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Method Exploration of Integrating Materials Mechanics with Teacher's Research Project

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Abstract: The article explores feasible paths and methods for integrating materials mechanics with teacher's research projects, especially in the direction of laser additive manufacturing. The existing problems for the integration of research and teaching are teachers' motivation, teaching design, students' cognition, management mechanism and evaluation system. The teaching model with "foundation of basic theories - cutting edge cases - critical discussions - further evolution of content" is proposed. By integrating additive manufacturing examples, such as stress concentration experiment, beam structure performance test and 3D printing competitions, the students' intuitive understanding of theoretical knowledge and practical abilities can be enhanced. At the same time, a diversified and process-oriented assessment system has been established, which emphasizes the comprehensive evaluation of students' scientific research literacy, innovation ability and practical ability. The research aims to promote the transformation of scientific research resources into teaching resources, enhance the cutting-edge nature, practicality and student engagement of Materials Mechanics, and provide a reference for cultivating high-quality engineering talents.

1. Introduction

The basic courses for science and engineering majors in higher education are highly theoretical and specialized. The students are often trapped by some profound theories and complex formulas during the learning process. The university teachers often play a "dual-shoulder" role, that is, they handle both research and teaching. The projects of the course instructors are usually related to the specialized courses. If the research projects can be integrated with the content of professional courses, that is, the research can feed back into teaching, it can help students better master their professional knowledge and form a more distinctive teaching model with professional characteristics[1]. The students can not only acquire professional knowledge but also gain access to the cutting-edge research in their respective fields.

At present, the scholars from various disciplines have begun to explore methods for using research results to support teaching. Fu et al.[2] explored the application and practice of research feeding back into teaching in the course of economic forest entomology. By changing teaching methods, relying on research projects and introducing practical cases, they enhanced the students' learning experience and their ability to solve practical problems. Fang et al.[3] integrated the research results on the spatiotemporal characteristics of seismic motion into their teaching, which aimed to cultivate the students' innovation ability and comprehensive quality, as well as to stimulate their interest in scientific research and enhance their practical ability. Yan[4] relied on the platforms such as research laboratory and engineering research center to explore the methods for establishing a mechanism to transform scientific research resources and achievements into course teaching resources. Based on the research projects of professional teachers, teaching is fed back through the means such as classroom teaching reform, experimental project development, college students' innovation and entrepreneurship projects, and laboratory development funds. Zhou et al.[5] took the course of mechanical manufacturing technology as an example and explored the methods of integrating scientific research and teaching by introducing the Analytic Hierarchy Process and the fuzzy comprehensive evaluation method.

The automotive industry is the pillar industry of Chinese manufacturing sector, which requires a large number of professional talents every year. The vehicle engineering major is an engineering discipline that cultivates industry talents for the automotive industry. Materials Mechanics is a fundamental course for this vehicle engineering major, which plays a crucial role in connecting the previous knowledge with the subsequent learning during the students' training process. The course of Materials Mechanics involves a large amount of theoretical knowledge and the application of formulas, which has a certain level of learning difficulty[6].

2. Problems of integrating research and teaching

2.1 Problems of teachers

Any reform requires a significant amount of effort. The university teachers generally have to handle multiple tasks such as teaching, research, administration and social/corporate services. However, teaching seems to be of little importance in the process of professional title evaluation. This has led to the situation that the university teachers have no motivation at either the subjective or objective aspect to change the original teaching model. The teachers in the "top" universities have devoted almost all energy to research, which leaves no time for integrating research and teaching. Meanwhile, the teachers in the ordinary universities are mostly lacking in research projects and thus unable to carry out the integration of research and teaching.

2.2 Problems of teaching design and implementation

Scientific research projects generally possess cutting-edge and in-depth professionalism, while the knowledge covered in professional courses is overly fundamental and theoretical. One must not sacrifice fundamental theories in an excessive and blind pursuit of the cutting-edge of knowledge. This will lead to the fragmentation of the entire curriculum system and teaching content. The discontinuous teaching will make it difficult for students to grasp the core thread of the course, which results in an imbalance between depth and breadth. Research projects are integrated into the existing framework of disciplinary knowledge systems, so that students can not only better understand the theoretical knowledge but also have access to the latest research results. This is a problem that needs to be addressed in the current process of teaching design and implementation. If not handled properly, it is like building a tall building in the desert. Without a stable foundation, no matter how grand the building on top is, it will collapse.

The implementation of scientific research projects requires a large number of scientific experiments. The teaching classes usually have a large number of students. How to ensure that all these students can have access to scientific experiments is a challenging issue. One issue is that the school lacks large-scale experimental equipment. Some cutting-edge experiments often need to be conducted at other schools and institutions. Second, the space for scientific research experiments is limited and cannot meet the practical requirements of numerous students. Undergraduate students have limited knowledge reserves and experimental capabilities. Most of them have not received professional training. It is extremely difficult for them to complete the experiments required in the projects by themselves. Teachers need to provide in-depth and detailed training to students in order to enable them to independently complete experiments, which requires a great deal of energy from teachers.

2.3 Problems of students

Students in lower grades or those with poor academic performance lack sufficient knowledge reserves and practical abilities. When they learn the advanced knowledge, it difficult to fully concentrate and achieve good results. This will further dampen students' enthusiasm and motivation for learning. Objectively, undergraduate students without scientific research training lack the necessary research skills. They are unable to independently formulate scientific questions and have difficulty completing tasks such as literature review, experimental design and data analysis. Subjectively, a large proportion of students are not interested in research. The purpose of taking a course is merely to obtain credits. Forcing students to do something they are not interested in is likely to have the opposite effect and undermine the teaching effectiveness of the entire course. In fact, students are under academic pressure and often fail to strike a balance between research and schoolwork. Scientific research consumes more time and energy than academic study. Under the current credit system, students have to devote a great deal of energy to their studies, extracurricular activities, academic competitions and certification exams, which leave no spare energy for research.

2.4 Problems of management and evaluation

The integration of research and teaching is a systematic task that requires coordination among multiple sectors including education, research, colleges and laboratory management. However, most schools lack overall planning, incentive policies and coordination mechanisms, which makes it difficult for them to provide institutional guarantees. Scientific research often requires the use of multiple experimental equipment. However, the mechanism for sharing large-scale equipment in some schools is not well-established. There are management barriers and issues related to usage priority, which makes it impossible to carry out numerous research and teaching integration activities.

It is very difficult to evaluate students' performance in the process of integrating research and teaching fairly and objectively. The traditional assessment of course mainly focuses on students' mastery of theoretical knowledge. The assessment method is mainly the closed-book examination. The assessment of research capabilities (including research literacy and innovation ability) is difficult to be conducted objectively and fairly under the current evaluation system. The influence of students' innovative ability and research literacy demonstrated during the integration of research and teaching in the course on their academic performance is a long-term process, which is difficult to be quantitatively evaluated in a short period of time. Moreover, a long-term tracking and evaluation mechanism is lacking.

2.5 Problems of target location and cognitive level

The integration of research and teaching is a very broad and general term. In most cases, the integration of research and teaching does not have a clear goal. Is the purpose of integrating research and teaching to popularize cutting-edge scientific knowledge among students? Is it to cultivate students' interest in scientific research? Is it to train students' problem-solving skills? Do you teach students how to produce specific research results? These goals are all vague and lack a clear direction for implementation.

The cognitive biases between teachers and students often make it difficult to promote the integration of research and teaching. Some teachers believe that the integration of research and teaching involves introducing their research projects and achievements in class, which has a certain popular science nature. However, they lack the consideration of integrating research thinking and methodology throughout the entire teaching process, and thus cannot bring about a qualitative change in course teaching. Students think that scientific research is too difficult. Moreover, for those who enter enterprises right after graduating from undergraduate studies, scientific research is a burden and of little use for their future development. Instead, it wastes their study time.

3. Examples of teaching model for integrating research and teaching

This article takes the integration method of the author's scientific research project and some knowledge of Materials Mechanics as an example to expound the measures of integrating research and teaching. First of all, the relevant knowledge points of materials mechanics course are extracted from the scientific research project. Secondly, the chapters that can be integrated with the project are extracted from materials mechanics course. Finally, the convergence point will be found to integrate the two and achieve the goal of promoting teaching through scientific research. The specific methods of integrating research and teaching are shown in Fig. 1.

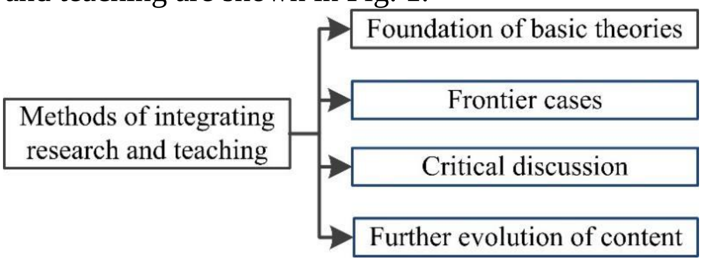

Figure 1. Methods of integrating research and teaching

(1) Foundation of basic theories: The core classic theories are clearly explained.

(2) Frontier cases: The 1-2 frontier research papers or technological breakthroughs are introduced as examples. The methods of applying and expanding these achievements into the classic theories learned are analyzed.

(3) Critical discussion: Teachers guide students to discuss the limitations of these cutting-edge studies, unsolved problems and possible directions for improvement, and even put forward their own conjectures.

(4) Further evolution of content: Teachers incorporate their own research data, failure experiences and success stories as "loose-leaf pages" into their teaching plans, which allow students to see how knowledge is created.

Most of the author's research projects focus on additive manufacturing. Additive manufacturing is an advanced manufacturing technology, which features free forming. This technology forms by layer-by-layer deposition and has been widely applied in engineering[7-9]. The phenomena and problems in the additive manufacturing forming process can be combined with the content in Materials Mechanics. The following examples illustrate the methods of integrating additive manufacturing with the content of Materials Mechanics course.

(1) The book only presents the basic concepts of stress concentration, shows the stress cloud diagram of a flat plate with circular holes and explains the theoretical stress concentration coefficient.

Students cannot observe the specific stress concentration phenomenon. Students can be allowed to use CAD drawing software to draw a series of tensile specimens with different hole diameters and different notch shapes, and then use 3D printers for rapid prototyping. During the tensile test, students observe the morphology of the failure site and directly experience the stress concentration effect caused by the geometric shape and size.

(2) By taking advantage of the free forming characteristics of additive manufacturing, the beams of equal weight with different cross-sectional shapes (solid circular cross-sections, hollow circular cross-sections, rectangles, I-beams, frames, and T-shapes, etc.) can be printed. Simple supported beam, cantilever beam or overhanging beam are built. Load the beam, measure its deflection, and compare the experimental results with the theoretical values. Students are enabled to directly perceive which cross-sectional shapes of beams have better bending resistance performance.

(3) In the experimental teaching process, students can independently select materials and prepare standard samples through additive manufacturing. Students can experience the entire process of material mechanical property analysis, from "sample design and preparation", "clamping", "loading", "data acquisition (force-displacement curve)" to "calculation and analysis (yield strength, tensile strength, elastic modulus)".

(4) Additive manufacturing and materials mechanics can be integrated. Based on this, students can participate in subject competitions. For instance, a "3D Printed Bridge/Cantilever Beam Load-Bearing Competition" can be held with restrictions on the weight or volume of the printing material. Participants will be required to design and print a bridge or a cantilever beam structure. The final evaluation is based on the load-bearing efficiency (maximum load / self-weight). While participating in the competition, students need to apply CAD/CAE software, learn to use 3D printers, and master knowledge such as bending strength, stiffness, stability and structural optimization. This can greatly stimulate students' competitive awareness and creativity. Students will actively study various truss structures and thin-walled structures. Their own designs will be repeatedly iterated and optimized. Many college students' mechanical and structural innovation competitions (such as the National College Students' Mechanical Innovation Design Competition) involve topics like lightweight and optimized design. Course projects can be used as incubators for these competitions.

4. Course assessment system for integration of research and teaching

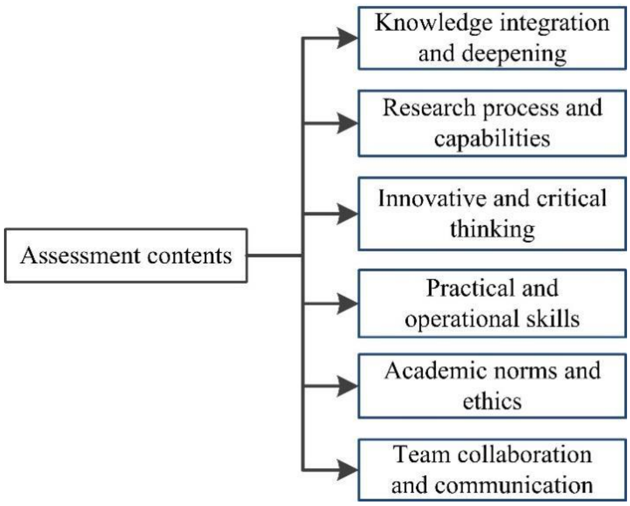

Figure 2. Assessment contents of course

The traditional course assessment method still mainly relies on the final exam, which is not suitable for evaluating the effectiveness of the integration of research and teaching. The assessment system for the integration of research and teaching should be characterized by integration, process orientation, diversity, development orientation and authenticity. The assessment should be carried out throughout the entire process. The specific assessment contents are shown in Fig. 2.

The specific assessment methods are shown in Fig. 3.

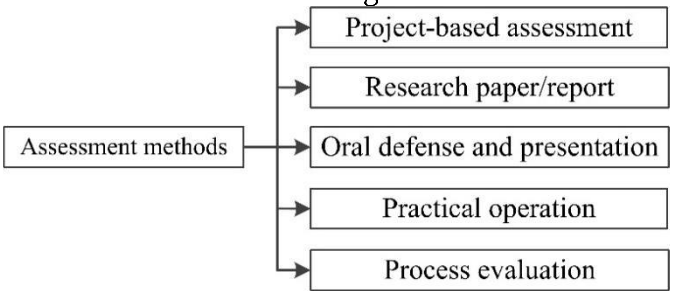

Figure 3. Assessment methods of course

(1) Project-based assessment: the students can apply for the university's student innovation and entrepreneurship projects, the Challenge Cup and the Mechanical Innovation Competition, etc., based on the theoretical knowledge of the course and related additive manufacturing projects. The approval status and grade of the projects will be used as the criteria for assessment.

(2) Research paper/report: The students can write research papers or reports that are in line with academic standards based on the theoretical knowledge of the course and related projects in additive manufacturing. They can also submit their works to formal academic journals to achieve the goal of training students in academic paper writing.

(3) Oral defense and presentation: The students can present their results in the form of PPT or physical objects and give an oral report as well. This can help them improve PPT-making skill and oral communication ability.

(4) Practical operation: The teachers set up or the students conduct relevant experimental operations independently. The experimental design and operation process are scored and evaluated.

(5) Process evaluation: The entire process of students' performance is evaluated, and a comprehensive score is given by combining teachers' evaluations, students' self-assessments and group scores.

5. Conclusion

Materials mechanics is an important foundational course for engineering disciplines such as vehicle engineering. The course is characterized by the strong theoretical nature and abstract content. This article explores the integration path between the materials mechanics course and the teachers' research projects (particularly in the field of laser additive manufacturing), and proposes a feasible model of "research feeding back to teaching". This model is based on fundamental theories and takes cutting-edge cases as the starting point. Through critical discussions and content re-evolution, it achieves the organic integration of scientific research thinking and teaching content so as to enhance the practicality, cutting-edge nature and students' participation in the course. At the same time, this article proposes a diversified assessment system based on projects and oriented towards the process, which emphasizes the comprehensive evaluation of students' scientific research literacy, innovation ability and practical ability. In the future, the integration of research and teaching in materials mechanics and other professional courses should further strengthen goal orientation, optimize resource allocation, improve incentive mechanisms and promote the effective transformation of scientific research resources into teaching resources. Through continuous exploration and practice, the integration of research and teaching is expected to become an important approach to cultivate high-quality engineering talents with innovative spirit and practical ability.

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References

[1] Yang Y C, Tian X, Li W. Exploration of Research-Based Embedded Teaching Model for Science and Engineering Courses-Taking "Thin Film Materials and Technology" as an Example[J]. Heilongjiang Education (Higher Education Research & Appraisal), 2020, 5: 32-34.
[2] Fu N N, Bi Y G, Su X Y, et al. The Application and Practice of Scientific Research Feedback in the Teaching of Entomology for Economic Forests[J]. Journal of Smart Agriculture, 2025, 14: 185-188.
[3] Fu D J, Sun J Q, Yang R H, et al. Practice and Exploration of Scientific Research Feeding Back to Seismic Teaching of Buildings [J]. University Education, 2025, 7: 75-80.
[4] Yan B. Teaching Reform Practice and Innovation of Industrial Catalysis Principles Course Based on the Concept of Research Reinvesting in Teaching[J]. Tianjin Chemical Industry, 2025, 39(4): 172-174.
[5] Zhou J Y, Peng H M, Xue B, et al. Research on the Integrated Teaching Model Combining Undergraduate Teaching and Research-Taking the Mechanical Manufacturing Technology Course of Nanning University as an Example[J]. Journal of Higher Education, 2025, 21: 38-41.
[6] Song S N. Implementation and Thinking of Materials Mechanics Course Based on the Requirements of Application-oriented Talent Training-Take the Vehicle Engineering Profession as an example[J]. Auto Time, 2021, (22): 41-42.
[7] Huang W B, Zhao X Y, Lu W J, et al. Ratcheting effect of 304 stainless steel manufactured by laser metal deposition[J]. Steel Res Int, 2024; 95: 2300737.
[8] Wang D, Deng G W, Yang Y Q, et al. Research progress on additive manufacturing of metallic heterogeneous materials[J]. Journal of Mechanical Engineering, 2021, 57(1): 186-198.
[9] Ao N, He Z, Wu S, et al. Recent progress on the mechanical properties of laser additive manufacturing AlSi10Mg alloy[J]. Transactions of the China Welding Institution, 2022, 43(9): 1-19.