicates a large practical significance, suggesting that the observed differences have meaningful educational implications beyond statistical significance.

Second Hypothesis Results

The second research hypothesis proposed that there would be no statistically significant difference at the 0.05 level between mean scores of students in the experimental group who received Perkins and Blythe model-based instruction and students in the control group who received traditional instruction on the scientific values scale.

Comprehensive statistical analysis was performed using identical procedures to those employed for the first hypothesis. Results of this analysis are presented in the following detailed table.

Table (7) t-value between Mean Scores of Scientific Values Scale for Research Groups

Variable	Group	N	Mean	Standard Deviation	Calculated t-value	Significance Level
Scientific Values	Experimental	33	176.909	23.029	5.509	Significant favoring experimental
	Control	36	149.750	17.785		

The statistical analysis yielded a calculated t-value of 5.509, which clearly exceeds the critical value of 2.000 at the 0.05 significance level with 67 degrees of freedom. These results demonstrate a statistically significant difference between group means on the scientific values scale, with the experimental group showing substantially higher scores than the control group. The effect size indicates moderate to large practical significance, suggesting meaningful differences in scientific values development between the two instructional approaches.

Discussion of Findings

The significant findings observed in this research can be attributed to several key characteristics of the Perkins and Blythe model and its implementation within the biology education context. The framework's emphasis on deep understanding rather than superficial learning appears to have created optimal conditions for both conceptual acquisition and values development among participating students.

The innovative nature of the Perkins and Blythe model contributed substantially to enhancing students' cognitive frameworks and strengthening the knowledge foundations necessary for meaningful concept acquisition. Research in cognitive science consistently demonstrates that conceptual knowledge and the relationships between concepts serve as essential prerequisites for genuine understanding rather than mere memorization (Cary & Branchaw, 2022). The systematic progression through the model's stages, beginning with identification of understanding goals and advancing through collaborative knowledge construction, provided students with multiple opportunities to examine concepts from various perspectives while developing deep comprehension.

The emphasis on understanding-generating performances within the Perkins and Blythe framework proved particularly effective in promoting student engagement and conceptual development. These carefully designed activities challenged students to apply knowledge in novel contexts while receiving continuous feedback and support. This approach aligns with contemporary research on active learning, which demonstrates that students achieve deeper understanding when they are actively engaged in constructing knowledge rather than passively receiving information (McDaniel et al., 2022).

The collaborative learning environment fostered by the Perkins and Blythe model created conditions that supported both cognitive and social dimensions of learning. Students worked together on authentic problems and investigations while engaging in meaningful dialogue about biological concepts and processes. This social constructivist approach provided opportunities for students to articulate their thinking, consider alternative perspectives, and refine their understanding through negotiation and shared inquiry (Triantafyllou, 2024).

The ongoing assessment component of the framework contributed significantly to student learning by providing timely, specific feedback that helped students monitor their progress and adjust their learning strategies. This formative assessment approach contrasts sharply with traditional evaluation methods that typically occur at the end of instructional units and provide limited opportunities for improvement. Research consistently demonstrates that effective feedback enhances learning by helping students understand their current performance level and identify specific areas needing attention (Ko et al., 2024).

The development of scientific values among experimental group students can be attributed to the authentic nature of learning experiences provided through the Perkins and Blythe model implementation. Students engaged in genuine scientific practices including hypothesis formation, investigation design, data analysis, and evidence-based reasoning. These experiences helped students develop appreciation for the intellectual honesty, curiosity, and collaborative spirit that characterize scientific inquiry (Blotnicky et al., 2023).

The connection between academic content and real-world applications proved particularly important in fostering both conceptual understanding and scientific values development. The Perkins and Blythe model's emphasis on generative topics that connect to students' experiences and interests created meaningful learning contexts that enhanced motivation and engagement. Students could see the relevance of biological concepts to their lives and communities, which increased their investment in learning and their appreciation for scientific knowledge (Goudsouzian & Hsu, 2023).

The teacher's role as facilitator rather than information transmitter created a learning environment that encouraged student autonomy and intellectual risk-taking. This approach supported the development of scientific thinking skills and dispositions while helping students develop confidence in their ability to construct understanding independently. Research indicates that such learning environments are particularly effective in promoting both cognitive and affective learning outcomes (Richter et al., 2024).

The systematic nature of the Perkins and Blythe model provided clear structure while maintaining flexibility for responsive teaching based on student needs and interests. This balance between structure and flexibility appears to have been crucial in supporting diverse learners while maintaining focus on essential learning goals. The model's emphasis on making thinking visible through ongoing assessment and reflection helped both teachers and students monitor progress and adjust instruction as needed (Project Zero, 2024).

CONCLUSION

The findings of this research provide compelling evidence for the effectiveness of the Perkins and Blythe model in enhancing both biological concepts acquisition and scientific values development among eleventh-grade students. The statistically significant differences observed between experimental and control groups on both dependent variables demonstrate that this innovative pedagogical approach offers substantial advantages over traditional instructional methods in biology education contexts.

The large effect sizes observed for biological concepts acquisition and the moderate to large effects for scientific values development indicate that these differences have practical significance beyond statistical significance. Students who experienced instruction based on the Perkins and Blythe model demonstrated markedly superior understanding of fundamental biological concepts while simultaneously developing stronger scientific values and dispositions. These dual outcomes suggest that the framework successfully addresses both cognitive and affective dimensions of science learning.

The research findings align closely with contemporary theories of learning and instruction that emphasize the importance of active knowledge construction, collaborative inquiry, and authentic assessment. The Perkins and Blythe model appears to provide an effective framework for implementing these theoretical principles in practical educational settings while maintaining alignment with curricular standards and institutional expectations.

The success of this intervention suggests that biology educators should consider adopting pedagogical approaches that prioritize deep understanding over content coverage while providing opportunities for students to engage in authentic scientific practices. The integration of ongoing assessment and feedback mechanisms appears particularly important in supporting student learning and maintaining focus on essential understanding goals.

These findings have important implications for teacher preparation and professional development programs, which should provide educators with both theoretical understanding of constructivist learning principles and practical knowledge of how to implement frameworks like the Perkins and Blythe model. Successful implementation requires significant shifts in pedagogical thinking and practice that may require sustained support and collaboration among educators.

Future research should explore the long-term effects of Perkins and Blythe model implementation on student achievement, motivation, and career aspirations in scientific fields. Additionally, investigation of the model's effectiveness across diverse educational contexts and student populations would provide valuable insights into its generalizability and adaptability. Research examining the specific components of the framework that contribute most significantly to positive outcomes could inform efforts to refine and optimize implementation strategies.

The development of comprehensive professional development programs and instructional resources to support widespread implementation of the Perkins and Blythe model represents an important area for future work. Such efforts should include development of assessment tools, curriculum materials, and support systems that facilitate effective implementation while maintaining fidelity to the framework's core principles.

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