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The effectiveness of an integration based training program in developing interdisciplinary thinking skills and students' attitudes towards transdisciplinary projects

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ABSTRACT

This research aims to investigate the effectiveness of an integration-based training program in developing interdisciplinary thinking skills and students' attitudes towards Transdisciplinary Projects. To achieve this, a quasi-experimental design with a single group and pre- and post-testing was used. The measurement tools consisted of an interdisciplinary thinking skills test and an attitude questionnaire towards Transdisciplinary Projects. The research was conducted with a group of (60) first-year students at the College of Public Health, Imam Abdulrahman Bin Faisal University, Kingdom of Saudi Arabia, during the second semester of the academic year (2024-2025). The research yielded several results, most notably that the integration-based training program contributed to developing interdisciplinary thinking skills and improving students' attitudes towards Transdisciplinary projects. This has already led to their inclusion in the curriculum of some courses. Based on these results, the research recommends a set of recommendations.

KEYWORDS: postmodernist features, Kazim Ali's poetry, technology, technological advancements

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Introduction

Since the beginning of the third millennium, the world has faced numerous challenges impacting long-term sustainability, such as biodiversity loss, global warming, environmental pollution, poverty and hunger, overpopulation, and concerns related to health and well-being, among others. These challenges have permeated all aspects of life and have become so severe and complex that no single scientific specialist can address them alone, either now or in the future. Addressing these challenges requires not just knowledge, but also a suitable mechanism for its application and contextualization in a purposeful manner.

Many educational program designers have pointed out that "science is not an isolated island, and interdisciplinary and integrative thinking must be at the heart of educational policies. Any call for isolation within a single discipline is futile, as addressing problems must involve more than one discipline and consider multiple perspectives." (Ruan, 2024, p. 280) Thus, openness to different disciplines and the pursuit of integration or knowledge exchange have become a systematic awareness in global culture. This has provided opportunities to utilize knowledge tools from other fields to solve complex problems. After the dominance of specialization in the knowledge arena and the consolidation of boundaries and separations between disciplines, and the independence of each, there is now a contrasting trend that calls for the integration of different sciences to achieve knowledge integration. New research approaches have emerged, including the interdisciplinary approach, which has become a requirement for many scientific studies (Zaher, 2018; Lazraqi, 2021).

Interdisciplinary approaches play a crucial role in science education because they provide new fields for the advancement of science and technology, such as medical physics, biochemistry, computational biology, bioengineering, and physical chemistry. Furthermore, students frequently face gaps in their knowledge due to a lack of coordination and interaction between different disciplines (Marcu, 2007). In this context, the Vision and Change Report identified core competencies and interdisciplinary practices in biology education, emphasizing the need to link biology with other disciplines. (Hosaini & Akhyak, 2024, p. 26) (American Association for the Advancement of Science (AAAS), 2011)

Interdisciplinary thinking has also become a goal of several modern scientific projects, such as The Astro-STEM project. This project aims to raise learners' awareness of astronomy and space sciences and prepare them to contribute to real-world society by equipping them with interdisciplinary thinking skills. It integrates science, technology, engineering, and mathematics (STEM) with astronomy within an engaging and democratic learning environment where questions are raised, discussions are held, and collaborative learning teams are formed to conduct interdisciplinary research. Other such projects include Project-Based Learning (PBL), Integrated Assessments, and Inquiry Circles. The importance of interdisciplinary thinking, as highlighted by the Association of American Colleges and Universities, can be attributed to the complexity of nature and society, the exploration of problems that cannot be solved by a single scientific discipline, and the attraction of students to interdisciplinary courses, especially those related to society. (Cai, et al., 2024)

In the same vein, Hosaini and Akhyak (2024) emphasized that one of the most important goals of education is to help students become citizens with the knowledge to think broadly. Individuals capable of interdisciplinary thinking can contribute valuable to modern research challenges by understanding and recognizing interdisciplinary relationships and working in diverse teams. (Hosaini and Akhyak, 2024) Furthermore, several educational publications and previous studies have stressed the importance of an interdisciplinary approach for interdisciplinary thinking among biology teachers and those in other scientific disciplines. They recommended the importance of teaching and developing interdisciplinary thinking for teachers, both pre-service and in-service, and training them to teach and cultivate it in learners at different educational levels. Among these studies are:

- Rafiq's (2024) study, which emphasized the importance of interdisciplinary study and thinking in developing an ethical understanding of many ethical issues in the biological sciences. Teaching these issues solely through the discipline of biology is not suitable for understanding them ethically. Because it requires studying different perspectives: scientific, geographical, social, political, historical, ethical, legal, and economic, provided by various disciplines, and achieving an interdisciplinary understanding of these issues.
- -Wang and Sang (2024) study recommended revising pre-service teacher training programs to include strategies that develop interdisciplinary thinking skills. It also recommended training secondary school

physics, chemistry, and biology teachers to design activities that aim to develop interdisciplinary thinking skills in their students and integrating these skills into the teaching objectives of those subjects.

- Ismail and Ibrahim (2022) study concluded that it is crucial for teachers, especially geography and physics teachers, to possess interdisciplinary thinking skills. These skills help them dedicate teaching time to finding connections between students' subject matter and other disciplines, and to provide diverse analogies that deepen students' understanding of the interrelationship between disciplines. Furthermore, these skills create opportunities for teachers from different disciplines to collaborate, thus supporting their students' interdisciplinary experiences.

Despite the importance of the interdisciplinary approach, some conferences and previous studies have indicated shortcomings in its application and recommended its use and implementation in studying scientific, technological, and environmental issues and problems in society. (Chandra, Hitchcock & Seno-Alday, 2025). (Anand & Singh, 2025) (Rana, Aitken, & Chimoriya, 2025) (Didham, Fujii & Torkar, 2024)

This led to the need for the current research, which aims to investigate the effectiveness of an integration-based training program in developing interdisciplinary thinking skills and students' attitudes toward Transdisciplinary Projects.

Therefore, the following main question was formulated: **What is the effectiveness of an integration-based training program in developing interdisciplinary thinking skills and students' attitudes toward Transdisciplinary Projects** among first-year undergraduate students at the College of Public Health, Imam Abdulrahman Bin Faisal University?

This leads to the following questions:

1. What is the effectiveness of the integration-based training program in developing interdisciplinary thinking skills among first-year undergraduate students in the health track (College of Public Health) at Imam Abdulrahman bin Faisal University in the Kingdom of Saudi Arabia?
2. What is the effectiveness of the integration-based training program in developing first-year undergraduate students' attitudes toward Transdisciplinary Projects in the health track (College of Public Health) at Imam Abdulrahman bin Faisal University in the Kingdom of Saudi Arabia?

Research Objectives

This research aims to:

1. Develop a training program based on the philosophy of integration that supports the interdisciplinary approach.
2. Develop interdisciplinary thinking skills among first-year undergraduate students in the health track at Imam Abdulrahman bin Faisal University.
3. Develop positive attitudes toward Transdisciplinary Projects among first-year undergraduate students in the health track at Imam Abdulrahman bin Faisal University.

The Importance of Research

The importance of this research stems from the following:

Theoretical Importance

- It highlights the close relationship between scientific disciplines, specifically biology and chemistry, and emphasizes their interdisciplinary necessity as presented by biochemistry.

Applied Importance

- It offers research experience with integrated scientific content between biology and chemistry for university students.
- It provides reliable and valid tools: an interdisciplinary thinking skills test and a scale measuring attitudes toward Transdisciplinary Projects.

Research Limitations

The research limitations were as follows:

1- Human Limitations:

The research was conducted on a single experimental group consisting of (60) first-year undergraduate students in the health track at the College of Public Health.

2- Temporal and Spatial Limitations:

The research experiment was implemented during the second semester of the 2024-2025 academic year at the Deanship of Preparatory Year and supporting Studies at Imam Abdulrahman bin Faisal University, Kingdom of Saudi Arabia.

Research Methodology

In pursuit of the research objectives, which aimed to identify the effectiveness of an integration-based training program in developing first-year undergraduate students' attitudes toward Transdisciplinary Projects, a quasi-experimental design with a single experimental group was used, employing pre- and post-tests. This quasi-experimental design was chosen to ensure that any differences in the levels of the dependent variables (interdisciplinary thinking skills and attitudes toward Transdisciplinary Projects) were more accurately attributed to the independent variable (an integration-based training program) than to other variables.

Research Tools

The research tools included:

1. An Interdisciplinary Integrative Thinking Skills Test.
3. A questionnaire measuring attitudes toward Transdisciplinary Projects.

Research Hypotheses

The current research hypotheses included the following two hypotheses:

1. There is no statistically significant difference at the significance level ($\alpha \geq 0.05$) between the mean scores of the experimental group students in the pre- and post-tests for the Interdisciplinary Thinking Skills Test as a whole, and for each of its dimensions individually.
3. There is no statistically significant difference at the significance level ($\alpha \geq 0.05$) between the mean scores of the research group students in the pre- and post-applying for the questionnaire measuring attitudes toward Transdisciplinary Projects.

Research Procedures

To answer the research questions and verify its hypotheses, the researchers followed these procedures:

First: Theoretical framing of the main research variables and analysis of relevant research and studies.
Second: The field framework, which includes designing and implementing an integrated training program, preparing and conducting a pre-test of the research tools.
Third: Conducting the research experiment and a post-test of the research tools.
Fourth: Presentation, discussion, and interpretation of the research results.
Fifth: Research Recommendations.

The following is a detailed presentation of these procedures:

First: Theoretical Framework of the Research:

Interdisciplinary Approach:

Historical Development of the Integration Approach (Interdisciplinary):

Educational literature has referred to the term "interdisciplinary" as a compound term consisting of two parts: "inter" and "disciplinary." The first part, "inter," means "between," and the word "discipline" refers to a specific field of study. In the last twenty years, many researchers have discussed the interdisciplinary approach, and a trend has emerged towards rejecting the boundaries between disciplines that hinder a comprehensive understanding of societal phenomena and issues. The use of the interdisciplinary approach

has gradually developed in education at all levels. (Al-Jalawi, 2020) (Abdul-Munim & Ibrahim, 1999) (Makaki, 2021) (Makroum, 2022)

The Concept of the Interdisciplinary Approach

Educational literature and studies have presented a range of concepts for the interdisciplinary approach under various names, reflecting the differing philosophies and objectives of interdisciplinarians. One such study is by Usmonov (2025). The integration of two or more disciplines is referred to as "integration," a term encompassing all these concepts as levels of integration. These levels share the characteristics of being learning approaches that aim for the holistic development of the learner's personality. However, they differ in their thinking strategies, the degree of interrelationship between disciplines, and the complexity of the contexts through which integration occurs. These levels can be illustrated in Figure (1) below:

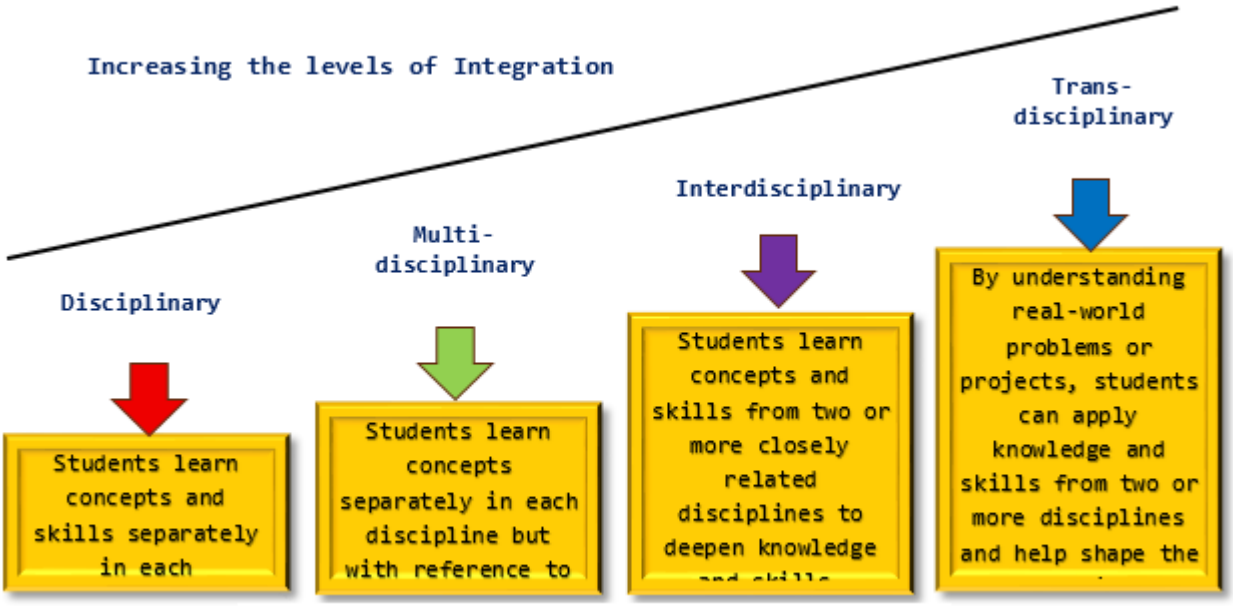

Figure (1) Levels of Integration

As can be seen from Figure (1) above:

- That specialization, interdisciplinary studies, and interdisciplinary studies are all forms of integration, but only partial integration, while transdisciplinary studies represent complete integration. The stronger the integration, the greater the comprehensiveness, depth, and overall perspective.
- That each of these is important for students to learn concepts and skills and to solve problems. Students choose the type that best suits their objective, the nature of their specialization, and their ability to find the connections that achieve integration. This is confirmed by the studies:(Kolmos, Holgaard & Routhe, 2025) (Yeni, Sand et al., 2024), which explained that integration is the merging of disciplines to achieve comprehensive knowledge, and that it occurs through a continuous series of levels. This begins with integration (the simple merging of parts of subjects within a single discipline), then its level increases in multi-disciplinary fields, and then it becomes stronger in interdisciplinary fields, until it reaches its highest level in transdisciplinary fields where the boundaries between disciplines disappear.

Interdisciplinary Thinking

First: The Concept of Interdisciplinary Thinking

Usmonov (2025) defined it as the ability to integrate knowledge and thinking patterns from two or more scientific fields to form a broad cognitive understanding, explain a phenomenon, solve a problem, or create a product that cannot be achieved through the means of individual scientific fields.

As defined by Mohammed and Zouine (2016), interdisciplinary thinking is the ability to integrate knowledge and thinking methods from two or more disciplines. It is a type of thinking that aims to develop the capacity to shift disciplinary perspectives and create meaningful connections between different disciplines. Mustafa (2017) defined it as a distinct type of thinking that can combine perspectives and tools from different

specialized fields.
Analyzing these definitions, there is a consensus that interdisciplinary thinking is:

- A type of process practiced when attempting to integrate knowledge, methodologies, or tools from more than one scientific field.
- Often occurs when addressing a comprehensive topic, issue, or problem.
- Directed by the primary goal of achieving a comprehensive and in-depth understanding or reaching comprehensive and effective solutions.

Secondly: The Importance of Interdisciplinary Thinking in Higher Education

Until recently, interdisciplinary thinking was very limited in higher education. However, over the past two decades, studies, research, and efforts have increased, outlining university educational projects based on the interdisciplinary approach. Among these are the notable efforts of UNESCO, which has conducted numerous studies in this field, identifying some interdisciplinary skills that educational programs should strive to cultivate. Higher education focuses on developing interdisciplinary thinking skills, particularly the necessary conditions for their development, such as students' personal characteristics, motivation, and maturity. It also considers the learning context, including the degree of interdisciplinary thinking, faculty collaboration, and the learning process itself, such as learning activities and the development of interdisciplinary thinking (Rizq et al., 2021).

The importance of interdisciplinary thinking in university education stems from its ability to foster numerous cognitive and practical skills that align with the educational trend toward developing 21st-century skills. These include critical thinking, problem-solving and decision-making, learning how to learn, metacognition, communication and collaboration skills, information literacy, communication and information culture, citizenship, life and career, and personal and social responsibility. Learning these skills requires more than just individual disciplines; it necessitates interdisciplinary approaches, such as the STEM approach, and the design of learning experiences that integrate different disciplines, allowing for the practice of diverse interdisciplinary thinking styles, work methods, and communication with others (Podgórska & Zdonek, 2024).

Third: Types Interdisciplinary Thinking

There are two main types of interdisciplinary thinking.

The first is: Narrow Interdisciplinary Thinking

This includes the ability to create cognitive integration of specialized fields within a specific science, such as the integration between biology, physics, and chemistry within the sciences.

Second: Broad Interdisciplinary Thinking

This involves the ability to integrate knowledge across different disciplines, such as the integration of natural and social sciences.

The goal of interdisciplinary learning in higher education should be to empower students and graduates with the mechanisms for integrating knowledge across various scientific fields. The skills inherent in interdisciplinary learning include the ability to shift perspectives within specialized fields and to create meaningful connections between scientific disciplines. This helps them address complex issues that arise in scientific and professional environments (Ming, van der Veen & MacLeod, 2025).

Fourth: Interdisciplinary Thinking Skills

Interdisciplinary thinking is characterized as a complex mental skill, composed of a set of sub-skills (such as higher order thinking skills like creative, critical, and metacognitive thinking) and specific thinking patterns related to specialized fields (scientific thinking, geographical thinking, etc.). These patterns are used to construct interdisciplinary knowledge and are linked to the scientific method in study and problem-solving. A review of relevant literature and previous studies confirms this complexity and the integration of interdisciplinary thinking skills. Several classifications of interdisciplinary thinking have been presented, including the following studies:

- Wang's 2024 study, which classified interdisciplinary thinking skills into five main components: subject-

specific knowledge, knowledge of subject-specific models, interdisciplinary knowledge and higher-order thinking skills, and communication skills. (Wang, 2024, p. 240)
- Shuford's 2024 study, which classified interdisciplinary thinking skills into three components: subject-specific knowledge, integration, and critical awareness. (Shuford, 2024, p. 110)
- Al-Jalawi's 2020 study, which classified interdisciplinary thinking skills into two main components: knowledge acquisition and skills acquisition. (Al-Jalawi, 2020, p. 30)
- Abdel Fattah's study (2022) classified interdisciplinary thinking skills into three categories: interdisciplinary understanding of problems, interpreting phenomena from different perspectives, and solving interdisciplinary problems.
- Ismail and Ibrahim's study (2022) classified interdisciplinary thinking skills into four categories: interdisciplinary inquiry, interdisciplinary communication, finding interdisciplinary connections, and interdisciplinary understanding.

The American Association of Colleges and Universities (AACU) (2009) also identified a set of environmental competencies that are prerequisites for practicing interdisciplinary thinking. These include the learner's ability to solve problems that rely on multiple specialized fields, to create cognitive integration between knowledge, skills, tools, and perspectives from multiple specialized fields, to understand the complexity of societal realities, to ask questions, to be open-minded, to have scientific curiosity towards multidisciplinary fields, to possess cognitive flexibility and adaptability, to solve problems, to conduct research, to write, to communicate orally and listen, to work within a team, to understand group dynamics, to be willing to help others, and to grasp the big picture, not just their own area of specialization. (Shuford, 2024)

Second: The Field Framework of the Research

To achieve the objectives of the current research, which are to develop both interdisciplinary thinking skills and attitudes towards transdisciplinary projects among first-year public health students, the researchers adhered to the following procedures:

- Designing a training program based on the philosophy of integration.
- Preparing and refining the research tools.
- Conducting the research experiment: This is detailed below:
- Designing a training program based on the integration approach:

The training program based on the integration approach was built according to several stages, which can be detailed as follows:

A. Program Foundations

The training program was developed based on a review of educational literature and previous studies related to this topic. The program components were designed as follows:

General Objectives of the Training Program

The main objective of the training program is to develop the knowledge of public health students through training content based on an integrated approach. It also aims to develop their skills and attitudes related to interdisciplinary fields. The general objectives of the training program can be summarized as follows:

- Understanding the philosophy and origins of interdisciplinary integration.
- Recognizing the importance of an integrated approach to thinking.
- Understanding the nature of Transdisciplinary Projects.
- Understanding nature, characteristics, importance, and skills of interdisciplinary thinking.

Developing the ability to establish connections between the disciplines of biology and chemistry.
Employing different thinking styles (scientific, critical, creative, metacognitive) to integrate the disciplines of biology and chemistry in addressing problems and issues relevant to society.

B. Training Program Content

The program content was selected and organized according to the following criteria:

- Suitability for achieving the program's objectives.
- Achieving integration, consistent with the nature of the interdisciplinary approach.
- Emphasizing students' practice of interdisciplinary thinking skills.
- Providing opportunities to develop students' attitudes towards Transdisciplinary Projects.

C. Training Strategies

To achieve the training program's objectives, a range of training strategies were employed that are appropriate to its nature and goals, and suitable for the learners' abilities and needs, encouraging them to practice interdisciplinary thinking skills. These strategies include cooperative learning, case studies, discussion, brainstorming, problem-solving, inquiry, mind mapping, and projects. These are among the most suitable strategies for developing interdisciplinary thinking and attitudes towards Transdisciplinary Projects.

D. Training Program Implementation Timeline

The training program implementation timeline was developed to ensure the achievement of its targeted learning outcomes, the implementation of its strategies and activities, and the evaluation of those learning outcomes. The training program was implemented over approximately 16 hours over four days during the second semester of the 2024-2025 academic year.

Validity of the Training Program

The validity of the training program was confirmed by presenting the training content and PowerPoint presentations to a group of expert reviewers specializing in curriculum and teaching methods, as well as biology and chemistry. Their suggestions and opinions were considered, resulting in the final version of the training program.

Preparation and Adjustment of Measurement Instruments

The research included the following instruments:

1. Interdisciplinary Thinking Skills Test.
2. Attitudes Towards Transdisciplinary Projects.

The process of preparing and adjusting these tools involved the following steps:

First - Preparation for the Interdisciplinary Thinking Skills Test

The following procedures were followed in preparing the Interdisciplinary Thinking Skills Test:

1- Defining the Test Objective

The test aimed to measure the level of Interdisciplinary thinking skills among the students in the research group.

2- Defining the Dimensions of the Interdisciplinary Thinking Skills Test

Based on a review of relevant previous studies, a preliminary list of dimensions for the Interdisciplinary Thinking Skills Test was prepared. These items were then formulated into a questionnaire to determine the final list of dimensions. The preparation of this questionnaire involved the following steps:

3- Determining the Test Type

The short essay type of test was chosen because it is suitable for measuring the student's ability to practice interdisciplinary thinking skills and express the resulting interdisciplinary perspective.

4- Formulating the Test Items

The test items were formulated according to the standards of good formulation for this type of test, including clarity, precision, comprehensiveness, variety, and relevance to the test dimensions, in accordance with its intended purpose.

5. Establishing the Test Scoring System

To assess the level of interdisciplinary thinking skills, holistic rubrics were used. These rubrics were designed both quantitatively and qualitatively to determine the overall level and were structured into five levels, as follows: (5) points for each correct answer and (0) points for each incorrect answer, or if there was no answer to the question.

6. Defining the Test Instructions

7. Preparing for the Initial Test

The initial version of the test included (26) items accompanied by instructions for answering them.

A. Test Validity

The initial version of the test was presented to a group of expert reviewers specializing in curriculum and teaching methods to ensure its validity in terms of the clarity and precision of the wording, the relevance of the items to the test dimensions, their suitability for the research group, the accuracy of the instructions, and to provide any other comments for modification, addition, or deletion.

Based on the reviewers' feedback, appropriate modifications were made to ensure the test included (26) items measuring (26) indicators.

B- Pilot Test of the Test

The test was administered to a group of first-year public health students in the fall semester of the 2024/2025 academic year, excluding the research group, consisting of (15) student teachers, using Microsoft Forms. This was done to calculate the following:

C- Test Reliability

The test's reliability coefficient was calculated by determining the percentage of agreement between scorers using Cooper's formula. The researchers scored the responses of (15) students on the Interdisciplinary Thinking Skills Test, and the agreement coefficient reached (84.32%). This indicates that the test has an acceptable degree of reliability, and therefore its results can be trusted.

D- Determining Test Time

The test time was determined by calculating the average time taken to complete the test. This was done by summing up the time taken by each student and then dividing the result by the number of students. The total time for completing the test was determined to be (120) minutes.

Y- Preparing the Final Version of the Test

After confirming the test's validity and reliability and calculating the appropriate time for its administration; The test, in its final form, is now valid for application, containing (26) items, distributed according to the opinions of the referees across four dimensions; hence, the maximum score for the test is (130) points. Table (1) shows the specifications of the test in its final form - as follows:

Test Domains	Number of items /domains	Items	Total degrees	Ratio
Cognitive mastery	11	1-2-3-4-5-6-7-8-9-10-11	55	42.31%
Interdisciplinary understanding	8	12-13-14-15-16-17-18-19	40	30.77%
Higher order thinking skills	5	20-21-22-23-24	25	19.23%
Communication skills	2	25-26	10	7.69%
Total	26		130	100%

Table (1) shows the specifications of the test in its final form

Second: Developing an attitude toward Transdisciplinary Projects Questionnaire

The questionnaire included the following sections: the concept of Transdisciplinary Projects, their importance, their effectiveness in university teaching, and the challenges of using them in university teaching (45 statements).

A. Formulating the Questionnaire Items
After defining the dimensions of the attitudes toward Transdisciplinary Projects list, the questionnaire items were formulated, considering clarity, specificity, precision, avoidance of overlapping, coverage of all dimensions of Transdisciplinary Projects, and each item belonging to the dimension it measures.

B. Establishing a Scoring System for the Questionnaire
A system was developed to rate the responses according to a five-point Likert scale: (5) Strongly Agree, (4) Agree, (3) Unsure, (2) Disagree, (1) Strongly Disagree.

C. Questionnaire Validity
The questionnaire was presented to a group of expert reviewers specializing in curriculum and teaching methods to ensure the suitability of the initial version of the list for use. This was to allow them to provide feedback on the clarity and accuracy of the wording, the relevance of each statement to its designated area of measurement, its suitability to the students' characteristics, and to write any comments suggesting modifications, additions, or deletions. The questionnaire was revised based on the reviewers' feedback, with some statements being rephrased. The final version was then designed, comprising four areas and represented by (45) statements. Table (2) illustrates the questionnaire's areas in its final form, as follows:

Domains of the Attitude Questionnaire	Number of Statements	Percentage
Nature of Transdisciplinary Projects	9	20%
Importance of Transdisciplinary Projects	14	32%
Effectiveness of their use in university teaching	11	24%
Challenges of their use in university teaching	11	24%

Table (2) Final Form of the Attitude questionnaire

d. Preparing the Initial Version of the Questionnaire
The initial version of the scale included (45) items. Students were required to mark each item with a checkmark (√) indicating their level of agreement.

e. Establishing the Scoring System
A five-point Likert scale was used for scoring positive items. For negative reasons, the weights were reversed.

f. Scale Validity
The extent to which the scale items represented their intended objectives was verified through content validity. This was achieved by presenting the initial version of the scale to a panel of experts to ensure its suitability. The scale was finalized to include (45) items.

Y- Pilot Test of the Attitudes questionnaire: The questionnaire was administered to a group of first-year public health students during the second semester of the 2024/2025 academic year, separate from the research group, consisting of (15) students. Microsoft Forms was used to calculate the following:

1- Scale Reliability: The scale's reliability was calculated using Cronbach's alpha, yielding a reliability coefficient of (0.89), indicating a high degree of reliability suitable for use with the research group.

2- **Scale Time**: The average student response time was calculated, resulting in a total response time of (30) minutes.

3- **Finalization of the Scale**: After confirming the scale's validity and reliability, and calculating the appropriate administration time, the scale was finalized and ready for use.

Third: Presenting and Interpreting the Research Results

To calculate the research results and the statistical methods used to verify the research hypotheses, the SPSS statistical software package, version (20), was used. These results were interpreted considering what was confirmed by educational literature and the results of studies and research included in the theoretical framework of the research. Finally, some recommendations were presented. The details are as follows:

A- The first hypothesis was verified, which states: "There is no statistically significant difference at the significance level ($\alpha \geq 0.05$) between the mean scores of the students in the experimental group in the pre- and post-tests of interdisciplinary thinking skills as a whole, and for each of its dimensions individually." This was achieved using t-tests to determine the significance of the difference between the mean scores of the students in the experimental group in the pre- and post-tests of interdisciplinary thinking skills, and for each of its dimensions individually. The effect size of applying the training program based on the integration approach in developing students' interdisciplinary thinking skills was also determined, as shown in the following table (3):

Test Domain	Measurement	Degree	Mean	Standard Deviation	T. value	Significance	D	Level of effect
Cognitive mastery	Pre	55	10.46	3.43	68.21	Significant Level (0.05)	12.46	Large
	Post		48.66	4.07				
Interdisciplinary understanding	Pre	40	7.26	2.19	44.61	Significant Level (0.05)	8.15	Large
	Post		33.56	3.79				
Higher order thinking skills	Pre	25	4.76	1.52	53.9	Significant Level (0.05)	9.85	Large
	Post		20.8	2.2				
Communication skills	Pre	10	3.96	1.15	19.56	Significant Level (0.05)	3.57	Large
	Post		8	0.74				
Test as a Whole	Pre	130	26.4	7.29	68.17	Significant Level (0.05)	12.46	Large
	Post		111.03	10.09				

Table (3) illustrates the effect of applying the training program based on the integration approach on developing students' interdisciplinary thinking skills.

It is clear from the above Table (3) that:

- The calculated "t" values exceeded the tabulated "t" values at a significance level of ($\alpha \geq 0.05$), which indicates a statistically significant difference between the mean scores of the experimental group students in the pre- and post-tests for the interdisciplinary thinking skills test as a whole, and for each of its dimensions, in favor of the mean scores of the experimental group students in the post-test. Thus, the null hypothesis was rejected, and the alternative hypothesis was accepted, which states: There is a statistically significant difference at a significance level of ($\alpha \geq 0.05$) between the average scores of the experimental group students in the pre- and post-tests of interdisciplinary thinking skills as a whole, and for each of its dimensions separately, is in favor of the average scores of the experimental group students in the post-test.
- The effect size value using Cohen's D-value for the test as a whole was (12.46), indicating a large effect size of the training program in developing interdisciplinary thinking skills. The effect size values for each of the four dimensions of the interdisciplinary thinking skills test were (12.46, 8.15, 9.85, and 3.57), respectively, indicating a large effect size for each dimension of the test individually. This confirms that the training program based on the integration approach brought about a significant and substantial change in the development of interdisciplinary thinking skills among the students.

The researchers attribute this result to:

The training program based on the integration approach provided students with the opportunity to learn interdisciplinary thinking and develop their skills. This approach stems from the philosophy of interdisciplinary thinking, which involves identifying relationships, connecting, and integrating perspectives, knowledge, skills,

methods, tools, and languages within the fields of biology and chemistry. This achieves cognitive mastery, interdisciplinary understanding, higher order thinking skills, and communication skills. This, in turn, influenced the program's structure and implementation, supporting and developing interdisciplinary thinking skills.

Content selection and organization: The interdisciplinary approach focused on selecting content from biochemistry. Studying biochemistry as a science necessitates identifying relationships, connections, and integration between the perspectives, knowledge, and skills of biology and chemistry. Achieving this integration requires defining the network relationships between the knowledge of these sciences. These relationships are the essence of thinking processes in all their forms and skills. Indeed, thinking is the perception of relationships between elements and subjects, between cause and effect, and between the known and the unknown, which aligns with the findings of Abdel-Razzaq et al. (2022). Integration also requires linking general thinking skills with the specific thinking patterns of each scientific field, which contributed to the formation of biochemistry. Thus, biochemistry supports the practice of interdisciplinary thinking skills. Biology is linked to the practice of scientific and metacognitive thinking, and even works to develop it, as agreed with Alwan's study (2020). Similarly, it supports creative thinking, as agreed with Al-Sarhan's study (2022), and critical thinking, as agreed with Shihab's study. (2019), all of which are interdisciplinary thinking skills. Chemistry is also linked to the practice of scientific thinking, as confirmed by Al-Maamari and Al-Masrouri's study (2019), as well as creative thinking, as confirmed by Hilat's study (2013), and critical thinking, as confirmed by Ibrahim's study (2015). Identifying relationships, connections, and integration between biology and chemistry requires integrating the thinking patterns inherent in both. This explains the contribution of the proposed program to developing students' achievement and interdisciplinary thinking skills.

Furthermore, the inclusion of biochemistry content addressing problems and issues related to life on Earth, such as the problem of biodiversity loss (extinction) and its associated issues of pollution and global warming, has helped students practice all interdisciplinary thinking skills. These are all higher-order thinking skills: scientific, critical, creative, metacognitive, and future-oriented for a thorough study of the problem and an attempt to reach comprehensive and innovative solutions. This aligns with what was explained and confirmed by the studies of Usmonov (2025) and Shuford (2024). (Didham, Fujii & Torkar, 2024), all of which emphasized the necessity of practicing interdisciplinary thinking skills in solving major and complex problems.

- The training program included training methods that contributed to developing interdisciplinary thinking skills, such as problem-solving, cooperative learning, a research project with interdisciplinary tasks, and discussions that allowed for the practice of critical thinking skills while students presented their perspectives. These methods guided the discussion to identify relationships, establish connections, and arrive at an interdisciplinary perspective between the two disciplines. Inquiries directed students to seek knowledge from the disciplines of biology and chemistry, identify relationships, and connect and integrate them. Mind maps were also important in clarifying relationships, which aligns with the study by Yeni and others (2024).
- The design of teaching and learning activities and tasks helped students create an interdisciplinary product based on practicing interdisciplinary thinking skills through collaboration. Examples include writing reports and interdisciplinary summaries, the interdisciplinary project implemented by the students, and completing the worksheets included in the training. Students were also guided to utilize diverse learning resources. My specialization is biology, and chemistry, such as images, concept maps, references, statistics, and scientific material included in the program.

2) - **Results verifying the second hypothesis, which states: There is no statistically significant difference at the significance level ($\alpha \geq 0.05$) between the mean scores of the research group students in the pre- and post-applying for the questionnaire measuring attitudes toward Transdisciplinary Projects.**, using the t-test for independent groups. To determine the significance of the difference between the average scores of students in the pre- and post-applying, measuring students' attitudes toward transdisciplinary projects, and calculating the effect size of implementing the proposed training program based on the integration approach on developing students' attitudes toward Transdisciplinary Projects, the following Table (4) illustrates:

Applying	Score	Mean	Standard Deviation	"t" Value	ŋ 2	Significance	Effect Size Level
Pre	225	109.96	4.02	76.83	0.99	Significant at the	Significant
Post		185.56	3.58			0.05 level	

Table (4) The values of t and their significance for the difference between the mean scores of the pre- and post-applications of the test of attitudes towards interdisciplinary projects and calculating the effect size where n = 60 students.

Table (4) above shows:

- The calculated t-values exceeded the tabulated t-values at a significance level of ($\alpha \geq 0.05$), indicating a statistically significant difference between the mean scores of the two research groups in the post-test of the student attitudes toward interdisciplinary projects and interdisciplinary learning scale, in favor of the post-test mean score. Therefore, the previous null hypothesis was rejected, and the alternative hypothesis was accepted: There is a statistically significant difference at a significance level of ($\alpha \geq 0.05$) between the mean scores of the research group in the pre-test and post-test of the student attitudes toward interdisciplinary projects scale, in favor of the post-test mean score.
- The effect size value using eta-squared (Δ^2) for the scale as a whole was (0.99), indicating a large effect size for the proposed program in developing student attitudes toward interdisciplinary projects. This confirms that the training program based on the integration approach has produced a significant and substantial change in improving the attitudes of the research group students toward interdisciplinary projects.

This result, in the view of the researchers, is attributed to:

The proposed program, based on the interdisciplinary approach, provides students with opportunities to develop their attitudes toward integration by targeting the academic, personal, and social development of students, raising their level of proficiency in interdisciplinary teaching, and informing them of these goals and the importance of the program in achieving them. This is consistent with the study of (Anand & Singh, 2025) (Abdul Razak et al., 2022). The program includes strategies and learning activities that rely on active learning among students, such as problem-solving strategies, project-based learning, inquiry-based learning, discussion, and case studies. These all contribute to the formation of positive beliefs and attitudes toward interdisciplinary learning, as learners are active, enjoy using their minds, practice diverse thinking skills, discover their abilities and skills in searching for information and arriving at solutions, and practice several social skills that stimulate learning. This is consistent with studies by:(Ming, van der Veen, & MacLeod, 2025); (Kolmos, et al., 2025); (Usmonov, 2025); (Ruan, Xu & Su, 2024); (Hassan, Ibrahim, & Hussein, Hisham, 2022); (Atallah & Al-Jaber, 2017). (Faqihi, Yahya, and Al-Maliki, 2021)

Fourth: Research Recommendations

Considering the findings, the researchers recommend the following:

- Develop professional development programs for biology and chemistry teachers, based on an interdisciplinary approach, allowing for the development of achievement, thinking skills, and attitudes toward integration between scientific disciplines.
- Benefit from the interdisciplinary approach in developing students' skills, which contributes to improving their future professional performance and achieving better learning outcomes.

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