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Interdisciplinary Integration in High School Biology Teaching and the Cultivation of Students' Comprehensive Qualities

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Abstract: This paper aims to explore the teaching design and practice of interdisciplinary integration in high school biology teaching and analyze its impact on the cultivation of students' comprehensive qualities. The research method combines biology with knowledge from subjects such as chemistry and physics through project-based learning and inquiry-based learning, and encourages students to solve practical problems from multiple disciplinary perspectives. The teaching implementation steps include early interdisciplinary lesson preparation and cooperation with teachers, mid-term independent learning through group cooperation and project tasks, and late stage deepening of understanding through actual cases, and continuous adjustment through classroom feedback. The evaluation system covers multiple dimensions such as knowledge mastery, innovation ability, problem-solving ability, and teamwork spirit. It comprehensively evaluates student performance by combining quantitative data with qualitative analysis. The experimental results show that interdisciplinary integrated teaching significantly improves students' performance in mastering and applying subject knowledge, innovation ability, critical thinking and teamwork. Specific data show that students' answer rate on interdisciplinary knowledge points has increased from 70%-90% to 90%-97%, the number of innovative solutions has increased significantly, and teamwork scores have generally improved, demonstrating the positive effect of interdisciplinary integrated teaching in improving students' comprehensive quality. Interdisciplinary teaching not only promotes the integration and application of students' subject knowledge but also stimulates innovative thinking and teamwork, proving its importance and feasibility in modern education.

1. Introduction

With the acceleration of globalization and technological progress, modern society has put forward higher requirements for students' comprehensive qualities. The traditional independent subject teaching model is difficult to effectively cultivate students' ability to deal with complex problems. Especially in a rapidly changing world, interdisciplinary knowledge integration and

innovation capabilities have become the key to solving contemporary problems. However, in high school biology teaching, how to organically integrate biology with other subjects such as chemistry and physics to cultivate students' interdisciplinary thinking, innovation and problem-solving abilities is still a major challenge in educational practice. To address this problem, interdisciplinary integrated teaching as an innovative educational model has gradually attracted widespread attention.

The contribution of this article is to explore and practice specific methods for implementing interdisciplinary integration in high school biology teaching, aiming to promote the effective combination of biology with chemistry, physics and other subjects through teaching methods such as project-based learning and inquiry-based learning. The study not only designed a teaching framework based on interdisciplinary integration, but also constructed a multi-dimensional student comprehensive quality assessment system, covering aspects such as knowledge mastery, innovation ability, problem-solving ability and teamwork, to comprehensively evaluate the impact of interdisciplinary teaching on students' comprehensive quality. Experimental data verified the significant effect of this teaching model in improving students' subject integration ability, innovative thinking and teamwork.

The second part of this paper reviews the existing research on interdisciplinary integrated teaching and analyzes its theoretical background and current practice; the third part introduces the teaching design, implementation steps and evaluation system of this study; the fourth part shows the experimental results and discusses the role of interdisciplinary integrated teaching in improving students' comprehensive quality through data analysis; finally, the fifth part summarizes the research findings and puts forward suggestions for improvement in future research and practice.

2. Related Work

Interdisciplinary research has become a key approach to addressing contemporary complex issues, and the integration of different disciplines provides new solutions and perspectives for global challenges. Priyadi studied the coordination between Islamic finance and conventional economic theory, revealing its interdisciplinary nature and potential to address global financial challenges[1]. Horn et al. proposed a new interdisciplinary competence framework, emphasizing the importance of cognitive stability and cognitive adaptability in interdisciplinary knowledge integration, and analyzed the impact of different competence types on interdisciplinary cooperation on sustainable development issues based on empirical data [2]. Peek and Guikema addressed these and other pressing issues by assessing recent advances in interdisciplinary research on hazards and disasters [3]. Akhmedova et al. focused on the existing interpretation of the concept of communicative competence, the interdisciplinary and comprehensive characteristics of the concept, and the views of domestic and foreign researchers, based on which a comprehensive approach to the formation of future teachers' communicative competence was proposed [4]. Kuziyevich studied how to improve the quality of the education system in the context of the Republic's Third Renaissance through interdisciplinary integration and effective organization of modern technologies in order to cope with global competition and cultivate competitive talents [5]. PU and HUANG discussed the cross-integration of geography and resource science in China, emphasizing the promotion of the development of new fields and the improvement of disciplinary research level through interdisciplinary penetration, theoretical innovation and method transplantation [6]. Bertel et al. discussed a large-scale project at Aalborg University (AAU) as an example of a large-scale and systematic approach to integrating ESD principles (particularly interdisciplinarity) into PBL [7]. Lent et al. discussed the importance of interdisciplinary collaboration in life science education, emphasized the cultivation of students' core competencies by integrating biology education with other disciplines, and called for strengthening collaboration between biologists and educational

researchers [8]. Özen ç-Ira and G ültekin reviewed the music integration approaches used in preschool to secondary education in Turkey, analyzed the interdisciplinary integration of music with subjects such as mathematics, science, and language arts, and explored the impact of different integration styles on educational, cognitive, and affective outcomes [9]. Pasculli integrated the findings of such research to provide a preliminary interdisciplinary theory of the global causes of cybercrime and assesses what governments can do to mitigate it [10]. Although these studies demonstrate the broad potential of interdisciplinary collaboration, there is still a lack of a systematic framework and unified standards. Future innovation lies in establishing a more clear and operational interdisciplinary collaboration mechanism.

3. Methods

3.1 Interdisciplinary Integrated Teaching Design

The core of interdisciplinary integrated teaching design is to select cross-cutting and related content to ensure that knowledge between different disciplines can penetrate and complement each other. For example, combining the cell metabolism process in biology[11] with chemical reactions can help students understand the mechanisms of biochemical reactions; or combining the energy transformation principles in physics with the energy flow in biology can help students more comprehensively understand the energy changes in life activities. In curriculum design, project-based learning and inquiry-based learning are effective teaching models. Through these methods, students can actively analyze and solve practical problems from the perspectives of multiple disciplines. Interdisciplinary courses usually revolve around practical problems, such as environmental protection, health management, etc. Students need to combine the knowledge they have learned in biology, chemistry, physics, etc. to propose multi-angle solutions. In addition, the use of modern information technology and online resources can further enhance the effectiveness of interdisciplinary teaching. Through virtual experiments and interactive platforms, students can simulate interdisciplinary experimental processes without actual operating conditions, thereby enhancing their hands-on ability and spirit of exploration. Finally, organizing interdisciplinary teamwork is also a key link in interdisciplinary teaching design. Through group work, students can not only combine knowledge from different disciplines but also divide the work within the team, improve their communication and collaboration skills, and gain new ideas and insights from other students' perspectives, further deepening their understanding of interdisciplinary issues[12].

3.2 Teaching Implementation Steps

The first step in teaching implementation is preliminary preparation. During this stage, teachers need to prepare lessons and cooperate across disciplines and select appropriate interdisciplinary teaching topics. Teachers should carefully select content that can combine knowledge from multiple disciplines based on course objectives and students' subject foundation to ensure that the subject matter has interdisciplinary breadth and depth. At the same time, teachers also need to cooperate with teachers of other subjects, communicate and coordinate teaching plans[13] to ensure that the content of each subject can be effectively connected and integrated. In the teaching implementation process, the course is usually divided into multiple stages, each stage is designed for different learning objectives. In the initial stage, teachers mainly guide students to understand the interdisciplinary knowledge framework and related theories; in the middle stage, students begin to explore and solve problems independently through project-based learning and inquiry-based learning; in the later stage, students deepen their understanding of interdisciplinary issues through actual case analysis and group cooperation. The entire teaching process emphasizes students'

independent learning and exploration, and encourages students to actively discover and raise questions during the learning process. In addition, feedback and adjustment are important links in interdisciplinary teaching. Teachers should keep abreast of students' learning progress and understanding through group discussions, student assignments, and classroom feedback, and make appropriate adjustments based on students' feedback and questions. Through continuous adjustment and optimization, teachers can ensure the smooth progress of interdisciplinary integrated teaching and help students gain a deeper understanding and more comprehensive ability development in the multidisciplinary learning process.

3.3 Comprehensive Quality Assessment of Students

In order to comprehensively assess students' performance in interdisciplinary integrated teaching, we have established a multi-dimensional assessment system including knowledge mastery, innovation ability, problem-solving ability and teamwork spirit. Quantitative data[14] is obtained through test, project results and homework scores to evaluate students' performance in various ability dimensions; qualitative data is supplemented by classroom observation, student interviews and peer assessment to help understand students' classroom interaction and cooperation. Finally, the comprehensive scoring table is used to quantify the evaluation results and obtain the total score, which provides teachers with intuitive feedback and optimizes teaching strategies. Table 1 is a data table of comprehensive quality evaluation of students.

Table 1: Student comprehensive quality evaluation data table

Student Name	Knowledge Mastery Score (20 points)	Innovation Ability Score (20 points)	Problem Solving Ability Score (20 points)	Teamwork Score (20 points)	Classroom Participation Score (10 points)	Total Score (90 points)
Student A	17	18	16	15	8	74
Student B	15	17	18	16	9	75
Student C	19	20	17	18	10	84
Student D	14	16	15	14	7	66
Student E	16	18	19	17	9	79

The knowledge mastery score is based on test scores and homework performance, with a total score of 20 points; the innovation ability score is based on the innovation in the project task, with a total score of 20 points; the problem-solving ability score evaluates the effectiveness of students in solving interdisciplinary problems, with a total score of 20 points; the teamwork score is based on participation and communication skills, with a maximum score of 20 points; the classroom participation score is based on the students' enthusiasm for discussion and interaction, with a maximum score of 10 points. Quantitative analysis reveals students' strengths and weaknesses, while qualitative analysis[15] supplements quantitative data through classroom observation and self-evaluation to explain differences in scores. Comprehensive assessment helps teachers gain a comprehensive understanding of student performance and optimize teaching strategies [16-17].

4. Results and Discussion

In order to verify the effect of interdisciplinary integrated teaching on improving students' comprehensive quality, this experimental design aims to evaluate students' performance in subject knowledge integration, innovation ability, teamwork, etc. The experimental subjects were two groups of high school students, the experimental group and the control group, with 20 students in each group. The experimental group studies under the framework of interdisciplinary integrated teaching, including the cross-application of content from subjects such as biology, chemistry, and physics. Through project-based learning and inquiry-based learning, students are encouraged to combine knowledge from multiple disciplines to solve practical problems. The control group adopts the traditional single-subject teaching model, focusing on independent teaching of each subject. Before the start of the semester, all students will undergo a preliminary assessment to evaluate their subject knowledge, innovative thinking level, critical thinking ability, and teamwork ability. During the experiment, students in the experimental group will participate in multiple interdisciplinary project tasks. Each task involves knowledge of subjects such as biology, chemistry and physics, requiring students to work in groups and propose innovative solutions. At the end of the experiment, students' abilities will be reassessed through tests, project evaluations, and teamwork scoring. After data collection, a before-and-after comparative analysis was conducted to evaluate the impact of interdisciplinary integrated teaching on students' comprehensive qualities through changes in the answer rate of subject knowledge points, the number of innovative solutions, and teamwork scores. Finally, through quantitative and qualitative analysis, the actual effect of interdisciplinary integrated teaching in improving students' knowledge integration ability, innovative thinking and teamwork is revealed.

4.1 Integration and Application of Subject Knowledge

In interdisciplinary teaching, the integration and application of subject knowledge is crucial, especially in terms of students’ ability to master and apply interdisciplinary knowledge. In order to evaluate students’ mastery of interdisciplinary knowledge, we can set the “correct answer rate of interdisciplinary knowledge points” as a measurement indicator. This indicator reflects the extent to which students can understand and correctly apply knowledge from different subjects in actual learning. By analyzing the correct answer rate of students in interdisciplinary content, we can clearly understand the students' mastery of knowledge integration and application. To this end, designing relevant tests and recording each student's answers on interdisciplinary knowledge points can provide intuitive data support. By comparing the data, we can clearly see the changes in students' mastery of interdisciplinary knowledge in these two areas, helping teachers evaluate the actual effect of the reform and optimize teaching methods in a targeted manner. Figure 1 shows the comparison of the correct answer rate of interdisciplinary knowledge points.

This set of data shows the changes in the correct answer rates of 20 students in biology and chemistry and physics and chemistry knowledge points before and after the interdisciplinary teaching reform. The answer rates after the reform were generally higher, indicating that the interdisciplinary teaching method has a positive impact on students' knowledge mastery. In terms of biology and chemistry knowledge points, the answer rate of most students increases from 70% before the reform to 90% after the reform, especially Student 3, whose answer rate increases from 88% to 97%, and Student 9, whose answer rate increases from 86% to 100%. However, the answer rates of some students, such as Student 1 and Student 15, decrease, which may be related to the adjustment of teaching content or the differences in students' adaptation to the new method. In terms of physics and chemistry knowledge points, the answer rate also improves after the reform, especially for Student 5 and Student 6, which increase from 72% and 84% before the reform to 94%

and 92% after the reform. The answer rates of some individual students, such as Student 8 and Student 9, decline, which may be related to individual differences or the mastery of subject content. Interdisciplinary integrated teaching has significantly improved students' knowledge in two subject areas. Although the grades of a few students have fluctuated, the overall trend shows that interdisciplinary teaching has effectively improved students' comprehensive subject ability and interdisciplinary knowledge integration ability.

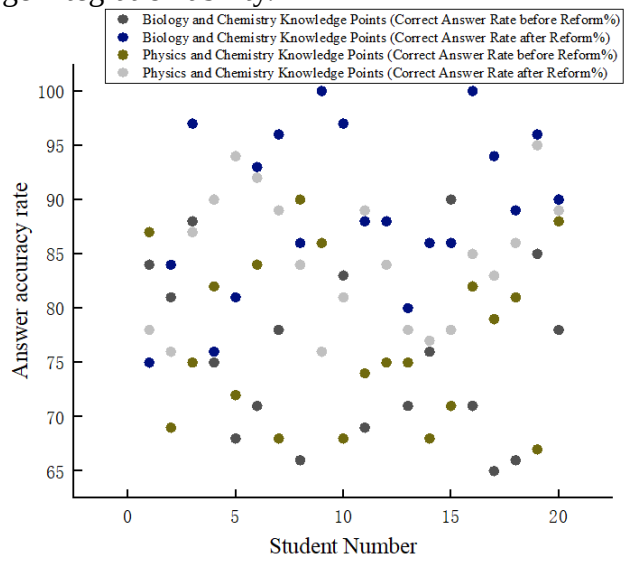

Figure 1: Comparison of correct answer rates for interdisciplinary knowledge points

4.2 Innovation Ability and Critical Thinking

In interdisciplinary integrated teaching, the improvement of innovation ability is the key to the development of students' comprehensive quality. Innovative thinking is usually measured by the number of innovative solutions proposed by students, reflecting their creativity and practical ability in solving interdisciplinary problems. Before the reform, the number of students' innovative solutions was relatively average, and the depth and breadth of innovation were limited. After the reform, students' innovative ability was significantly improved, and the number of solutions generally increased, showing that the interdisciplinary teaching model has stimulated students' active thinking. Through more interdisciplinary tasks, students can combine knowledge from multiple disciplines, try new solutions, and develop stronger innovative thinking. In groups with stronger teamwork, the number of innovative solutions is more prominent, showing the role of cooperation in promoting innovation. Overall, after the reform, students not only proposed more innovative solutions but also improved the quality and feasibility of the solutions, which verified that interdisciplinary teaching effectively cultivated students' innovative thinking. The following is a comparison of the number of innovative solutions of 20 students before and after the reform.

Figure 2 shows the changes in the number of innovative solutions of 20 students before and after the interdisciplinary integrated teaching reform. It can be seen that the number of innovative solutions has increased significantly after the reform, indicating that interdisciplinary teaching has effectively promoted students' innovative ability. Before the reform, the number of innovative proposals proposed by students is mostly concentrated between 1 and 4, and only a few students propose more innovative proposals. After the reform, the number of innovative proposals of the vast majority of students increase, especially for Student 5 and Student 6, whose numbers increase from 3 and 4 to 7 and 8, respectively, showing a significant improvement. The overall trend shows that interdisciplinary teaching has stimulated students' active thinking and prompted them to come up

with more innovative solutions. After the reform, students' innovative ability has been significantly enhanced, and the number of innovative solutions has generally increased, proving the positive role of interdisciplinary integrated teaching in cultivating students' innovative thinking.

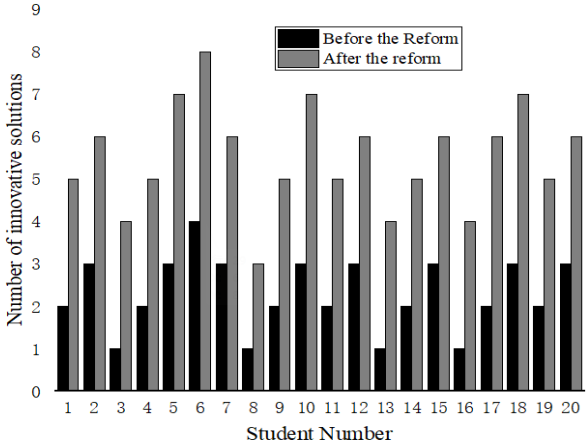

Figure 2: Comparison of the number of innovative solutions before and after the reform

4.3 Teamwork and Communication Skills

In interdisciplinary integrated teaching, the cultivation of teamwork and communication skills is crucial, which helps to improve students' collaborative spirit and collective problem-solving ability. Before the reform, students' teamwork scores were scattered, and some groups received lower scores due to poor communication or uneven task distribution. After the reform, the teamwork scores generally improved, indicating that interdisciplinary teaching has prompted students to pay more attention to collaboration and information sharing, and improved the efficiency of group work. Many groups were able to reasonably allocate tasks, clarify responsibilities, communicate more smoothly, and achieve significant cooperation results. Some groups, such as the groups of students 6 and 10, had particularly outstanding teamwork scores, demonstrating a strong spirit of collaboration. Overall, interdisciplinary teaching effectively promoted students' teamwork and communication and coordination skills. Figure 3 is a comparison of the teamwork scores of 20 students before and after the reform (full score 20 points):

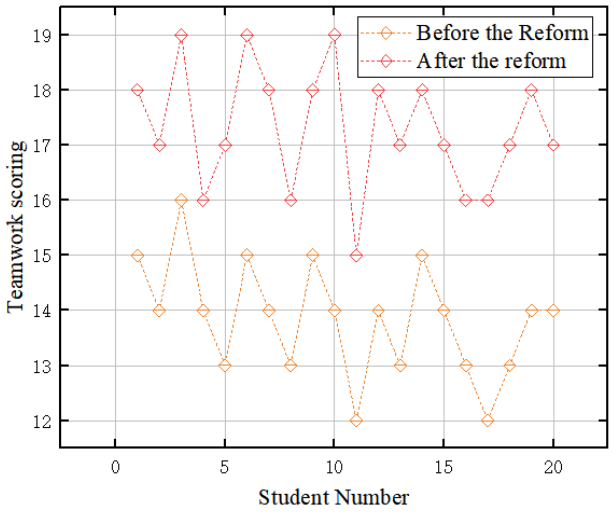

Figure 3: Comparison of teamwork ability scores before and after the reform

As can be seen from Figure 3, the teamwork scores after the reform are generally high, indicating that interdisciplinary teaching has effectively improved students' teamwork ability. Before the reform, students' teamwork scores are mostly concentrated between 12 and 15 points, and some students perform poorly, possibly due to problems in communication or task allocation. However, after the reform, the teamwork scores of all students improve, and most students' scores are concentrated between 16 and 19 points, showing the positive impact of interdisciplinary integrated teaching in promoting students' collaborative ability. In particular, student 6 shows significant improvement, with his score increasing from 15 to 19. Overall, the teamwork scores generally improve after the reform, indicating that interdisciplinary teaching promotes the improvement of students' communication, task allocation, and collaboration efficiency, and enhances their teamwork spirit and collective problem-solving ability.

5. Conclusion

This study significantly improved students' comprehensive quality by implementing interdisciplinary integrated teaching in high school biology teaching, especially in the mastery and application of subject knowledge, innovation ability, teamwork and other aspects. The experimental results show that interdisciplinary integrated teaching effectively enhances students' ability to integrate subject knowledge, the number and quality of innovative solutions have been significantly improved, and teamwork scores have generally improved, indicating that this teaching model has obvious advantages in cultivating students' ability to solve complex problems. The research contribution of this paper is that it provides an operational interdisciplinary integrated teaching framework through the combination of project-based learning and inquiry-based learning, and designs a comprehensive student comprehensive quality assessment system, which provides a theoretical basis and practical guidance for educational practice. This research has important practical significance, especially in cultivating students with the ability to solve complex problems in future society. This study also has some limitations, such as the small sample size, and the teaching design and evaluation methods may need to be further optimized. Future research can expand the sample range to further explore the best model for integrating different disciplines, and how to more efficiently cultivate students' interdisciplinary thinking and innovation capabilities to meet the changing social needs.

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