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A Study of the Factors that Influence Learners' Scientific Research Ability and the Strategies for Promoting It

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Abstract:

The cultivation of learners' scientific research ability is an important element when it comes to training learners in higher educational institutes. In recent years, this research topic has received much attention in China. Focusing on current learners' scientific research ability, this paper first analyses the important places for this topic and the trends in the research. Then, it outlines the factors that influence learners' scientific research ability. By adopting interpretive paradigms, the paper constructs a multi-level hierarchical model of the factors influencing learners' scientific research ability. It proposes the following measures and suggestions: strengthen the top-level design; enhance the mechanism for guarantees; integrate team resources; improve tutors' level of scientific research and teaching; stimulate learners' motivation to learn and enhance learners' internal drive to develop their scientific research

Keywords: *Scientific research ability, Research hotspots, Research frontier, Research trends, Influential factors.*

I. RESEARCH BACKGROUND

The cultivation of students' ability is an important reference for measuring the quality of the education of students in higher education. To build a powerful higher education system, China has pointed out that it is necessary to "accelerate the construction of first-rate universities and disciplines and develop the connotations of higher education." Since students' scientific research ability is an important component of their overall ability, enhancing their scientific research ability is important for ensuring "first-class universities and disciplines, connotative development, and the development of high-quality talents. It is also a prerequisite for making the country strong in terms of higher education. Many scholars in China have studied students' scientific research ability. The question of how to improve students' scientific research ability has been an important one in domestic academic circles. However, no scholars have made a visual analysis of the research into the cultivation of students' scientific research ability. Nobody has built a model that shows its influencing factors. Therefore, using methods for visualizing bibliometric analysis, this paper visually analyzes the research trends and evolution of the existing research on the cultivation of students' scientific research ability. It examines 503 high-level academic papers published in

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the Peking University core periodical catalog or the CSSCI (Chinese Social Sciences Citation Index) between 1992 and 2021. These are retrieved from the CNKI database. It compares the factors that influence students' scientific research ability. Based on these, a multi-level hierarchical diagram is generated, and corresponding strategies are put forward to provide inspiration and reference for research into how to cultivate Chinese students' scientific research skills. Thus, the study contributes to the development of higher education.

CiteSpace software [1] is a tool for visualizing knowledge that is mainly used for bibliometric analysis. It can deal objectively with a large number of scientific studies and with information related to visualization. It was developed by Professor Chaomei Chen's team [1] and runs in the Java environment.

1.1 Research Hotspots

The keywords reflect the general gist of a paper. By analyzing the co-occurrence of keywords using visual analysis software, we can find out how certain research themes have developed. Using the keyword clustering technique, [1] 696 nodes were obtained along with 1,344 lines. The results of the keyword clustering are shown in TABLE 1, where Q = 0.6843. This indicates that the clustering is reasonable since the Q-value is greater than the critical value of 0.3. The keywords with high frequency and high centrality levels are combined, deleted, and summed up into four clusters: the cluster of "scientific research ability," the cluster of "innovation ability," the cluster of "student cultivation in higher education institutions," and the cluster of "experimental and practical teaching." These keywords are the main research hotspots and focal points in this field. This demonstrates that when it comes to the cultivation of students' scientific research ability, Chinese higher education institutions pay more attention to the promotion of students' innovation and creativity through experimental and practical teaching. By summarizing and classifying the keywords that occur frequently, it becomes clear that research into the cultivation of students' scientific research ability in China mainly focuses on the following three research topics: the importance of cultivating students' scientific research ability, the content involved in cultivating students' scientific research ability, and the ways that students' scientific research ability can be cultivated. For this reason, three research topics were explored. Research topic 1: stemming from the demands of the new era, requirements for high-quality student training, students' internal needs, and other aspects, scholars including Huang Zijian [2] and Lin Zhang [3] point out that higher educational institutions should pay attention to cultivating talents with outstanding scientific research and innovation abilities. Research topic 2: scholars such as Wang Chuanyi [4] believe that fostering students' scientific research literacy, innovation, thinking, practical skills, cooperation, and responsibility are important when it comes to cultivating students' scientific research ability. Research topic 3: scholars like Huang Zijian and Qiu Yuting [5] have suggested that students' scientific research ability can be improved by consolidating their basic knowledge, searching the literature, refining scientific problems, carrying out experiential scientific research and training, independently designing and implementing experimental research programs, strengthening academic exchanges, composing proposals for scientific research projects, writing scientific research articles, participating in various scientific research competitions, and more.

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TABLE I. Cluster map of research topics of student's scientific research

Serial Number	count	Centrality	First year	Keywords
1	52	0.23	2004	postgraduate students
2	35	0.18	2003	innovation ability
3	27	0.18	2000	academic ability
4	25	0.14	1999	undergraduate students
5	28	0.12	2003	experimental teaching
6	27	0.12	2000	scientific literacy
7	39	0.10	2001	SC (scientific research)
8	21	0.10	2003	scientific research ability

1.2 Research Trends

By using CiteSpace's burst detection technology, we can find out the burst words that occur frequently in a certain period. The burst words reflect the frontiers for research and trends involved in a certain research theme. With the setting of Top N = 50, this article obtains the first 15 burst words related to students' scientific research ability. The results are shown in TABLE II. As can be seen from TABLE II, in addition to the research themes related to "scientific research" and "research ability," as well as other related keywords such as "undergraduate students," "college students," and "postgraduate students," the keyword "innovation" had the longest burst duration from 1999-2008; the burst duration of "scientific literacy" lasted from 2004 to 2008; the burst duration of "experimental teaching" and "research methods" lasted three years. With the emergence of the burst phrase "experimental teaching," studies of Chinese students' scientific research ability have proliferated rapidly. Since 2017, burst words like "talent cultivation mode" and "scientific spirit" have gradually appeared. As far as the strength of burst words is concerned, words such as "experimental teaching" (strength = 4.22) and "scientific literacy" (strength = 3.32) are strong. In a review of the literature related to these words, we found that the following articles had an important impact on "experimental teaching" and "scientific literacy": Li Xue-hui et al(2008).'s article, "Exploration and practice for enhancing the innovative capability of undergraduate based on promoting scientific research and experiment teaching each other," and Li Bing-yan(2008)'s article "Scientific inquiry, scientific literacy, and science education."

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TABLE II. Bursts of keywords related to the theme of cultivating students' scientific research ability in china

Keywords	Strength	Begin	End	1992-2021
scientific research	3.57	1992	2010	
undergraduate students	2.72	1999	2008	
innovation	2.96	2003	2009	
scientific literacy	3.32	2004	2008	
research	2.01	2007	2010	
research ability	1.73	2007	2014	
experimental teaching	4.22	2008	2010	
academic ability	2.83	2009	2009	
research methods	1.76	2010	2012	
college students	3.12	2011	2013	
academic research	2.7	2011	2014	
postgraduate students	2.35	2012	2015	
cultivation	2.41	2017	2017	
cultivation mode	1.79	2017	2017	
scientific spirit	1.76	2020	2021	

II. AN ANALYSIS OF THE FACTORS THAT INFLUENCE STUDENTS' SCIENTIFIC RESEARCH ABILITY AND THE CONSTRUCTION OF A STRUCTURAL MODEL

The research status, hotspots, and frontiers for students' scientific research ability show that this research theme has grown in importance each year. Its core research institutions mainly consist of the long-established universities, such as the "985 Project" and the "211 Project" series of key universities, as well as first-rate universities. Local colleges and universities need to strengthen their research on this topic. The research hotspots and research frontiers further indicate that higher education institutions should pay attention to the cultivation of students' comprehensive abilities, especially their scientific research ability. This would promote the connotative development of higher education institutes. Only through connotative construction can we promote the high-quality development of local higher education institutions. Additionally, since development will be the theme of various colleges and universities at different levels for a long time to come, it is necessary to clarify the factors that influence students' scientific research

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ability. This can be used to construct a multi-level hierarchical model with the use of interpretive paradigms.

Interpretive paradigms [8] can be used to produce multi-level hierarchical results for systems with many variables and complex relationships. They have a wide range of applications related to energy, the economy, enterprises, and other fields. They are part of a specialized research method related to educational technology. The implementation procedure involves the following steps, form the implementation group, set up the key problems, select the leading influential factors and the correlations between the key problems, establish the adjacency matrix and the reachability matrix, and establish the structural model.

The cultivation of students' scientific research ability in local colleges and universities is influenced by many factors. According to the above literature review and the suggestions from eight experts on the research topics of students' scientific research ability, ten key factors were extracted regarding the cultivation of students' scientific research ability in local colleges and universities. These are shown in TABLE 3. The adjacency matrix and the reachability matrix were established by using the interpretive structure model for the influential factors, with the reachability matrix shown in TABLE 4. According to the reachability matrix, a multi-level hierarchical structure diagram of the factors influencing the cultivation of students' scientific research ability in local colleges and universities was finally obtained. This is shown in Fig 1.

TABLE III. Influential Factors of Students' Scientific Research Ability Cultivation

Serial Number	Influential Factors	Detailed Interpretation of Influential Factors
1	T1: Talent cultivation mode	Set clear cultivation goals, optimize, and integrate the arrangements of teaching and scientific research resources, choose suitable talents (students and teachers), lay a foundation for professional knowledge and experimental practical skills, create a cultural atmosphere admiring scientific research, and pay attention to the way of cultivating talent in scientific research training.
2	T2:Scientific research conditions	Sufficient research funds, space, experimental equipment, and library resources are important material guarantees for students' scientific research ability.
3	T3:Scientific research atmosphere	This refers to the academic atmosphere of the scientific research created by the state, society, universities, and teams.
4	T4:Academic exchanges	Academic innovation could be promoted through exchanges and interactions between different universities in different regions.
5	T5: Academic level and scientific research ability of tutors and teams	Teachers' influences on students in terms of teachers' own scientific research literacy, innovation, creative thinking ability, and teaching methods are the guarantees of teaching staff for students' scientific research ability cultivation.
6	T6:Curriculum system and content design	It includes the curriculum for theoretical and experimental practice designed to influence students' scientific research ability through the teaching content, teaching methods, and so on.
7	T7:Students' research interests	The internal drive to explore scientific problems. Students influence their level of scientific research ability through a rigorous, realistic, and persistent scientific attitude. It also involves a sense of responsibility to protect the environment and promote sustainable development.
8	T8:Students' independent scientific research ability	The independent innovation ability of scientific research is a kind of internal, active, and spontaneous behavior, which is the main factor to improve students' scientific research ability, including students' mature

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		thinking and deep insights.
9	T9:Quantity and quality of students participating in scientific research projects	The number and level of scientific research projects directly affect whether students have the opportunity to participate directly in scientific research projects for scientific training. [8]
10	T10:Students' scientific research literacy	Academic ethics and academic norms.[8]

TABLE IV. Reachability Matrix of Factors that Influence the Cultivation of Students' Scientific Research Ability

Tj / Ti	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
T1	1	1	1	1	0	1	1	1	0	1
T2	1	1	1	1	1	1	1	1	1	1
T3	1	1	1	1	0	1	1	1	0	1
T4	0	0	1	1	1	1	0	1	0	1
T5	1	0	1	1	1	1	1	1	1	1
T6	0	0	0	1	1	1	1	1	0	1
T7	0	0	0	1	0	0	1	1	0	1
T8	0	0	0	0	0	0	1	1	1	0
T9	0	0	0	0	0	0	1	1	1	1
T10	0	0	0	0	0	0	1	1	1	1

Notes: If Ti has an influence on Tj, the corresponding position in the table is 1, and if it has no influence or the same influence, it is 0 (i, j=1,2….8)

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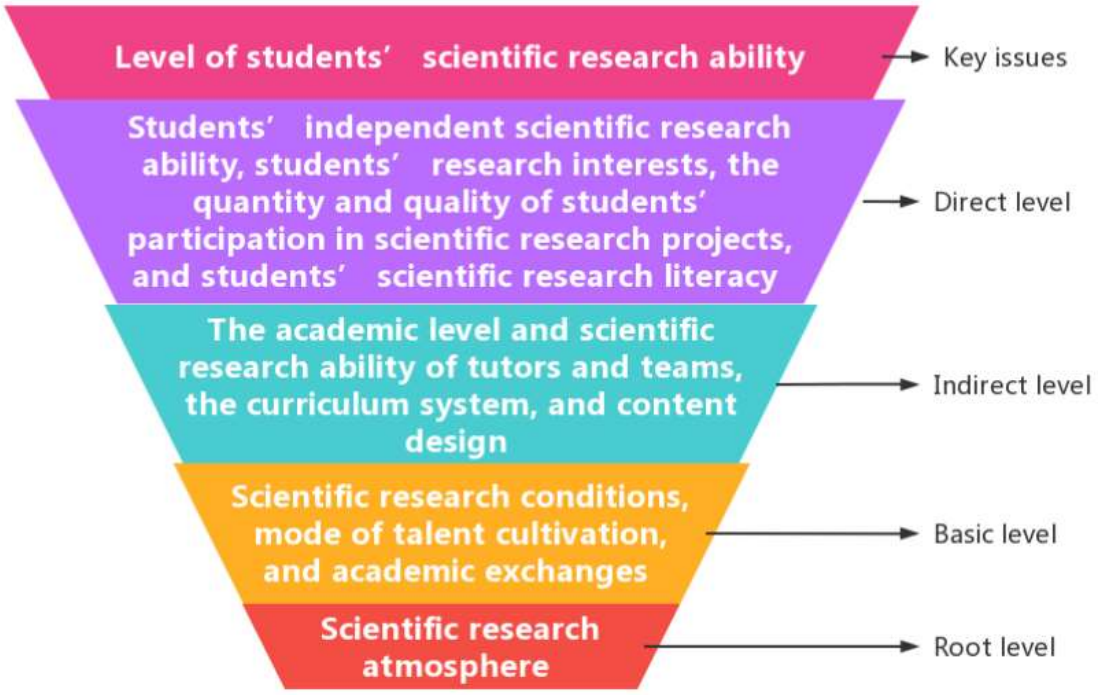

Fig 1: multi-level hierarchical model of the factors that influence students' scientific research ability

III. PROMOTION STRATEGIES TO IMPROVE CURRENT STUDENTS' SCIENTIFIC RESEARCH ABILITY

As shown by the multi-level hierarchical model of the factors that influence students' scientific research ability, the influential factors for this research theme are categorized into four levels: the root level, basic level, indirect level, and direct level. The level of students' scientific research ability is directly affected by four factors: students' independent scientific research ability, students' interest in scientific research, the quantity and quality of students participating in scientific research projects, and students' scientific research literacy. Furthermore, students' ability is indirectly influenced by the academic level and scientific research ability of their tutors and teams, as well as by the design and content of the curriculum. The factors of scientific research conditions, mode of cultivating talent, and academic exchanges can improve students' scientific research ability. Finally, the scientific research atmosphere is the root influence on students' scientific research ability. Creating a proper scientific research atmosphere could have a significant impact on the other nine factors. Based on the influence that these ten factors have on students' scientific research ability, relevant strategies could be adopted to improve students' scientific research ability. More specific suggestions are displayed in the following sections.

3.1 Strengthen the Top-level Design and Improve the Guarantee Mechanism

Western developed countries usually display proper top-level design and overall arrangement in the way that they cultivate students' scientific research ability. Their overall future development is clearly defined by formulating professional development plans that pay attention to the severe challenges that students can face when cultivating their scientific research skills. The people responsible for top-level

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design in higher education institutions should create a well-structured, scientific, standardized, mature, efficient, and practical system for cultivating students' scientific research ability. They should create a moderate atmosphere for scientific research, improve the relevant mechanism for guaranteeing hardware and software, formulate a way of cultivating talents that foster scientific research ability, and strengthen academic exchanges. This would provide logistical support for cultivating students' scientific research ability.

3.2 Integrate Team Resources and Improve Tutors' Level of Teaching Regarding Scientific Research

At present, some problems in the teaching staff hinder the development of students' scientific research skills. These include an incomplete structure, low-quality and scattered resources, and insufficient experience. Therefore, it is important to improve the specialized construction level of teaching staff and perfect the relevant support plans. Regarding the construction of the teaching staff, efforts should be made to build a scientific research team composed of junior, senior, and expert tutors with a proper structure. Team-wide scientific research and teaching resources should be integrated. Based on solid theoretical knowledge of scientific research, the curriculum and the content should be reasonably constructed, with practical training provided for teaching scientific research skills. Tutors should fulfill their roles in teaching and education to cultivate students' scientific research ability by developing their thinking skills in scientific research and promoting their mastery of scientific research methods and their application of research technologies.

3.3 Stimulate Students' Motivation to Learn and Enhance Their Internal Drive for Scientific Research and Development

Many students have an insufficient ability to learn, the root cause of which is a lack of motivation and internal drive to develop their scientific research. After three years of intense study in high school, students are prone to the illusion that they no longer need to devote themselves to serious learning once they enter university. To strengthen their motivation for learning, students should, first of all, take part in training sessions to teach them scientific research methods. They should make use of the scientific research conditions in their school, take initiative, and constantly reflect on their scientific knowledge and literacy. Second, higher education institutions or other educational departments should formulate effective incentive mechanisms and reward systems. These rewards should be given to students who have been innovative in their study methods, made breakthroughs with difficult scientific problems, or improved their scientific research skills. Only in this way will students become interested in scientific research. This will eventually encourage students' scientific research skills by boosting their internal desire to engage in scientific research.

IV. CONCLUSION

Training students is a perennial focus for higher education institutions. Higher education institutions need to develop students' scientific research skills so they can develop to a high standard. There are various challenges related to developing students' scientific research ability, but through combined efforts

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to strengthen top-level design, integrate the resources of the faculty, and stimulate students' internal drive for scientific research, the abilities of students to engage in scientific research will improve. This will lead to improvements in the quality of higher education institutions throughout the nation.

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