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Investigation the Current State of University Physics Teaching: A Case Study of Taishan University

Tingting Liu[1] & Haibin Sun[1]

[1] College of Physics and Electronic Engineering, Taishan University, Tai'an, Shandong, 271000, China

Correspondence: Haibin Sun, College of Physics and Electronic Engineering, Taishan University, Tai'an, Shandong, China. E-mail: sunhbphy@tsu.edu.cn

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Abstract

University Physics is a foundational course offered to undergraduate students in science and engineering programs outside of physics majors and it represents a foundational discipline in science and engineering education. However, traditional University Physics instruction has many areas in need of improvement. A questionnaire for undergraduate students was prepared and implemented in order to grasp the current status of teaching and learning of University Physics at our institution. Based on the statistical analysis of the survey data, the learning and teaching status of University Physics courses were identified, and teaching suggestions to improve the quality of classroom instruction were proposed.

Keywords: university physics learning, university physics teaching, questionnaire, quality of classroom instruction

1. Introduction

Physics is a natural science that studies the basic structure, forms of motion, interactions, and the laws of transformation of matter. The thinking methods embodied in physics have profoundly influenced the way of thinking of human beings and their basic understanding of the material world, and are an important cornerstone of the development of human civilization (Getty et al., 2020; Jiang, 2024). The University Physics course, which focuses on the fundamental theories of physics, is a foundational course offered to undergraduate students in science and engineering programs outside of physics majors. University Physics mainly includes the basic theories of mechanics, thermal physics, electromagnetism, optics, atomic physics and other branches of physics, and is characterized by solid theoretical studies, abstract concepts and complex formulas. It requires a high level of students' foundation of high school physics knowledge and proficiency in calculus. The University Physics course not only provides the necessary knowledge base for students to learn the subsequent specialization courses, but also play a vital role in cultivating students' scientific literacy and innovative thinking, and improving their analytical and problem-solving abilities (May et al., 2022; Scherr et al., 2023).

However, the traditional teaching of University Physics in China still has the following problems (Wang et al., 2022; Zhang et al., 2021):

(1) Theoretical knowledge is abstract and difficult to understand, and students' learning experience is poor.

The content of University Physics is often obscure and difficult to understand, covering a wide range of knowledge, and complex topics. Furthermore, the traditional method is based on classroom instruction and theoretical knowledge, and presents abstract concepts, unclear physical images, leaving most students with fragmented knowledge lacking summarization and integration. This leads to the students' difficulty to find correlation between the concepts and build a coherent knowledge framework. As learning becomes more difficult, students' interest and enthusiasm in learning physics gradually fade.

(2) Theoretical knowledge is disconnected from applications in real-world situations and society, leading to low student participation.

Traditional physics teaching fails to connect with real-life situations, classroom experiments and demonstrations are scarce, students are often unable to intuitively experience the actual physical phenomena and processes; due to the lack of sufficient hands-on experience, many students develop a fear of physics, and struggle to transfer their physics knowledge to other contexts. Their ability to practice physics and the ability to explore and analyze the problem solving ability requires improvement.

(3) Limited course hours and monotonous teaching resources.

University Physics covers a wide range of topics, but in the actual teaching arrangement, the teaching hours of University Physics are very limited, and it is very difficult to cover all the topics. The content of textbooks is too focused on the theoretical aspects, and hinders students from deeper exploration from a research perspective, affecting students' ability to grasp to the deeper essence and spirit of physics.

The importance of teaching University Physics in colleges and universities specializing in science and engineering is particularly prominent, and as a supportive discipline in engineering education, university physics teaching should play an active role in the development of new engineering disciplines. This study aims to assess the current state of students' learning experiences and teaching practices in University Physics for undergraduate students in science and engineering programs outside of physics majors through a questionnaire survey for undergraduate students at Taishan University, and proposes relevant teaching strategies to enhance the quality of classroom instruction in University Physics.

2. Research Process and Methodology

2.1 Content of the Study

The study mainly investigates the learning and teaching conditions of the University Physics course at Taishan University, including (1) current state of students' learning in University Physics; (2) students' interest in learning University Physics; (3) learning difficulty of University Physics; (4) students' satisfaction with the teaching of University Physics; (5) whether there is a significant difference in the evaluation of the teaching of University Physics for students in different majors; and (6) whether there is a significant difference in the evaluation of the teaching of University Physics between male and female students.

2.2 Research Design

This study is based on extensive reference to existing research, and designed the questionnaire "*University Physics Learning Status Survey Questionnaire*" for university students based on the years of teaching experience of the course team in University Physics. The first draft of the questionnaire was designed and then revised and finalized after a group discussion by the University Physics teaching team. The questionnaire consisted of students' basic information, students' self-assessment of their learning in University Physics, and students' evaluation of University Physics teaching.

2.3 Data Collection and Analysis

The respondents of this study were first-year undergraduate students at Taishan University who were enrolled in the University Physics course during the second semester of the 2023-2024 academic year. The questionnaire was conducted in the form of an online survey at the beginning of July 2024 through the Wenjuanxing platform (https://www.wjx.cn/), and a total of 650 questionnaires were collected. Responses that were incomplete or submitted in less than 90 seconds were excluded, yielding 608 valid questionnaires, with a validity rate of 93.54%.

The questionnaire consists of three main parts: the first part is the basic information, which involves the students' majors and gender; the second part is the students' learning of University Physics; the third part is the teaching evaluation on learning interest, learning difficulty and satisfaction. The scale questions used a 5-point Likert self-assessment format, with the levels being "Strongly Agree," "Agree," "Neutral," "Disagree," and "Strongly Disagree," assigned values of 5, 4, 3, 2, and 1, respectively. The score for each question reflects the degree to which students endorse the given item.

For the reliability test, the Cronbach's α coefficients for the dimensions of interest in learning, difficulty in learning, and satisfaction were 0.812, 0.910, and 0.821, respectively. This indicates high reliability of the questionnaire and good internal consistency. In the validity test, the KMO value was 0.873 and the Bartlett's test of sphericity results showed statistical significance, indicating that the variables were correlated and suitable for factor analysis.

In this study, we used Excel and other software to conduct descriptive statistical analysis and variance analysis of data to analyze students' evaluation of the quality of University Physics teaching, students' self-assessment of their learning, and differences in evaluation based on gender or major. The findings from data analysis provide a basis for proposing effective strategies to improve the quality of classroom instruction in University Physics classrooms.

3. Results

3.1 Basic Information on Students

Of the 608 students who participated in the questionnaire survey, 445 (73.2%) were male and 163 (26.8%) were female; the distribution of students by majors is shown in Table 1.

Table 1. Distribution of Survey Respondents by Majors

Major	Frequency	Percent
Software Engineering (Intelligent Software Services)	30	4.93
Intelligent Manufacturing Engineering (Intelligent power transmission and transformation equipment)	18	2.96
Artificial Intelligence	72	11.84
Civil Engineering	45	7.40
Civil Engineering (Upgraded)	44	7.24
Computer Science and Technology (Mobile Internet Technology)	40	6.58
Computer Science	165	27.14
Mathematics and Applied Mathematics	41	6.74
Mechanical Design, Manufacturing and Automation	60	9.87
Electronic Information	93	15.30
Total	608	100.0

3.2 Status of University Physics Learning

The survey showed that 66.10% of the students expect to be “proficient” in University Physics. This indicates that most students have clear learning objectives.

Regarding the state of classroom engagement, 24.5% of the students “always follow the teacher's thoughts and seldom get distracted” 53.1% of the students “listen attentively most of the time and occasionally get distracted”, and 18.8% of the students “listen only some of the time and are often distracted”. The main reasons of students distraction in class were: occasionally feeling sleepy and doze off (49.5%); the teacher's pace of lecturing is too fast making it hard to keep up with it, requiring recollection of previously learned concepts (47%).

The students’ preparation practices were: prepare for every class (5.9%), often prepare (9.7%), and sometimes prepare (64.8%). 64.6% of students reported that they were “able to keep up with the pace of the teacher” in class. This suggests that the majority of students who were able to maintain focus in class and those who prepare before class were able to keep up with the teacher's pace during lectures.

The survey shows that the some challenges in University Physics that students may face: the content of University Physics is too abstract (62.7%); struggling with advanced mathematics (48.4%); the course pace is too fast to keep up (30.6%); had not studied physics in high school (20.6%). In order to overcome learning difficulties students: consulted their classmates (61.8%); searched for information in the library or online (57.2%); sought help from teachers during class or on line (35%). Regarding the completion of homework: only 17.3% of the students “completed the homework independently”; 66.6% of the students completed the homework after “referring to problem sets and other resources”, and 10% “completed the homework after seeking help from others”. This suggests that students have a certain level of initiative in their learning process and are able to overcome their learning difficulties through peer collaboration, independent exploration, and teacher guidance.

The survey shows that the teaching resources that students prefer to use in the learning process include: textbooks (70.7%), courseware (62.7%), and online resources (55.2%). When studying university physics, 70.9% of the students reported watching university physics MOOC or micro-courses; the most commonly used learning platforms were: Zhihuishu, Chinese University MOOC (iCourse), and Chaoxing. This shows that students are able to utilize fragmented time for learning and possess initiative and motivation in their studies.

3.3 Current Status of Classroom Instruction in University Physics

The results of the survey showed that the students recognize positive aspects of classroom instruction in University Physics: the lecturing style of their instructor (68.3%), the teaching methodology (50.8%), and the classroom interaction (50%). However, students also noted that the course content was too large (62.8%) and the teaching pace was fast (57.2%).

The aspects of university physics teaching that students thought needed to be improved included: more lectures on problem-solving approaches and methods (57.2%), integrating more real-life applications (50.8%), and more demonstration experiments (41.4%).

Regarding the teaching method, 71.5% of the students preferred "combination of board writing and PPT presentation" 43.6% preferred "combination of online and offline learning" and only 16.4% preferred "completely relying on PPT presentation". Only 16.4% of the students preferred "relying entirely on PPT courseware explanations". This indicates that, during the teaching process, instructors provide students with a variety of educational and course resources. In their learning, students not only rely on textbooks and PPT slides but also make full use of online resources for University Physics.

3.4 Physics Learning Interest

Students' perception of the role and importance of University Physics affect their interest, so the questionnaire investigated students' interest in learning university physics from three aspects: the role of university physics, the importance of the course, their level of interest in learning, and the scores are shown in Table 2. The statistical results show that, compared with the other required courses in this major, the importance score of University Physics course is 4.19, which is slightly higher than the level of "very helpful"; the average score of the role of University Physics within the study of their majors is 3.73, which is close to "very helpful"; the interest level of students in studying University Physics is 3.63, which is close to the level of "moderately interested." The overall average score of the students' learning interest was 3.85.

Table 2. Statistical Scores of University Students' Interest in Learning University Physics

		Importance	Level of learning interest	Role	Total
Gender	Male	4.15	3.68	3.66	11.49
	Female	4.28	3.52	3.90	11.70
Major	Software Engineering	4.33	3.93	3.73	11.99
	Intelligent Manufacturing Engineering	4.72	4.33	3.78	12.83
	Artificial Intelligence	4.07	3.39	3.67	11.13
	Civil Engineering	4.38	3.62	3.96	11.96
	Civil Engineering (Upgraded)	3.68	3.16	3.36	10.20
	Computer Science and Technology (Mobile Internet Technology)	4.23	3.63	3.40	11.26
	Computer Science	4.07	3.62	3.60	11.29
	Mathematics and Applied Mathematics	4.22	3.61	3.95	11.78
	Mechanical Design, Manufacturing and Automation	4.25	3.60	3.95	11.80
	Electronic Information	4.40	3.89	3.94	12.23
Total		4.19	3.63	3.73	11.55

Table 3. Test Statistics [a,b] of the Kruskal-Wallis Test Results for Learning Interest

	Importance	Level of learning interest	Role
Chi-Square	25.361	30.027	23.362
df	9	9	9
Asymp. Sig.	.003	.000	.005

a. Kruskal Wallis Test

b. Grouping Variable: Major

Table 3 is the Kruskal-Wallis test results for university students' interest in University Physics across different majors The results show that the p-values for students' interest in University Physics, as well as the perceived importance and relevance of University Physics across different majors, are all less than 0.05. In other words, there are significant differences in learning interest across different majors. Intelligent Manufacturing Engineering students showed the highest interest, with a score of 12.83 and Civil Engineering (Upgraded) students had the lowest interest, with a score of 10.20.

Table 4. Independent Sample T-test Results of Gender Differences of Learning Interest

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Importance	Equal variances assumed	10.217	.001	-1.381	606	.168	-.123	.089	-.299	.052
	Equal variances not assumed			-1.555	371.940	.121	-.123	.079	-.279	.033
Level of learning interest	Equal variances assumed	1.647	.200	1.612	606	.108	.155	.096	-.034	.344
	Equal variances not assumed			1.685	314.991	.093	.155	.092	-.026	.336
Role	Equal variances assumed	17.591	.000	-2.611	606	.009	-.233	.089	-.408	-.058
	Equal variances not assumed			-2.860	348.776	.004	-.233	.081	-.393	-.073

Table 4 shows an independent samples t-test that was conducted to analyze the average scores in students' learning interest, importance of University Physics, and role of the course, for the male and female groups.

For the importance of University Physics, Levene's test showed that there was a significant difference in the variance between male and female students ($p = 0.001 < 0.05$). This requires analysis with unequal variances. The corresponding independent samples t-test showed no significant difference between male (n = 445, Mean (M) = 4.15) and female students (n = 163, M = 4.28), t (df = 371.940) = -1.555, $p = 0.121 > 0.05$.

In terms of interest in learning, Levine's test showed that there was no significant difference in the variance between male and female students. The results of the independent samples t-test showed no significant difference in learning interest between male (n = 445, M = 3.68) and female students (n = 163, M = 3.52), t (df = 606) = 1.612, $p = 0.108 > 0.05$.

For the role of University Physics, Levine's test showed that there was a significant difference in the variance between male and female students ($p = 0.000 < 0.05$). Independent samples t-test analysis showed that female students (n = 163, M = 3.90)) had significantly higher mean scores than male students (n = 445, M = 3.66), t (df = 348.776) = -2.860, $p = 0.004 < 0.05$.

In conclusion, among the students who participated in the survey, there is a statistically significant difference between male and female students in their perceptions of the role of University Physics, while there is no significant difference between male and female students in the level of importance of University Physics or their learning interest.

3.5 Learning Difficulty

The survey assessed the difficulty of learning University Physics by assigning a value of 1, 2, 3, 4 and 5 to the scale of "very easy", "relatively easy", "average", "relatively difficult" and "very difficult" respectively. The students' perceived difficulty scores for each unit and the overall course in University Physics are shown in Table 5, with an average difficulty score of 3.512 across the units. Students found that Mechanics was the least difficult section, with an average score of 3.38, which is close to "average". Electromagnetism was the most difficult, with a score of 3.72, approaching "relatively difficult". The reason is that students have a lot of opportunities to encounter mechanics concepts more frequently in everyday life, and have concrete experiences of it. In contrast, electromagnetism has a wide range of real-world applications but is more abstract, and students struggle to get intuitive experience and practical understanding of the concepts. The results of the survey showed that students perceived the overall difficulty score of the entire University Physics course to be 4.09, a score value significantly higher than the average of the difficulty scores for each unit. This suggests that students find it somewhat more difficult to integrate their knowledge of University Physics to solve related physics problems than they do to solve problems related to specific units like mechanics or thermal physics.

Table 5. Statistical Scores of University Students' Learning Difficulty of University Physics

		Mechanics	Thermology	Electro Magnetism	Optics	Modern Physics	University Physics	Total
Gender	Male	3.38	3.42	3.68	3.51	3.48	4.05	21.52
	Female	3.39	3.47	3.82	3.64	3.48	4.19	21.99
Major	Software Engineering	2.90	2.93	3.23	3.17	3.07	4.10	19.4
	Intelligent Manufacturing Engineering	2.61	2.78	3.00	2.83	3.00	3.67	17.89
	Artificial Intelligence	3.25	3.29	3.74	3.44	3.40	4.07	21.19
	Civil Engineering	3.56	3.73	3.82	3.71	3.58	4.27	22.67
	Civil Engineering (Upgraded)	3.89	4.14	4.23	4.25	4.14	4.66	25.31
	Computer Science and Technology (Mobile Internet Technology)	3.68	3.75	3.75	3.80	3.77	4.23	22.98
	Computer Science	3.40	3.42	3.70	3.48	3.44	3.95	21.39
	Mathematics and Applied Mathematics	3.63	3.59	3.95	3.83	3.54	4.15	22.69
	Mechanical Design, Manufacturing and Automation	3.23	3.17	3.52	3.27	3.27	3.83	20.29
	Electronic Information	3.30	3.33	3.76	3.54	3.47	4.14	21.54
Total		3.38	3.43	3.72	3.55	3.48	4.09	21.65

Table 6. Test Statistics [a,b] of the Kruskal-Wallis Test Results for Learning Difficulty

	Mechanics	Thermology	Electro Magnetism	Optics	Modern Physics	University Physics
Chi-Square	35.200	52.089	34.207	52.285	35.133	40.373
df	9	9	9	9	9	9
Asymp. Sig.	.000	.000	.000	.000	.000	.000

a. Kruskal Wallis Test

b. Grouping Variable: Major

Table 6 shows the results of the Kruskal-Wallis Test for the difficulty of learning University Physics for students from different majors. The results showed that there was a significant difference in the perceived learning difficulty of the individual units of University Physics and the course as a whole by students from different majors (all p-values below 0.05). Students in Intelligent Manufacturing Engineering reported the lowest overall learning difficulty score, 17.89. Students in Civil Engineering (Upgraded) reported the highest overall learning difficulty score, 25.31. A major contributing factor is that nearly half of the students enrolled in upgraded Civil Engineering programs did not take physics in high school, leading to greater challenges in learning University Physics.

Table 7. Independent Sample T-test Results of Gender Differences of Learning Difficulty

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Mechanics	Equal variances assumed	2.345	.126	-.048	606	.962	-.004	.094	-.188	.179
	Equal variances not assumed			-.050	315.081	.960	-.004	.090	-.181	.172
Thermology	Equal variances assumed	3.877	.049	-.598	606	.550	-.054	.091	-.233	.124
	Equal variances not assumed			-.636	327.021	.525	-.054	.086	-.223	.114
Electro Magnetism	Equal variances assumed	8.876	.003	-1.664	606	.097	-.141	.085	-.308	.025
	Equal variances not assumed			-1.807	341.875	.072	-.141	.078	-.295	.013
Optics	Equal variances assumed	7.542	.006	-1.542	606	.124	-.134	.087	-.305	.037
	Equal variances not assumed			-1.682	345.382	.094	-.134	.080	-.291	.023
Modern Physics	Equal variances assumed	4.880	.028	-.068	606	.946	-.006	.088	-.180	.168

	Equal variances not assumed			-.073	331.604	.942	-.006	.083	-.169	.156
College Physics	Equal variances assumed	.740	.390	-1.843	606	.066	-.143	.078	-.295	.009
	Equal variances not assumed			-1.985	335.581	.048	-.143	.072	-.285	-.001

Table 7 shows the results of the independent sample T test for the gender groups. The results show that there was no significant difference between male and female students in the cognition of the difficulty of college physics learning.

3.6 Students' Satisfaction

Table 8. Statistical Scores of University Students' Learning Satisfaction of University Physics

		Textbook	Curriculum Resources	Classroom Teaching Quality	Learning Achievement	Total
Gender	Male	3.96	3.96	4.03	3.31	15.26
	Female	3.93	3.99	4.12	3.14	15.18
Major	Software Engineering	4.27	4.10	4.33	3.57	16.27
	Intelligent Manufacturing Engineering	4.28	4.11	4.11	3.67	16.17
	Artificial Intelligence	3.78	3.78	3.78	3.17	14.51
	Civil Engineering	3.78	3.89	4.09	3.24	15
	Civil Engineering (Upgraded)	3.75	3.98	4.14	2.45	14.32
	Computer Science and Technology (Mobile Internet Technology)	3.93	4.00	4.10	3.07	15.1
	Computer Science	4.05	3.99	4.07	3.29	15.4
	Mathematics and Applied Mathematics	4.00	4.07	4.15	3.39	15.61
	Mechanical Design, Manufacturing and Automation	3.98	3.93	4.05	3.42	15.38
	Electronic Information	3.90	4.00	4.02	3.43	15.35
Total		3.95	3.97	4.05	3.26	15.23

The questionnaire evaluated the satisfaction with the teaching of University Physics in four areas: textbooks, course resources, quality of classroom teaching, and personal academic achievement, and the scores are shown in Table 8. The statistical results show that students' satisfaction with classroom instruction has the highest average score (4.05), which is slightly higher than "relatively satisfied," while their satisfaction with textbooks and course resources is slightly lower than the "relatively satisfied" level. Students' self-satisfaction with their academic achievement in University Physics averaged 3.26, which is slightly above the "average" level.

Table 9. Test Statistics [a,b] of the Kruskal-Wallis Test Results for Learning Satisfaction

	Textbook	Curriculum Resources	Classroom Teaching Quality	Learning Achievement
Chi-Square	13.946	6.953	14.782	45.130
df	9	9	9	9
Asymp. Sig.	.124	.642	.097	.000

a. Kruskal Wallis Test

b. Grouping Variable: Major

Table 9 shows the results of the Kruskal-Wallis Test for satisfaction with the teaching of University Physics for students across different majors. The results showed that the p-value of academic achievement in University Physics was below 0.05 for students across different majors. That is, there are significant differences in the perceived achievement of students in different majors. The Intelligent Manufacturing Engineering students had the highest satisfaction score, 3.67, and Civil Engineering (Upgraded) students had the lowest satisfaction score, 2.45.

Table 10. Independent Sample T-test Results of Gender Differences of Students' Satisfaction

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Textbook	Equal variances assumed	11.534	.001	.351	606	.726	.029	.083	-.134	.193
	Equal variances not assumed			.381	341.746	.703	.029	.077	-.122	.180
Curriculum Resources	Equal variances assumed	2.772	.096	-.332	606	.740	-.026	.078	-.179	.127
	Equal variances not assumed			-.345	311.138	.730	-.026	.075	-.174	.122
Classroom Teaching Quality	Equal variances assumed	3.816	.051	-1.203	606	.230	-.087	.073	-.230	.055
	Equal variances not assumed			-1.291	333.140	.198	-.087	.068	-.220	.046
Learning Achievement	Equal variances assumed	7.672	.006	1.958	606	.051	.167	.085	-.001	.334
	Equal variances not assumed			2.055	317.778	.041	.167	.081	.007	.326

Table 10 represents the results of the Independent Sample T-test for the gender groups of students' satisfaction. It has been shown that boys were significantly more successful than girls on the learning achievement and university physics textbook. The average score of textbook satisfaction of boys (3.96) was higher than that of girls (3.93), and the average score of learning outcomes of boys (3.31) was higher than that of girls (3.14). There was no significant difference in curriculum resources scores of male students (M = 3.96) and female students (M =3.93). There was also no significant difference in classroom teaching quality scores of male students (M = 3.31) and female students (M =3.14).

4. Conclusion

The statistical results of the questionnaire survey show that although students think that the overall difficulty of University Physics is at a "relatively difficult" level, they recognize the importance of the course, and have a high level of learning interest. However, there are significant differences in learning interest across different majors.

Students were more satisfied with classroom instruction, textbooks, and course resources, while self-assessment of academic achievement was more objective, and reflecting a significant difference between male and female students.

5. Recommendations

5.1 Restructuring the Three-Dimensional Course Objectives: Knowledge, Skills, and Literacy

Based on the outcomes based education (OBE) approach, the course objectives for University Physics should be restructured to focus on knowledge acquisition as the foundation, skill development as the core, and value formation as the goal.

(1) Knowledge Objectives

Master the core theoretical knowledge of physics and learn to develop physical models by rational simplification of real-life problems; apply qualitative analysis, order of magnitude reasoning, and dimensional analysis and be able to judge the validity of the conclusions; understand and master the various forms of motion in physics and their interconnections.

(2) Skill Objectives

Acquire a solid understanding of experimental procedures of physics through use of instruments, experimental operations, observation, data recording and processing, analysis of experimental results, and writing of experimental reports; build the ability to apply the knowledge of University Physics to identify, analyze, and solve physical problems, practicing inductive and deductive reasoning when approaching physical problems.

(3) Literacy Objectives

Judge the scientific value of relevant problems based on acquired knowledge, develop the ability to correctly assess scientific events related to physics; promote a spirit of scientific research and cultivate a positive scientific attitude; establish a well-rounded worldview that reflects correct values and life perspectives.

5.2 Building an Open and Dynamically Adjustable University Physics Knowledge System

First, the content of University Physics courses should be improved and enriched. In the teaching process, the course content should center on core knowledge (concepts, laws, theorems, etc.) while extending toward the forefront of physics development and engineering applications, offering "windows" and "interfaces" to introduce the cutting-edge physics knowledge and major achievements in physics development, so as to realize the dynamic connection between University Physics and real-world production and society. This can help students to understand the real-world applications (such as the practical application of physics theory) based on the physical knowledge they have learned, and to understand physics based on the perception of social reality, so as to grasp the theoretical knowledge of physics more comprehensively. These include, for example, studying variable-mass motion, as it can introduce students to the achievements of rocket science; fluid mechanics problems in hydraulic engineering can introduce students to calculations often used in modern mechanics; the rotations of a rigid body around a rigid point can introduce students to the role of gyroscopes in aerospace navigation; the law of conservation of angular momentum can help with the analysis of the movements of athletes in Olympic diving and figure skating, as shown in figure 1. This makes the University Physics course more contemporary, highlighting the cutting-edge and higher-level content, and stimulating students' interest and motivation to learn. Fostering interest in physics is a key component in national and international physics education standards (Zoechling et al., 2022). A student will be successful in his lesson if there is a desire in the student to learn (Ikbal et al., 2021).

Figure 1. University physics "windows" and " interfaces " knowledge

Second, building a coherent body of knowledge in University Physics can help students. The body of knowledge of University Physics involves a complete and extensive knowledge of classical physics, and many concepts are closely interrelated. The course should leverage students' prior knowledge and take advantage of the commonality among concepts to connect numerous physical principles and laws in an organic way, facilitating positive transfer of learning. This approach helps students clarify the relationships between similar concepts and rules, guiding them to build on what they already know in order to grasp new knowledge and skills, thus constructing a complete and coherent knowledge framework. For example, after students learn the three fundamental theorems of particle mechanics, they can smoothly progress to the mechanics of particle systems by understanding the characteristics of internal forces within such systems (equal in magnitude, opposite in direction, and appearing in pairs). This allows them to successfully derive the three fundamental theorems of particle system mechanics based on their knowledge of particle mechanics. Figure 2 is a mind map of particle mechanics depicted by a student.

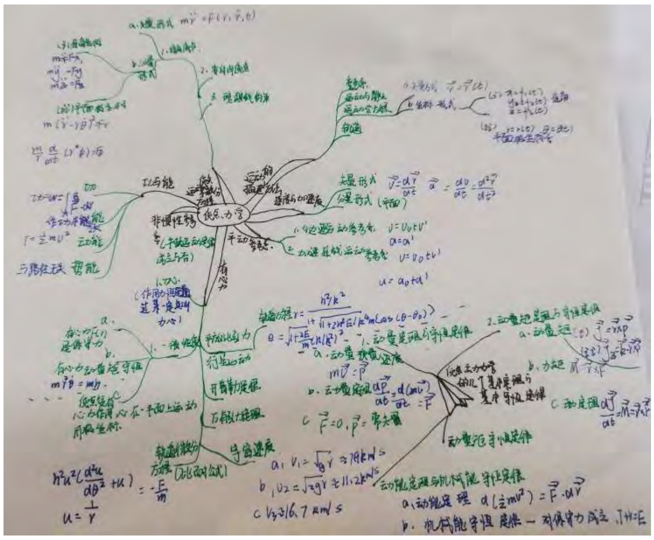

Figure 2. Student assignment: Mind map of particle mechanics

5.3 Strengthening Education on the Nature of Physics Science to Promote Students' Scientific Literacy

First, through the teaching of University Physics, it is essential to clarify fundamental concepts and help students grasp the nature of physics. The nature of science has been conceptualized to include concepts related to (1) how scientists work, (2) social and institutional dimensions of science, and (3) interactions between culture and science (Arbabifar & Nazerdeylamin, 2024; Kent-Schneider & Kruse, 2020). The conceptualization of physics is a process of continuous improvement and refinement. University Physics teaching should not only focus on giving definitions of physics concepts, but also on explaining the scientific nature that underlies physics concepts. Teaching activities should be centered on the nature of physics knowledge, guide students to trace the origins of ideas, help students clarify the evolution of knowledge, promote students to actively participate in the construction of knowledge, leading to meaningful learning and a deeper understanding of the scientific nature of physics. For example, through the teaching of mechanics can clarify the evolution of the concept of "force": as an important concept of classical physics, "force" has an preeminent position over other concepts in classical physics; the concept of force evolved from the ancient ideas of Chinese Mozi (also Mojing) and Aristotle, Galileo, through "Mathematical Principles of Natural Philosophy" by Newton, to "On the Conservation of Force" by Helmholtz. Many scholars have given different interpretations from different angles, and the concept has been revised and refined with the deepening of people's understanding of the natural world.

Secondly, through problem-based teaching and problem solving, the cultivation of students' physical modeling ability can be strengthened. The process of solving University Physics problems is essentially the process of building models based on physical situations. Physical models are the analysis of a physical problem or exercise situation, capturing the key elements and ignoring the irrelevant ones. The process of physical modeling is the process of properly understanding the scientific nature of a physics problem. In problem-based teaching, careful selection of exercises is essential, focusing on problems that are purposeful, set in realistic contexts, scientifically sound, and conducive to knowledge transfer. Students should solve these problems independently, share their solutions, and engage in collaborative discussions. The teacher should then demonstrates solutions and teaches problem-solving strategies, summarizing the underlying concepts, principles, and ideas within the problems. This process guides students to move from successfully solving a single problem to mastering "multiple approaches to one problem", enabling them to transfer this understanding to the scientific modeling of an entire class of problems. Finally, they synthesize the essential properties of that problem class by reducing multiple problems to a unified concept. Figure 3 is a multi-solution process of a mechanical problem. In the process of solving problems, students not only develop the ability of learning transfer, but also understand and master the essential scientific nature of physics problems. With improved transfer skills, students can be empowered to approach static problems more dynamically, seeing them as representatives of broader problem types. This allows them to escape the endless cycle of repetitive problem-solving and better understand the scientific principles underpinning physics.

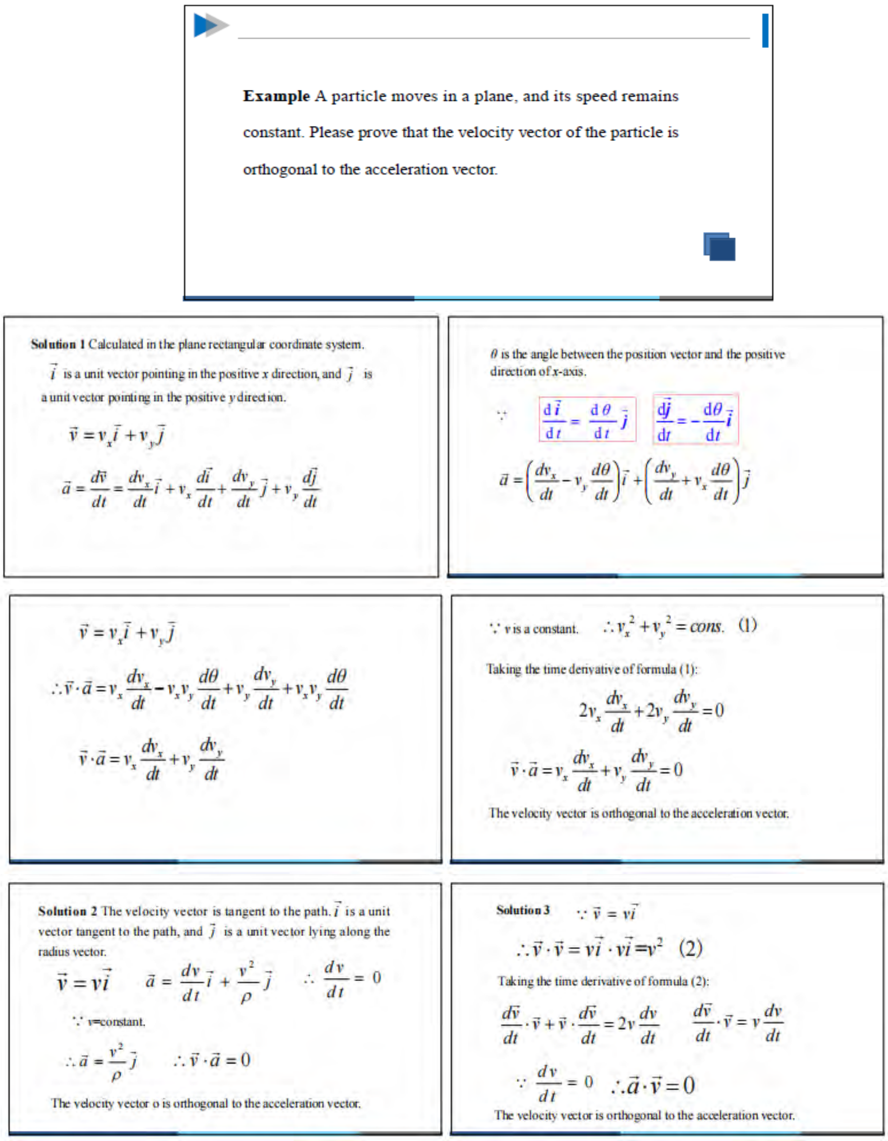

Figure 3. Example: multiple solutions to one problem

Thirdly, education in the scientific method should be strengthened to promote the development of students' thinking skills. In order to properly apply the scientific method, it is also necessary to unfold the process of applying the scientific method, presenting the process of establishing concepts and laws according to the internal logic of the scientific method. Instruction should incorporate specific physical problems to demonstrate the methods used to study such problems. By explicitly addressing these methods, students can develop a systematic understanding of the research approaches commonly employed in physics and their role in the discipline's development. Students should also master specific methods used in physics, such as ideal experiments, the concept of infinitesimals, the principle of conservation, dimensional analysis, order-of-magnitude estimation, and symmetry principles.

5.4 Implementation of Blended Learning Approach Combining Online and Offline Instruction

Relying on educational platforms, the development of MOOC and SPOC courses for University Physics allow for the implementation of blended learning that organically integrates of online and offline teaching. Teachers guide students to autonomous learning through the design of activities before, during and after class, fostering their motivation and engagement. Before class, teachers assign preparatory task sheets through the Super Star Learning App, where students do pre-study tasks independently; during in-class teaching, teachers incorporate in-class exercises, quick-response quizzes, and group discussions through the app, based on the course content.

After class, assignments are also distributed via the Xuexitong App. Considering the level of difficulty of the course content, certain parts (e.g., Newton's Laws of Motion, Conservative Forces, etc.) are made available for online study, and are followed by corresponding assessments. The implementation of blended teaching, while improving the quality of classroom instruction, also makes full use of students' fragmented learning time, effectively improving students' learning efficiency, and promotes the development of students' learning ability.

5.5 Enhancement of Physics Experiment Teaching

Physics is an experimental science and experiments are the foundation of physics. The teaching of University Physics must be based on experimentation, as it is determined by both the inherent characteristics of experiments and their role in physics education. Physics experiments can create an intuitive and vivid physical scenario for students, helping them to consolidate theoretical knowledge and promote the formation of scientific character and worldview; at the same time, through experiments can also cultivate students' observation, experimental, imaginative, and cognitive abilities. Figure 4 shows two entries of students participating in the China Undergraduate Physics Tournament: Upstream Stream and Colored Line. In the process of completing the work, students need to carry out research from both theoretical and experimental aspects. These experiments require fine and keen perception and observation to capture important phenomena promptly, so as to cultivate the observation ability; the design of experiments and the analysis of data can cultivate analytical and computational abilities. In the process of investigating causes, outcomes, and forming concepts, students engage in abstract and general logical thinking as well as dialectical reasoning. Through activities such as analysis, comparison, judgment, and inference, they develop logical thinking skills, including abilities in induction and analysis. The use of imagination and hypothesis helps strengthen and enhance their imaginative and creative abilities. Additionally, the practical aspects of conducting experiments and reporting results foster organizational and communication skills.

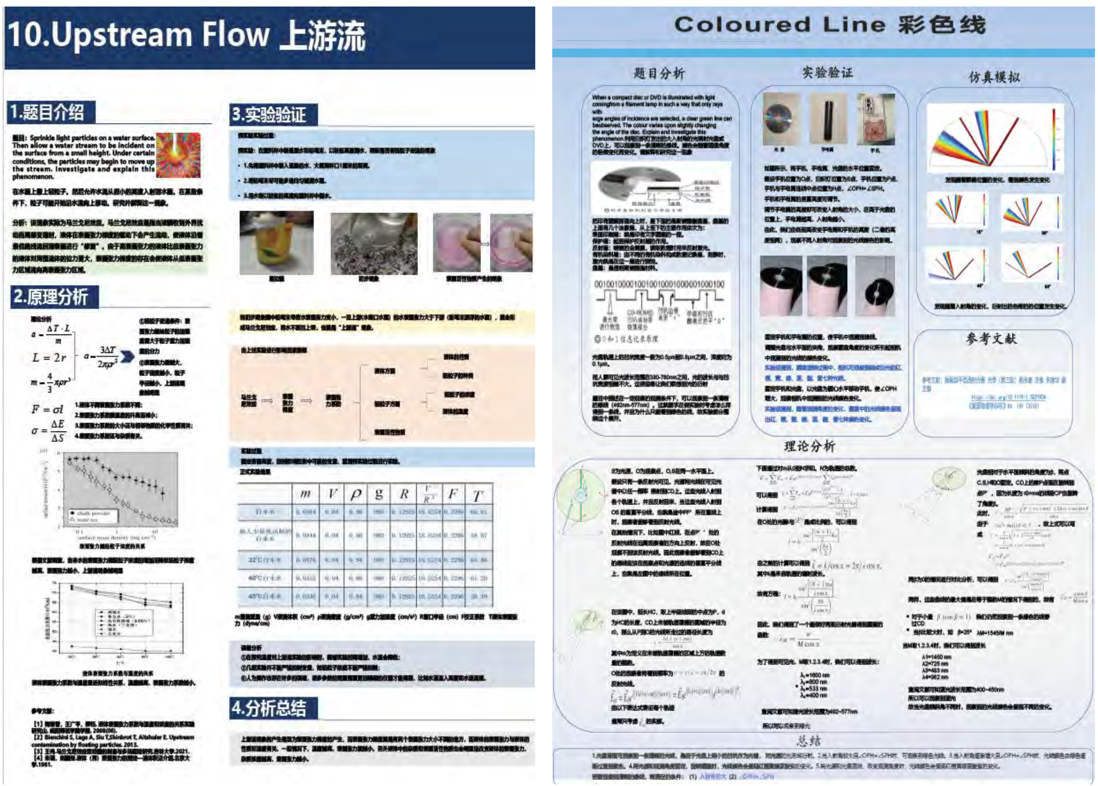

Figure 4. Entries of the China Undergraduate Physics Tournament

6. Limitation

Regardless of the promising results, it is critical to realize the limitations of this study. Firstly, the content of the questionnaire we designed is relatively simple. In order to fully grasp the present situation of college physics teaching in China, a more suitable modified questionnaire for undergraduate students is needed for further research. Second, the questionnaire survey was only conducted in one university. This means that the representativeness of our sample is not comprehensive enough.

7. Discussion

Modern information technology and booming artificial intelligence technology provide strong technical support for physics teaching. As we all know, the 2024 Nobel Prize in Physics was awarded to John Hopfield and Geoffrey Hinton for their pioneering contributions in the fields of neural networks and artificial intelligence. This major event is an effective booster for the popularization and application of artificial intelligence technology in University Physics teaching.

The application of artificial intelligence technology in University Physics teaching has the following characteristics: (1) The curriculum resources are rich and diverse. Teachers can include course resources such as lecture notes, courseware, animation, simulation experiments, and micro-classes to provide resource support for students ' online learning. (2) Diversified virtual physics experiments. Virtual experiment can solve the problems of insufficient experimental equipment and aging experimental equipment. The combination of virtual experiment and real experiment in teaching can provide students with virtual and real physics learning experience and stimulate students ' interest in learning (Schlummer et al., 2023; Velentzas et al., 2024). (3) Real-time dynamic interaction between teachers and students. Teachers can quickly respond to the needs of students and constantly optimize the teaching content. (4) Intelligent evaluation and feedback mechanism. Artificial intelligence technology can further analyze the learning situation based on students ' learning situation, help students adjust their learning progress and learning methods, so as to achieve better learning results. Of course, physics teachers should recognize the function of artificial intelligence, use the tool reasonably and correctly, and teach students in accordance with their aptitude, which cannot only rely on the use of intelligent tools.

In summary, the results of the questionnaire on the current state of University Physics teaching for undergraduate students indicate that students are willing to excel in the subject, show strong motivation to learn, and have a relatively high level of interest in studying University Physics. Classroom instruction in University Physics should be student-centered, building an open and dynamically adjustable knowledge and teaching system. It should adopt a blended learning method that organically combines online and offline instruction, strengthen physics experimental teaching, and emphasize the essence of physics, so as to enhance the quality of classroom instruction and the comprehensive development of students' scientific literacy.

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Authors contributions

Prof. Haibin Sun was responsible for study design and revising. Tingting Liu drafted the manuscript and Prof. Haibin Sun revised it. All authors read and approved the final manuscript. Authors have contributed equally to the study.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Obtained.

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Data sharing statement

No additional data are available.

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