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A Practice-Oriented Teaching Reform for Orthopaedic Instrumentation Education

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Abstract

The Orthopaedic Instrumentation course, as a representative interdisciplinary subject integrating medicine and engineering, plays a pivotal bridging role between engineering competence cultivation and clinical application understanding. In response to existing challenges—including outdated course content, insufficient integration of theory and practice, and a single-dimensional assessment system—this study adopts engineering competency development as its core orientation and constructs a three-dimensional collaborative reform framework encompassing content restructuring, practice enhancement, and diversified evaluation. The reform was systematically implemented across two consecutive teaching cycles. By incorporating cutting-edge technological modules, establishing a tiered practical training system, and developing a comprehensive process-oriented assessment mechanism, the proposed reform facilitates the integration of theoretical instruction and engineering practice. Empirical observations indicate that course performance, excellence rate, and student satisfaction all showed noticeable improvement after the reform. Moreover, students exhibited enhanced engineering analytical capability and interdisciplinary problem-solving competence. This study provides a transferable structural paradigm for optimizing professional curricula within the context of medical–engineering integration.

Keywords: Orthopaedic instrumentation; Rehabilitation engineering; Teaching reform; Practice-oriented education

1. INTRODUCTION

In the context of contemporary higher education, the deep integration of medicine and engineering has become a crucial driver for both medical technology advancement and innovation in talent cultivation. With the rapid development of disciplines such as biomaterials, mechanical engineering, and information technology, medical engineering programs have gained increasing significance, imposing higher requirements for the cultivation of interdisciplinary and innovative talents. Systematic course construction focusing on core medical engineering technologies has thus become an essential strategy for universities to enhance talent development quality [1-4].

Educational reform has become a global trend in response to evolving societal and technological demands, particularly in interdisciplinary and inclusive education contexts [5, 6]. In the field of medical education, continuous reform is essential to adapt to advances in healthcare systems and professional training requirements [7].

Orthopaedic instrumentation, as a key component of modern medical engineering, plays an irreplaceable role in diagnosis, treatment, functional reconstruction, and rehabilitation of musculoskeletal disorders. The development of internal fixation devices, joint replacement systems, and related assistive devices exemplifies the application of engineering to meet medical needs [8, 9]. The Orthopaedic Instrumentation course has been developed within this interdisciplinary context, and the quality of

teaching directly affects students' understanding of medical engineering applications and their ability to perform comprehensive analysis.

From a curricular perspective, the Orthopaedic Instrumentation course is typically embedded within Rehabilitation Engineering, Biomedical Engineering, and Medical Technology programs, serving as a bridge between foundational theoretical courses and applied professional courses [10]. The course is designed around orthopaedic clinical needs and engineering methods, integrating knowledge from anatomy, biomechanics, materials science, and mechanical design. Students are expected not only to master basic types and structures of orthopaedic instruments but also to understand design rationale, engineering constraints, and performance requirements in practical applications.

The inherent linkage among medicine, engineering, and clinical application in the course is illustrated in Figure 1.

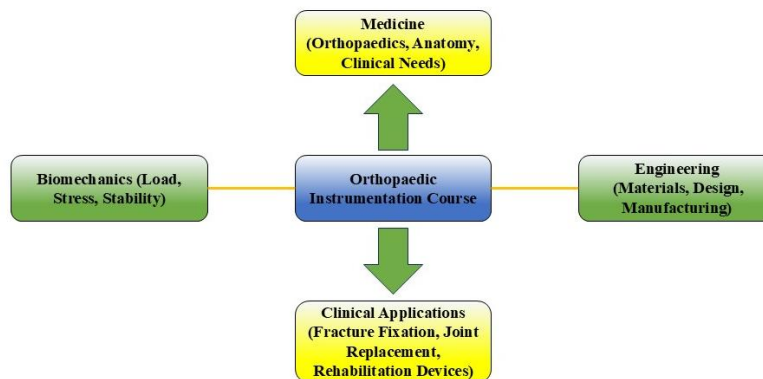


Figure 1. The inherent linkage framework among medicine, engineering, and clinical application in the Orthopaedic Instrumentation course.

The course is highly interdisciplinary and integrative. It combines foundational medical knowledge with engineering principles, requiring strong cross-disciplinary knowledge integration skills. Many of the instruments are drawn from real clinical scenarios, emphasizing application and practical relevance. Furthermore, with the continuous introduction of new materials, processes, and digital technologies in orthopaedics, the course content must remain contemporary and forward-looking to meet evolving professional needs.

2. Current Status and Challenges of Orthopaedic Instrumentation Education

Current practices in Orthopaedic Instrumentation education reveal room for improvement in teaching content, instructional organization, and assessment methods [11].

Course Content: Many courses remain focused on traditional instrument classification and structural principles, lacking systematic coverage of emerging materials, technologies, and applications. The course's frontier and integrative aspects need enhancement [12].

Instructional Methods: There is insufficient integration of theory and practice. Students' understanding of engineering problems in orthopaedics often remains conceptual, with limited exposure to systematic engineering analysis and applied experiences.

Assessment and Evaluation: Predominantly based on final exams, evaluation mechanisms insufficiently reflect students' learning processes, practical abilities, and comprehensive competencies, limiting insight into the achievement of course objectives.

These limitations constrain teaching effectiveness and hinder the cultivation of engineering competence and innovation. Therefore, a systematic reform of course content, practical teaching structure, and assessment mechanisms is warranted. Future exploration should emphasize dynamic course content updates, practical teaching platform enhancement, and integration of digital teaching tools to continuously elevate teaching quality and support the development of interdisciplinary talents.

3. Implementation Context

The teaching reform was implemented in the Orthopaedic Instrumentation course over two consecutive teaching cycles. The course was offered to undergraduate students majoring in Rehabilitation Engineering (or Biomedical Engineering).

In the initial cycle, the course followed a conventional teaching approach, primarily emphasizing theoretical instruction and final examination. In the subsequent cycle, a practice-oriented reform framework was introduced, focusing on content restructuring, enhanced practical training, and diversified assessment methods.

The effectiveness of the reform was explored through overall course performance, excellence rate, and student feedback. Observations from teaching practice indicate that the reformed approach contributed to improved learning outcomes and increased student engagement.

4. Teaching Reform and Implementation

4.1. Course Content Reform: Modular and Interdisciplinary Optimization

As a highly interdisciplinary course, Orthopaedic Instrumentation must reflect both engineering foundations and the evolving landscape of orthopaedic medicine. Traditional content focused on instrument classification and structural introduction is no longer sufficient.

The reform prioritized systematic updates and expansion of course content. Textbooks and syllabi are periodically reviewed and revised to incorporate new technologies, materials, and processes such as robot-assisted surgical systems, biodegradable materials, and intelligent orthopaedic devices. Conceptual introduction and engineering thinking guide students' understanding of the discipline's trajectory.

Additionally, foundational knowledge from biology, materials science, and computer science is integrated to highlight the interplay between orthopaedic design, biomechanics, material performance, and digital technologies, fostering students' analytical and innovative abilities.

Digital teaching resources—including instructional videos, structural demonstrations, simulation exercises, and interactive Q&A—are developed to support diverse learning preferences and independent study.

The overall framework and implementation pathway of the teaching reform are presented in Figure 2.

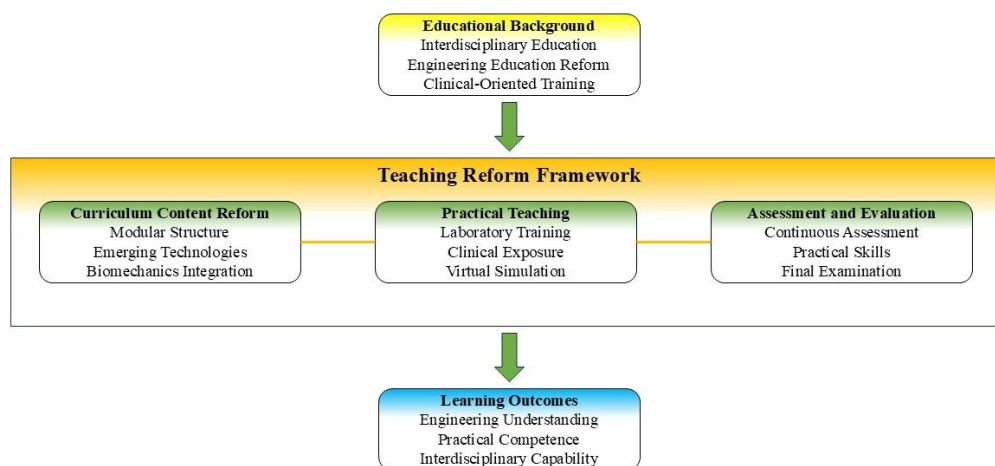


Figure 2. Framework and implementation pathway of the Orthopaedic Instrumentation teaching reform.

4.2. Practical Teaching Reform: Multi-Level Training System

Practical teaching constitutes a significant component of the course. To strengthen students' understanding of orthopaedic instrument structure and function, a multi-tiered practical teaching system was established.

Investment in laboratory equipment and teaching spaces has enabled hands-on interaction with real instruments through observation, disassembly, and assembly exercises. External resources, including clinical visits and enterprise collaboration, provide exposure to engineering characteristics and clinical demands. Virtual Reality (VR) and Augmented Reality (AR) technologies supplement traditional instruction to enhance intuitive understanding and learning experience.

4.3. Assessment Reform: Comprehensive and Multi-Dimensional Evaluation

Assessment was restructured from a single final exam to a combined process-oriented and summative evaluation model. Evaluation emphasizes not only knowledge mastery but also learning process, practical participation, and application capability.

Key assessment elements include online learning, class interaction, practical exercises, and end-of-term exams, forming a complete pre-class, in-class, and post-class evaluation system. Practical exercises and reports evaluate students' comprehension of instrument structure and function, while final exams assess integrated problem-solving and core knowledge mastery.

To ensure the comparability between the two teaching cycles, both cohorts were composed of students from the same major and similar academic level, with comparable class sizes. The course was delivered by the same instructor using a consistent syllabus framework, except for the implementation of the teaching reform in the second cycle. No substantial changes in teaching environment or student admission criteria occurred during the study period. Therefore, the observed differences in learning outcomes can be primarily attributed to the implemented teaching reform.

Table 1 presents an example of the assessment and evaluation system for the Orthopaedic Instrumentation course. By reasonably allocating different assessment forms and corresponding weightings, the system enables a comprehensive evaluation of students' learning outcomes. It also encourages students to place greater emphasis on the learning process, thereby improving overall learning quality.

Table 1. Example of the multi-dimensional evaluation system for Orthopaedic Instrumentation courses.

Dimension	Form (Weight)	Specifics (Weight)	Main Objective
Learning Process	Continuous assessment (20%)	Online videos (4%), classroom interaction tasks (8%), homework/exercises (8%)	Self-learning, engagement, knowledge mastery
Practical Ability	Practical assessment (30%)	Hands-on operation (16%), reports (8%), innovation/competition participation (6%)	Basic skills, synthesis, and innovation
Learning Outcomes	Final exam (50%)	Closed-book exam (50%)	Core knowledge and problem-solving

Outcome-based education (OBE), originally proposed by Spady (1994) [13], is a student-centered framework that emphasizes the achievement of clearly defined learning outcomes. In recent years, OBE has been widely applied in vocational and engineering education to enhance the alignment between curriculum design and practical skill requirements. A recent review study further highlights that OBE contributes to improving students' technical competence and employability, while also emphasizing the importance of curriculum flexibility and industry-oriented training [14].

The weighting scheme was designed to balance knowledge acquisition, practical competence, and learning engagement. The final examination accounts for core knowledge assessment, while practical evaluation emphasizes hands-on ability and engineering application. Continuous assessment encourages active participation and consistent learning throughout the course.

4.4. Teaching Support and Continuous Improvement

Faculty development focused on recruiting and training teachers with engineering backgrounds and research competence. Regular teaching seminars foster experience sharing and method innovation.

Student feedback and teaching quality evaluations create a continuous improvement loop, enabling timely adjustments in content and instructional methods. Over two consecutive teaching cycles, students

showed improvements in comprehension, practical ability, and application skills, suggesting the effectiveness of the reform. The results are described in Table 2.

Table 2. Comparison of teaching outcomes before and after reform

Indicator	Traditional Cycle	Reform Cycle
Average Score (Mean)	72.5	79.8
Excellence Rate (%)	18%	35%
Student Satisfaction	3.6 / 5	4.4 / 5

The results indicate a clear improvement across all indicators after the implementation of the teaching reform, suggesting its positive impact on student learning outcomes.

5. Discussion

The findings suggest that the proposed teaching reform contributes positively to students' learning engagement and overall academic development. Compared with traditional teaching approaches, the integration of practical training and process-oriented assessment facilitates a deeper understanding and application of engineering concepts.

These observations are consistent with previous studies highlighting the importance of interdisciplinary integration and practice-oriented education in medical engineering curricula [1–3, 14]. The incorporation of emerging technologies and diversified assessment strategies appears to further support students' active learning and innovation capability.

Nevertheless, this study is primarily based on teaching practice within a specific course context. Future work may explore the long-term impact of such reforms and extend the framework to other interdisciplinary courses in medical–engineering education.

6. Conclusion and Outlook

This study analyzed the teaching positioning and talent cultivation objectives of the Orthopaedic Instrumentation course, and explored reform paths in line with interdisciplinary integration and engineering education. Systematic optimization of course content, practical teaching, and assessment mechanisms established a reform framework tailored to the course characteristics and higher education practices. Teaching practice shows that reforms enhance content systematization, promote synergy between theory and practice, and strengthen students' analytical and application capabilities. Continuous course updates, practical platform development, and digital integration will further advance education quality, providing solid support for cultivating interdisciplinary talents with engineering literacy, innovation, and comprehensive competence in orthopaedic instrumentation. The proposed reform framework may serve as a practical reference for similar interdisciplinary curriculum development in medical–engineering education.

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REFERENCES

1. Pan Y, Xu Q, Wu Q, et al. Reform and effectiveness of interdisciplinary courses in physical medicine and rehabilitation for eight-year medical students. *Chinese Journal of Rehabilitation Theory and Practice*, 2020, 26(12): 1483–1488.
2. Wang X L, Wang F M, Lü T B. Research and practice on curriculum construction of “Physical Therapy Medicine” in interdisciplinary medical-engineering education. *China University Teaching*, 2024(09): 21–26.
3. Zhao X H, Xu D W, Chen Y H. Innovation of talent cultivation system in interdisciplinary medical-engineering education: Practice of Tsinghua-Berkeley Shenzhen Institute. *Research in Higher Engineering Education*, 2022(02): 81–86.
4. Hu J H, Chen J, Li G Q. Exploration of “medical-engineering integration” in prosthetics and orthotics education. *Modern Vocational Education*, 2023(33): 77–80.
5. Ahtiainen R, Pulkkinen J, Jahnukainen M. The 21st century reforms reshaping the education policy of inclusive and special education in Finland. *Education Sciences*, 2021, 11(11).
6. Narong D K, Hallinger P. Traversing the evolution of research on engineering education for sustainability: A bibliometric review (1991–2022). *Sustainability*, 2024, 16(2).
7. Habal M B. Medical education beyond health care reform. *Journal of Craniofacial Surgery*, 2011, 22(2): 377–378.
8. Zhang S Q, Sun J Y, Chen C, et al. Development and application of additive manufacturing in orthopaedic implantable medical devices. *Bioorthopaedic Materials and Clinical Research*, 2018, 15(1): 76–80.
9. Liu Y X, Zhang X Y, Li H, et al. Multifunctional applications of metal-organic frameworks in bone tissue engineering and orthopaedic disease treatment. *Chinese Journal of Tissue Engineering Research*, 2025, 29(10): 2151–2161.
10. Fan T, Chen H, Zheng P, et al. Exploration of curriculum construction and teaching reform in prosthetics and orthotics engineering under new circumstances. *China Rehabilitation*, 2023, 38(7): 446–448.
11. Luo C L, Liu W, Wang L Y. International standards and assessment systems for prosthetics and orthotics education. *Chinese Journal of Rehabilitation Medicine*, 2021, 36(2): 193–197.
12. Li Z M. Overview and prospects of prosthetics and orthotics technology. *China Medical Device Information*, 2019, 25(17): 32–33.
13. Spady W G. *Outcome-Based Education: Critical Issues and Answers* [M]. Arlington, VA: American Association of School Administrators, 1994.
14. Jaya D J, Sudira P, Raharjo N E, et al. Outcome-Based Education (OBE) approach in vocational education: Strategies, advantages, and challenges in Indonesia. *Papeles*, 2025, 17(33): 71–84. Approach in Vocational Education: Strategies, Advantages, and Challenges in Indonesia [J]. *Papeles*, 2025, 17(33).