Journal of Teaching & Research
teaching-and-research.jtr-nsp.com

Article

Effects of Research-Oriented Teaching Models on College Stu-dents' Innovative Thinking Development

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Citation: Chen, W., Xue, X., & Wang, X. (2026). Effects of Research-Oriented Teaching Models on College Students' Innovative Thinking Development. *Journal of Teaching & Research*, *1*(2), 57–66. https://doi.org/10.65170/jtr.v1i2.27

Abstract: In higher education, cultivating innovative thinking is an important goal to university students. The research-oriented teaching model, as an innovative pedagogical approach, aims to foster students' scientific inquiry and creativity by guiding them to participate in scientific research and solving real-world problems. This paper analyzes the impact of the research-oriented teaching model on the development of students' innovative thinking, identifying five primary effects: the stimulation of innovative thinking; the transformation of thinking patterns; the enhancement of thinking; the articulation of creative ideas; the integration with reverse thinking. However, the implementation of the research-oriented teaching model faces several challenges, including these issues: the insufficiency of resources and facilities, the limitations of teaching capacity and time availability, the pressure on students from projects and time management. With regard to these three questions, this paper puts forward corresponding solutions from the perspectives of re-sources, faculty construction, structure of courses and projects.

Keywords: Research-oriented Teaching Model; Innovative Thinking; Higher Education; University Students

1. Introduction

In today's society, whether an individual possesses innovative thinking has become an important factor to evaluate one's comprehensive quality(Karunarathne & Calma, 2024). Particularly in higher education, cultivating students' innovative thinking and creativity is a vital goal of education reform. Innovative thinking is not only the foundation of academic research but also the driving force behind the development of various industries(Wu, 2024). Therefore, the goal of university education is no longer merely to impart knowledge, but rather to emphasize the cultivation of students' innovative thinking(Yin, 2023).

The traditional teaching-centered model, which relied heavily on lectures, focused primarily on imparting knowledge and often fell short in stimulating and cultivating the student's innovative thinking. In contrast, the research-oriented teaching model integrates research into the educational process(Kuang, 2023). This model turns students to active learners and explorers. It allows students to develop their innovative thinking and problem-solving skills through actual research projects.

In recent years, many universities have begun to explore the application of this model and have achieved certain results. They established teaching practice bases(Li, 2025), developed research-based curricula(Shen et al., 2024), and introduced innovative experimental courses(Wu-Bin, 2020; Yingli et al., 2021) to cultivate students' research interests and innovative potential. However, although the research-oriented teaching model has been increasingly applied both domestically and internationally, systematic studies on its specific effects on students' innovative thinking are still somewhat insufficient. Existing research tends to focus on teaching outcomes within specific disciplines or fields, lacking a comprehensive exploration of its impact on students' innovative thinking across different disciplines and backgrounds.

Therefore, this study aimed to investigate the comprehensive influence of the research-oriented teaching model on the development of college students' innovative thinking through questionnaire survey and case analyses. It also identified the shortcomings in its practical implementation and proposed optimization strategies. The goal is to provide new insights for educational practice and useful references for higher education reform. This paper addressed the following core questions: What exactly is the connotation of the research-oriented teaching model? How does it influence college students' innovative thinking in practice and in what aspects? And how can it be optimized to better promote the cultivation of students' innovative thinking?

2. The Concept of the Research-Oriented Teaching Mode

The research-oriented teaching model is a teaching approach that takes research activities as its guiding principle, emphasizing the cultivation of students' scientific thinking and research abilities (Zhang et al., 2023). In this model, teaching is not confined to knowledge transmission, it enhances students' overall competence, especially their problem-solving and innovation skills, through participation in actual research work.

For universities, adopting a research-oriented teaching mode represents a shift from the separation of teaching and research ("science and education separation") to the integration of both ("science-education integration") (Yue, 2023). The teaching content is no longer confined to text-book knowledge but focusing on cutting-edge scientific issues. Students are exposed to the latest research findings and technologies in their fields. By engaging in real research projects, students could learn how to design experiments, collect data, analyze problems, and even publish results. Compared with traditional teaching-centered model, students play a more active role in this model, while teachers act as facilitators to guide students in exploring unknown problems.

3. Research Tools and Methods

This study was surveying undergraduate students online. We used an online questionnaire to gather data and investigate whether the research-based teaching mode impacts students' innovative thinking. At the same time, combined specific cases, such as curriculum reform in "Principles and Applications of Digital Signal Processing" and "Synthetic Biology" (Shuang et al., 2016; Zhang et al., 2025), This paper analyzed the specific aspects of the research-oriented teaching model impacting college students' innovative thinking.

This study employed the Williams Creativity Inventory (WILLIAMS, 1967) to examine college students' innovative thinking. A five-point scoring system was used, ranging from “strongly agree” to “strongly disagree,” with scores from 5 to 1. The scores for each item were summed or averaged, primarily covering four dimensions: risk-taking, curiosity, imagination, and challenge-seeking. Combined with the total score, we can obtain five scores. Higher scores indicate greater creativity levels.

4. Results

4.1 Survey Results and Statistical Analysis

4.1.1 Survey Population and Sample

This study surveyed college students. A total of 211 valid questionnaires were collected. The respondents covered different types students of universities. By gender, females accounted for 47% and males 53%. Freshmen accounted for 24.2%, sophomores 36.0%, juniors 27.0%, while seniors took a smaller proportion at 12.8%. By major, students across different disciplines were relatively even, with fewer students in arts and physical education majors. Additionally, 58.3% of the surveyed students had participated in courses primarily focused on research activities. The results were shown in Table 1 and chart 1.

Table 1. Descriptive Statistics

Category			Grade				Total
			Sophomore	Junior	Senior	Freshman	
gender	male	Count	40	37	12	23	112
		Percentage	35.71%	33.04%	10.71%	20.54%	100.00%
	female	Count	36	20	15	28	99
		Percentage	36.36%	20.20%	15.15%	28.28%	100.00%
major	Science & Engineering	Count	16	16	6	8	46
		Percentage	34.78%	34.78%	13.04%	17.39%	100.00%
	Agriculture & Medicine	Count	24	14	6	10	54
		Percentage	44.44%	25.93%	11.11%	18.52%	100.00%
	Arts & Humanities	Count	25	17	7	21	70
		Percentage	35.71%	24.29%	10.00%	30.00%	100.00%
	Arts & Sports	Count	11	10	8	12	41
		Percentage	26.83%	24.39%	19.51%	29.27%	100.00%
Total		Count	76	57	27	51	211
		Percentage	36.02%	27.01%	12.80%	24.17%	100.00%

4.1.2. Reliability and Validity Analysis

Reliability represents the consistency of the questionnaire. It is usually assessed by using Cronbach's Alpha coefficient. In this survey, the Cronbach’s Alpha coefficient for the scale was 0.973, indicating high reliability.

Validity represents the effectiveness of a questionnaire. The KMO value for this survey was 0.88, and the Bartlett test sig was 0.000. This indicates that the survey data is valid for analysis and that the data collected comes from a normally distributed population.

4.1.3. Survey Findings and Variation Analysis

This survey was conducted using the Creativity Trait Scale to assess the creative thinking of university students. Details of the participating students' creativity traits are presented in Tables 2, 3, and 4. The survey data reveals that the overall average creativity score for the university students was 174.36. The highest score achieved was 205, while the lowest was 88.

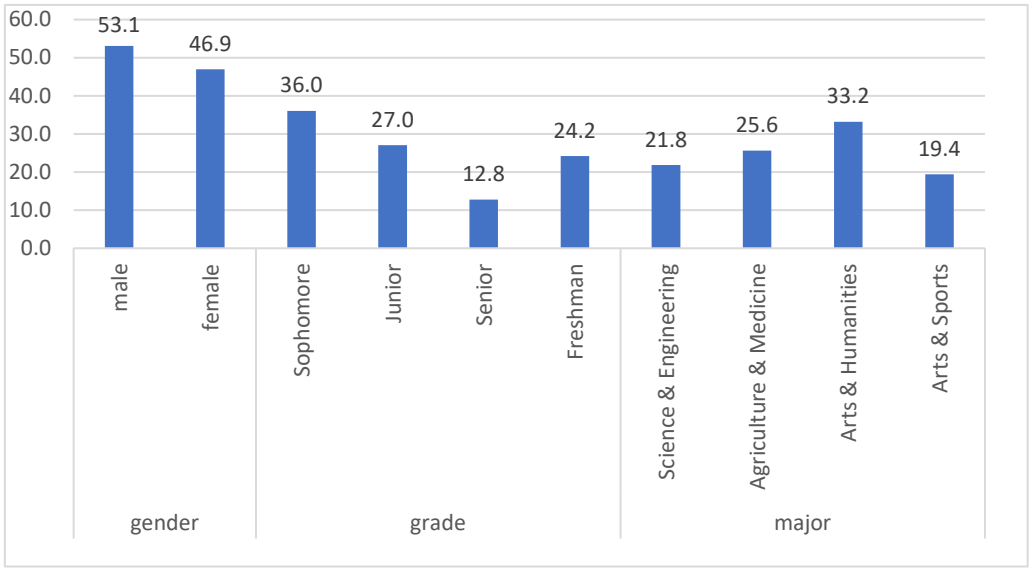

Chart 1. Sample Description Chart

This significant range suggests that there is a significant gap in creativity tendencies among participants, though the overall level is relatively strong. The mean scores for each scale item ranged from 1.8 to 4.18, with the average score of all items at 3.56. This suggests that the students showed a positive trend in creativity tendencies but remained a low overall level. Furthermore, the score differences across the various dimensions of creativity tendencies are not substantial, with overall performance hovering around 3.5. The mean score for curiosity was the lowest at 3.43.

When students were categorized based on participation in research-oriented courses, those who had participated scored around 3.5 across all dimensions. Only curiosity scores were lower among non-participants, The differences among other groups were not substantial. Among those who participated in research activities, students who participated more than three times had an average score of 3.7, while those who participated zero times or one to two times had similar average scores around 3.5. This suggests that research-oriented teaching models have a certain promotional effect on college students' innovative thinking, and students who participate in research activities more frequently exhibit more pronounced innovative thinking.

Table 2. Status of College Students' Creative Tendency

	N	Min	Max	Mean	SD	Var
Total	211	88	205	174.3649	37.21501	1384.957
Adventurousness	211	1.45	4.55	3.6092	0.86053	0.741
Curiosity	211	1.86	4.21	3.4306	0.63758	0.407
Imagination	211	1.69	4.46	3.6081	0.8112	0.658
Challenge	211	1.75	4.5	3.6209	0.83777	0.702
Creative Tendency	211	1.8	4.18	3.5617	0.76062	0.579

Table 3. The Score Performance of Students Who Participated in Scientific Research Courses or Not

	Adventurousness		Curiosity		Imagination		Challenge		Full Scale	
	Participation in Research-Oriented Courses									
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Number of Cases	123	88	123	88	123	88	123	88	123	88

Mean	3.650 407	3.551 653	3.459 93	3.389 61	3.635 397	3.569 93	3.653 117	3.575 758	3.593 821	3.516 818
Standard Deviation (SD)	0.844 664	0.883 85	0.630 982	0.648 073	0.788 525	0.844 958	0.815 686	0.870 405	0.745 593	0.783 22

Table 4. The Score Performance of Students Participating in Scientific Research Activities

	Full Scale	**Frequency of Participation in Scientific Research Activities**		
		0 times	**1 to 2 times**	**3 times and above**
Number of Cases	3.6209	3.5546	3.4772	3.7108
Mean	0.83777	0.76791	0.86061	0.56826
Standard Deviation (SD)	0.05767	0.06109	0.15981	0.116

4.2. The Impact of Research-Oriented Teaching Models on College Students' Innovative Thinking

Based on comprehensive analysis of student feedback and case studies from the survey results, research-oriented teaching models influence college students' innovative thinking primarily in the following five aspects:

4.2.1. Stimulation of Innovative Thinking

The research-oriented educational model innovates course design by creating a relaxed, open environment, where students can freely express ideas, engage in independent thinking and experiment boldly without being constrained by traditional frameworks. Moreover, students often encounter problems not covered in textbooks when participating in real-world research projects. It requiring them to step beyond traditional textbook frameworks to seek novel solutions. This teaching mode not only reinforces their understanding of classroom knowledge and teaches them how to apply it to diverse real problems, but also significantly stimulates their innovative thinking and academic enthusiasm. More importantly, it encourages students to question established conclusions rather than blindly accepting them and empowers them to actively explore scientific problems from different perspectives, solve issues with novel research approaches and pose questions from fresh angles. Thus, research-oriented teaching significantly stimulates innovative thinking among university students.

4.2.2. Transformation of Thinking Patterns

In research-oriented teaching, students often need to consult extensive academic literature to understand the theoretical knowledge about their projects. But it frequently usually covers not only their undergraduate major but also other disciplines. Students learn this theoretical understanding in the first, after gaining it, students apply it into practice during subsequent research, integrating these concepts continuously and forming their own knowledge framework ultimately. This interdisciplinary knowledge framework fosters their systematic and cross-disciplinary thinking patterns. When encountering research challenges across disciplines, students could generate innovative solutions through this cross-disciplinary thinking patterns while applying knowledge from their primary discipline and borrow theories and methodologies from other fields. This integration and application of interdisciplinary knowledge could cultivate students' comprehensive innovation capabilities(McChesney et al., 2025), it can enable them to address complex and cross-domain problems.

4.2.3. Enhancement of Thinking

The research-oriented teaching model focus on fostering students' innovative thinking and developing their critical thinking. Critical thinking requires students not merely to accept information when researching

scientific questions, but to analyze, evaluate, and question existing viewpoints and solutions. They must consider whether there are alternative explanations or more effective solutions. This is because existing theories or methods often fail to fully explain current scientific problems, necessitating students to challenge established research approaches or theories and innovate based them. So, under the research-oriented teaching model, students can boldly analyze and question existing solutions from multiple angles, it could significantly enhance their critical thinking skills. Moreover, enhanced critical thinking allows students to adjust strategies when encountering difficulties, avoiding repetitive ineffective attempts and improving innovation efficiency.

4.2.4. Articulation of Creative Ideas

The research-oriented teaching model sometimes requires college students to complete projects in teams, which places higher demands on their teamwork skills. In team cooperation, students need to demonstrate their own research capabilities, also need to learn how to communicate ideas with others, how to coordinate and integrate the shared resources of the team to make the team operate efficiently, and finally form research results. Through such teamwork, college students can draw inspiration from the collision of different thinking and stimulate more innovative ideas(Barak & Usher, 2019). That is, in the process of interacting with team members, students can learn how to find innovative breakthroughs among different ways of thinking and working methods. In addition, teamwork serves as a bridge, helping college students clearly convey their innovative inspirations.

4.2.5. Integration with Reverse Thinking

The research-oriented teaching model encourages students to make continuous attempts and learn from failures. It aims to help students break out of the conventional thinking framework, start from the results, and reversely deduce new solutions. In scientific research and exploration, failures are inevitable. When students find that their experimental data do not match their expectations, they may feel frustrated and confused, but this could be an opportunity to improve their research capabilities and thinking skills. This process of "learning from failure" helps students face failure more calmly, also helps cultivate their ability to combine innovative thinking with reverse thinking. This ability to integrate innovative and reverse thinking is not only crucial in research but will also become a significant advantage in their future careers for tackling complex problems and overcoming challenges.

5. Discussion

5.1 Application Limitations of Research-Oriented Education Models

Based on student feedback from the survey, the primary challenges encountered by students in participating in research activities within classrooms and schools are as follows.

5.1.1 The Insufficiency of Resources and Facilities

Research-oriented teaching requires a large amount of scientific research resources and equipment support. Especially in experimental and technology-intensive disciplines, universities usually have limited research equipment and laboratory resources, which cannot provide a research platform for all students and meet the all demands of participating in research projects. This creates objective limitations on students' research activities, preventing the research-oriented model from being effective. In addition, research projects usually require funding, and many universities are unable to provide sufficient financial support for every project. Therefore, students' research activities may face funding constraints, which could hinder the completion of projects.

5.1.2. The Limitations of Teaching Capacity and Time Availability

The research-oriented teaching model requires teacher possessing solid subject knowledge, research capabilities, project guidance experience, and dedicating sufficient time to student mentoring. However, not all faculty members have extensive research experience, and not all have adequate time to invest in undergraduate

research projects. This may lead students having difficulty obtaining timely and effective guidance when encountering challenges in their research. Teachers are unable to provide students with high-quality research guidance. They cannot effectively guide students to find innovative ideas for some complex research issues. Meanwhile, teachers do not invest sufficient time and energy in students' research projects, which ultimately leads to poor teaching effectiveness.

5.1.3. The Pressure of Students from Projects and Time Management

The research-oriented teaching model requires college students to participate in research projects in addition to their coursework. This undoubtedly increases the burden on college students. It is difficult for them to balance research tasks with other learning tasks, and they are more prone to fatigue and anxiety, which in turn affects the progress of research projects and the quality of their outcomes. In addition, some scientific research projects are too complex and highly challenging for most college students. Particularly in the early stages, students may struggle to quickly grasp research methodologies, which consuming substantial time that could otherwise be dedicated to coursework. This diversion inevitably impacts their academic performance.

5.2. Recommendations for Optimizing Research-Oriented Education Models

To enhance the cultivation of innovative thinking among university students through research-oriented teaching models, efforts must be made across multiple levels to build a student-centered educational environment that encourages innovation. This paper puts forward corresponding solutions from the perspectives of resources, faculty construction, structure of courses and projects for reference:

5.2.1 Resources

Firstly, universities can improve the efficiency of funding and equipment utilization by optimizing resource allocation and management: equipment can be shared among multiple student project teams to avoid idle resources; establishing a shared equipment platform allows students from different teams to schedule the use of the same equipment at different times; real-time monitoring through equipment management applications can enhance utilization. Secondly, universities can relieve financial and equipment pressures through corporate collaboration: universities and enterprises can establish long-term partnerships to jointly carry out research and development projects, enterprises provide financial support, assist in laboratory construction, and offer equipment and technical resources, while universities help commercialize technological innovations and involve students in the process. This approach not merely expose students to real research topics and technological applications, also teaching them how to transform scientific discoveries into practical products or technologies. These approaches enhance students' innovation abilities and provide insight for students the practical demands and market trends of scientific research. Finally, universities also can establish innovation and entrepreneurship programs and research competitions to stimulate students' creativity and practical skills in scientific research. These approaches above allow students to experience the entire research project cycle comprehensively, thereby deepening their theoretical understanding, fostering their innovation through competitions, and promoting their intellectual exchange.

5.2.2 Faculty Construction

First of all, colleges and universities can promote the training of young teachers, encourage and support them to improve their abilities through further studies, training, academic exchanges, etc. They can also set up special funds to support young teachers in enhancing their teaching and research capabilities by participating in international academic conferences, short-term research projects, and other means. Secondly, universities can adopt flexible employment methods, such as hiring external experts and part-time professors, to alleviate the problem of insufficient qualifications of some teachers. In addition, in cooperation with enterprises, universities can select a theoretical guidance teacher and a practical guidance teacher for college students from the school and the enterprise respectively, so that the teachers can provide sufficient and effective guidance for the college students. Through these methods, the problem of some teachers' insufficient experience and time in colleges can be effectively alleviated.

5.2.3 Structure of Courses and Projects

First of all, schools should reasonably arrange the number of courses and class hours according to the characteristics of each subject and should not excessively pile up course burdens. Especially for some courses that require practical results to be tested, schools should not set up too many assessment methods but should evaluate students' grades based on their project outcomes. Secondly, colleges should coordinate the assessment methods and times of different courses for students to avoid arranging a large number of assignments or exams in a concentrated manner during a certain period, thereby reducing students' exam pressure. Finally, the research-oriented teaching model encourages teamwork, and teamwork could enhance collective creativity and innovation capabilities. Teamwork also tends to alleviate students' time management pressures and the challenges posed by research problems. Institutions can increase the proportion of collaborative projects and interdisciplinary teams in teaching practices. Through group-based research projects, students take different roles, communicate ideas, and share perspectives. Addressing problems from multiple perspectives together enables them to solve complex issues beyond individual capabilities, thereby effectively alleviating research-related stress.

6. Conclusions

Research-oriented teaching models have multifaceted influences on college students' innovative thinking, including the stimulation of innovative thinking, the transformation of thinking patterns, the enhancement of thinking, the articulation of creative ideas, the integration with re-verse thinking. However, if want to better foster students' innovative thinking through such models, the key is providing a student-centered teaching environment that emphasizes autonomous learning, interdisciplinary collaboration, and practical exploration. Through multifaceted efforts, covering problem-driven research projects, independent inquiry, resource support, and teamwork, students can continuously be cultivated and developed innovative thinking throughout the research process, they can lay a solid foundation for their future academic and professional careers.

DATA AVAILABILITY STATEMENT

All data supporting the findings of this study are available within the article and its supplementary materials. Additional data may be obtained from the corresponding author upon reasonable request.

FUNDING

This study was supported by the key funding of Chongqing Higher Education Teaching Reform Research (NO.242056). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

AUTHOR CONTRIBUTIONS

Wei Chen: Conceptualization, Writing - original draft, Writing - review & editing, Investigation, Methodology, Data collection, Data analysis.

Xinyi Xue: Conceptualization, Writing - original draft, Investigation, Methodology, Data collection.

Xingyang Wang: Conceptualization, Writing - original draft, Writing - review & editing, Methodology, Investigation, Data collection.

ACKNOWLEDGEMENTS

The authors would like to thank all participants for their efforts in improving our paper.

COMPETING INTERESTS

The authors declare no competing interests.

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