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A Study on the Impact of Supervisor Styles on the Innovative Abilities of Graduate Students in Materials Science

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Abstract: Against the backdrop of increasingly fierce technological competition, the innovative development of materials science is of vital importance. As the backbone of the future of the discipline, graduate students' innovative abilities are of great concern. Tutoring styles, as a key factor, have an urgent need for in-depth exploration of their impact on the innovative abilities of graduate students in materials science. This study focuses on the impact of tutoring styles on the innovative abilities of graduate students in materials science. By combing through relevant literature and conducting practical surveys and analyses, the study explores the characteristics of different tutoring styles and their mechanisms of action on graduate students' innovative thinking, practical abilities, and other aspects. The study finds that scientific and rational tutoring styles can significantly enhance the innovative abilities of graduate students in materials science, providing theoretical basis and practical references for optimizing tutoring strategies and improving the quality of graduate student training.

Keywords: tutoring styles, materials science, graduate students, innovative abilities

1. Introduction

In today's world of rapid scientific and technological development, innovative ability has become a key indicator of the quality of graduate student training. Materials science is an important field that promotes scientific and technological progress and social development, which demands that graduate students must possess strong innovative abilities. Tutors play a crucial role in the training of graduate students, and their tutoring styles directly affect the development of graduate students' innovative abilities. Therefore, an in-depth exploration of this issue holds both theoretical and practical significance.

2. Types and Characteristics of Tutoring Styles

2.1 Authoritative guidance style

In the context of graduate student training in materials science, the authoritative guidance style is a relatively traditional and distinctive tutoring approach. Such tutors usually have extensive experience in the field of materials science, with rich research experience and profound professional knowledge. They hold high academic prestige and influence in their research areas, and their academic viewpoints and research ideas are often widely recognized within certain circles. When providing guidance to graduate students, tutors with an authoritative guidance style leverage their professional strengths to offer clear and detailed research plans. From material selection, experimental design to data analysis methods, the tutor provides specific instructions and requirements. Even at critical stages of the research process, strict supervision is maintained. For instance, in the study of the properties of new composite materials, the

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tutor will draw on their own research experience to clearly state which combination of matrix materials and reinforcements holds more research value, determine the preparation process to be used (e.g., hot-press sintering, melt blending), and specify the range of process parameters (Wang et al., 2024). During experiments, if graduate students encounter abnormal data or results that do not meet expectations, the tutor will rely on their rich experience to quickly identify the problem and directly provide a solution, guiding the students to conduct research in the predetermined direction. This guidance style can help graduate students avoid detours at the beginning of their research and quickly master the basic research methods and experimental skills in materials science, thereby ensuring that the research work is carried out efficiently and orderly. However, since the tutor dominates the research process, the space for graduate students to think independently is relatively limited, which may to some extent restrict the development of their innovative thinking. As a result, some graduate students may become accustomed to relying on the tutor's guidance and lack the courage to actively explore and attempt new research ideas. Under the authoritative guidance style, graduate students are prone to developing excessive dependence on their tutors. When faced with new research challenges without precedents to follow, they may lack the ability to cope independently. Moreover, the tutor's established experience and perspective may limit the graduate students' exposure to diverse academic ideas and hinder the development of a comprehensive and broad academic vision. In the long run, this can pose certain obstacles to improving the graduate students' overall academic literacy.

2.2 Heuristic guidance style

Contrary to the authoritative guidance style, heuristic guidance tutors in materials science place a greater emphasis on stimulating graduate students' independent thinking and innovative awareness. These tutors also possess solid professional knowledge in materials science and strong research capabilities. However, their approach focuses more on guidance rather than direct instruction (Tan et al., 2024). At the beginning of the research stage, instead of devising a detailed research plan for the students, the tutor highlights the cutting-edge research directions and key scientific issues in materials science. They provide graduate students with a wealth of literature and research leads, guiding them to gradually clarify their research interests and directions through independent reading and analysis. After the research topic is determined, the tutor encourages graduate students to independently design experimental plans. For example, in the study of the corrosion and protection properties of materials, the tutor does not directly stipulate which corrosion testing method to use or how to protect the coating material. Instead, they guide graduate students to consider the advantages and disadvantages of various testing methods, the mechanisms of material corrosion, and the mechanisms of protective coatings, enabling students to propose preliminary experimental plans based on their understanding and research objectives. During the experimental process, when graduate students encounter difficulties and confusion, the tutor does not immediately provide answers. Instead, they use a series of heuristic questions to guide students to think from different perspectives. For instance, when experimental data fluctuates, the tutor might ask, "In your opinion, what factors affect the stability of experimental data?" and "What impact might changing a certain experimental condition have on the results?" These questions encourage graduate students to actively review literature, analyze the experimental process, and independently seek solutions to problems. This guidance style can fully mobilize graduate students' enthusiasm and initiative in learning. In the process of independent exploration, their innovative thinking and ability to solve complex problems are continuously exercised. By independently designing experiments, analyzing data, and summarizing research findings, graduate students gain a deeper understanding of the essence of materials science research and gradually develop their unique research ideas and methods, laying a

solid foundation for subsequent innovative research work. However, the heuristic guidance style demands high levels of independent learning ability and self-discipline from graduate students. If a graduate student lacks a proactive attitude towards learning, they may experience aimlessness and slow development during the learning process. This, in turn, requires the tutor to invest more time and energy in tracking and guiding the student's progress.

3. Components of Innovative Abilities of Graduate Students in Materials Science

3.1 Innovative thinking ability

Innovative thinking ability is a core factor in the cultivation of innovative abilities for graduate students in materials science and has a significant impact on the learning and development of the discipline. For graduate students in materials science, innovative thinking ability refers to their capacity to break free from the constraints of traditional thinking and examine issues in the field of materials from a unique perspective. When conducting research and development on materials, graduate students are required to possess keen observational skills and foresight (Yu et al., 2024). For example, in the exploration of new materials, graduate students should be able to observe their microstructures and properties and identify potential characteristics and patterns. Just like graphene, the discovery of this new material with excellent properties began with researchers exploring the possibilities of two-dimensional materials with innovative thinking, leading to the identification of its unique electrical and mechanical properties. In their daily learning and research, graduate students in materials science need to cultivate curiosity and a thirst for knowledge and be sensitive to new theories and phenomena. Only in this way can they face the complex issues in materials science without being confined to existing knowledge and methods and boldly propose new hypotheses and ideas.

3.2 Practical operation ability

Practical operation ability is an essential component of the innovative abilities of graduate students in materials science and directly affects whether they can transform theoretical knowledge into practical research results. In materials science research, practical operation is a continuous process throughout the research, and material preparation is crucial (Wei, 2025). Graduate students need to be proficient in various material preparation techniques and methods, including but not limited to high-temperature sintering, chemical synthesis, and physical vapor deposition. Different preparation methods can significantly influence the structure and properties of materials. For example, in the preparation of nanomaterials, accurate control of reaction conditions and process parameters is key to obtaining high-quality nanomaterials. In actual work, graduate students need to continuously gain experience and learn from mistakes to ensure the preparation of materials that meet research requirements. During the operation, they should strictly follow experimental procedures to ensure experimental safety and accuracy. Moreover, performance testing of materials is also of great significance in practical operation. Graduate students must be proficient in the use of various material performance testing tools and techniques, including but not limited to X-ray diffractometers, scanning electron microscopes, and mechanical property testing equipment. Testing the performance of materials can provide a deeper understanding of the relationship between their structure and properties. For example, X-ray diffractometers can be used to analyze the crystal structure of materials, laying the foundation for optimizing their properties. In performance testing, graduate students should be able to operate the instruments accurately and correctly analyze and process the test data.

4. Mechanisms of Tutoring Styles on the Innovative Abilities of Graduate Students in Materials Science

4.1 Impact on the formation of innovative thinking

Tutoring styles play a crucial and multidimensional role in the development of

innovative thinking among graduate students in materials science. Different tutoring methods are like distinct styles of brushes, painting a variety of landscapes on the canvas of graduate students' innovative thinking. Authoritative tutors, with their profound academic foundations and extensive research experience, provide clear research directions and frameworks for graduate students. They systematically and rigorously impart the classic theories and cutting-edge knowledge of materials science, enabling students to quickly stand at the forefront of the discipline and gain an overall understanding of the field (Tang et al., 2025). However, this approach also has its limitations. If the tutor's influence is too strong during the guidance process, graduate students may easily become dependent on the tutor's thinking, suppressing their ability to think independently and question boldly. Nevertheless, if tutors can encourage students to express different views while providing authoritative guidance, it can create opportunities for innovation within the set research framework, prompting students to explore new perspectives in line with scientific norms and fostering the development of innovative thinking. Heuristic tutors, on the other hand, guide graduate students to independently explore knowledge by skillfully posing questions and setting contexts. In the field of materials research, tutors direct students to pay attention to special phenomena in materials and encourage them to independently analyze the causes behind these phenomena and propose hypotheses. This approach fully mobilizes the students' initiative, forming a habit of examining problems from multiple disciplines and perspectives. For example, when exploring the optimization of the properties of new materials, tutors guide students to consider how to integrate knowledge from multiple disciplines such as physics and chemistry, expanding their thinking boundaries and laying a solid foundation for the cultivation of innovative thinking.

4.2 Impact on the improvement of practical operation skills

Regarding the enhancement of practical operation skills among graduate students in materials science, tutoring styles play a decisive role, with different approaches yielding significantly different results. Authoritative tutors adhere to strict criteria and standards in guiding practical operations (Zheng et al., 2023). Drawing on their rich practical experience, they provide graduate students with in-depth explanations of the working principles and operational skills of various experimental devices, as well as the core content in key steps such as material preparation and performance evaluation. During experiments, tutors closely monitor the students' operations to ensure that each step complies with scientific standards. This rigorous guidance enables graduate students to quickly master correct operational skills, thereby avoiding experimental failures or safety accidents due to operational errors. However, overly strict guidance may cause students to feel nervous during operations, with insufficient space for independent play and innovation. If tutors can provide students with opportunities for independent attempts and encourage them to explore different operational methods while ensuring operational standards, it will be more conducive to the improvement of graduate students' practical operation skills and innovation abilities. Heuristic tutors focus on cultivating graduate students' independent thinking and problem-solving abilities in practical operation guidance. Instead of directly telling students how to operate, they guide students to analyze problems through questioning, enabling them to independently find ways to solve these problems. For example, when an experimental instrument malfunctions, tutors guide students to check, analyze possible causes, and attempt repairs on their own. This approach not only improves graduate students' practical operation skills but also cultivates their adaptability and innovative thinking (Gan et al., 2023). To solve practical problems, graduate students must continuously try new methods and ideas, thereby summarizing experience from practice and promoting the development of comprehensive abilities.

4.3 Impact on the cultivation of problem-solving abilities

Tutoring styles have a profound and distinct impact on the cultivation of problem-solving abilities among graduate students in materials science. Different tutoring styles have different orientations and shaping effects on the complex problems faced by graduate students in the field. Authoritative tutors, with their rich professional knowledge and problem-solving experience, provide direct and effective solutions for graduate students (Li et al., 2024). When graduate students encounter problems during their studies, tutors quickly identify the key to solving the problem and provide specific methods based on their authority and professional judgment. This approach enables graduate students to solve existing problems in a shorter time, avoiding excessive hesitation over problems and thus improving research efficiency. However, long-term reliance on direct tutoring from tutors may lead graduate students to lack the spirit of independent thinking and actively exploring problem-solving approaches. When faced with new, complex, and unsolved problems in the future, they may feel powerless. Therefore, authoritative tutors should, on the premise of providing solutions, guide graduate students to analyze the causes of problems and the idea of problem-solving, and cultivate their autonomy in problem analysis and solving abilities. Heuristic tutors mainly assist graduate students in independently identifying, analyzing, and handling problems through questioning, guidance, and inspiration. When graduate students have doubts, tutors do not provide direct answers but guide them to deeply thinking the essence of the problem through a series of questions. For example, when material performance does not meet expectations, tutors question the experimental conditions and raw material characteristics, urging them to analyze from multiple angles. This approach trains graduate students to think independently and actively explore, enabling them to use the knowledge and methods they have learned to find solutions on their own when encountering problems. Through continuous problem-solving, graduate students' problem-solving abilities are exercised and improved, and they gradually form their unique problem-solving thinking patterns.

4.4 Impact on the shaping of teamwork abilities

Tutoring styles play an undeniable important role in shaping the teamwork abilities of graduate students in materials science. Different tutoring styles create different teamwork atmospheres and form different teamwork abilities. Authoritative tutors are usually the leaders in guiding teamwork, with a clear understanding of team goals, division of labor, and work processes. Tutors use their authority and experience to draw up detailed plans and plans for the group, and stipulate the specific responsibilities of group members. In this tutoring style, team work efficiency is high and can quickly carry out work according to the tutor's requirements. However, due to the tutor's strong dominance, team members' initiative and creativity may be insufficient. In team collaboration, members mostly execute the tutor's orders and lack in-depth thinking and active participation in team affairs. In addition, communication and interaction among team members may be more focused on the tutor's needs, and interaction and collaboration among members may not be sufficient. To cultivate graduate students' teamwork abilities, authoritative tutors can appropriately give team members some autonomy to encourage them to express their thoughts and opinions and promote equal communication and collaboration among team members. Heuristic tutors focus on cultivating the autonomous collaboration abilities of team members, committed to guiding team members to jointly explore team goals and strategies and stimulating interaction and collaboration among members. When problems arise in the team, tutors will lead team members to analyze problems and find solutions together. This tutoring style mobilizes the enthusiasm and initiative of team members, enabling them to fully utilize their respective strengths to achieve team goals. For example, tutors may organize team discussion meetings where members share their research

progress and problems encountered, and then discuss solutions together. In this process, team members' communication and collaboration abilities are exercised and improved, and a sense of team consciousness and responsibility is formed.

5. Conclusion

This study has conducted an in-depth analysis of the role of tutoring styles in the cultivation of innovative abilities among graduate students in materials science. It has clarified the characteristics and mechanisms of different tutoring styles and analyzed the factors that influence the effectiveness of tutoring. Based on these findings, strategies for optimizing tutoring styles have been proposed. Future research should focus on long-term tracking studies to continuously improve the tutoring system. This will better promote the enhancement of innovative abilities among graduate students in materials science and cultivate more high-quality talents with innovative spirit and practical abilities for the development of the field.

Conflict of Interest

The authors declare that they have no conflicts of interest to this work.

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