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Effects of Different Teaching Methods on the Teaching Effectiveness of Mechanics Courses: A Network Meta-analysis

Li Haikang[a,*], Xue Quanting[b], Zhang Zhihong[c], Ma Yan'e[d], Heng Ting[e], Wang Zhenjiang[f]

School of Intelligent Engineering, Jinzhong College of Information, Jinzhong, China
[a]lhkang1993@126.com, [b]xuequanting7214@jzci.edu.cn, [c]574055042@qq.com, [d]376922270@qq.com, [e]1056157967@qq.com, [f]wangzhenjiang3118@jzci.edu.cn
**Corresponding author*

Abstract: *A network meta-analysis method was used to systematically evaluate the impact of eight different teaching methods on the teaching effectiveness of mechanics courses. Randomized controlled trials evaluating the effectiveness of teaching methods on mechanics courses were searched from domestic databases such as CNKI, Wanfang Database, VIP Database, and international databases such as Web of Science and PubMed. The search was conducted up to January 2024. After literature exclusion, screening, and quality evaluation, 42 articles and 82 sets of randomized controlled trial data were included. The results showed that blended teaching method (MD=1.313, 95%CI=1.054-1.571), simulation teaching method (MD=1.510, 95%CI=0.637-2.382), problem-based learning (MD=1.989, 95%CI=1.004-2.974), diversified teaching method (MD=1.001, 95%CI=0.479-1.524), and flipped classroom (MD=1.142, 95%CI=0.694-1.590) were significantly superior to traditional teaching methods, with statistically significant differences (P<0.05). There was no statistically significant difference between discussion-based teaching method, asynchronous teaching method, and thinking cultivation method and traditional teaching methods (P>0.05). The results of SUCRA ranking based on the cumulative probability area showed that problem-based learning was the optimal teaching method for mechanics courses, with the best teaching effect and a SUCRA probability value of 91.5%. Simulation teaching method and blended teaching method ranked second in teaching effectiveness. This study can provide a reference for the selection of teaching methods and the integration strategies of multiple teaching methods for mechanics courses.*

Keywords: *Mechanics; Teaching Methods; Randomized Control; Network Meta-analysis*

1. Introduction

Mechanics courses are important basic compulsory courses for engineering majors in mechanical, civil, material and vehicle engineering and technology fields, and play an important role in the professional training program [1]. Such courses play a role in the engineering curriculum, on the one hand, it has a close connection with the higher mathematics and basic physics courses learned in the previous period, so that the theoretical knowledge learned has engineering scenarios and practical applications; On the other hand, it provides theoretical support for the design of subsequent actual production and manufacturing cases. Mechanics courses are generally characterized by strong logic and systematicity, focusing on helping students learn the basic theoretical knowledge of engineering and physics, and cultivating students' rigorous and serious logical thinking and analytical problem-solving ability [2].

In recent years, with the continuous development and change of science and technology, China's higher engineering education has actively explored new directions to promote the construction of new engineering disciplines and the reform and innovation of engineering education talent training mode. The construction of new engineering disciplines advocates that the teaching of courses is application-oriented, competence-centered and student-centered [3].Given that the framework of the knowledge system of mechanics courses has a high degree of similarity, the difference is mainly reflected in the degree of depth of knowledge points taught and the degree of difference in problem solving, but their teaching methods and concepts can be borrowed from each other [1]. This study integrates the teaching effect of a single mechanics course and expands it to the teaching effect of a series of mechanics courses. For mechanics courses, the current teaching methods still rely mainly on the traditional teaching model, while other teaching methods are in a secondary position [4-6].

The traditional teaching method is centered on the teacher and the textbook, where the teacher teaches the knowledge and the students listen and think, so as to complete the learning of the course content. The method overemphasizes the teacher's teaching tasks and neglects the multidimensional assessment of students, which is difficult to meet the demand for talent training in the construction of new engineering disciplines and to adapt to the needs of modern course teaching [7]. Based on this, full-time teachers of mechanics courses actively innovate teaching methods and promote them into teaching practice. At this stage, a series of new teaching methods have been proposed and have achieved teaching results superior to traditional teaching methods [8-10]. Tan Zhouling [11] and others applied the flipped classroom teaching method in the teaching process of theoretical mechanics, which stimulated students' interest in learning, cultivated students' self-learning ability, communication ability, and teamwork ability, and effectively improved students' performance and teaching quality. Cui Yan [12] and others explored the application of problem-oriented teaching method based on the new engineering background in the course of thermodynamics of materials, which was highly recognized by students, and at the same time enhanced students' ability of independent learning and cooperative learning. Meng Qingcheng [13] and colleagues, aiming to address the issues of a singular teaching approach and insufficient student engagement in structural mechanics courses, integrated the Rain Classroom into their daily teaching activities. They proposed a hybrid teaching model that combines online and offline instruction and conducted experimental evaluations. The results indicated that this Rain Classroom-based hybrid teaching mode can significantly enhance students' learning autonomy and enthusiasm, thereby improving the overall quality of teaching. However, most of the above new teaching methods are direct comparisons of the teaching effects of courses with traditional teaching methods, and there is a lack of comparative evaluation of the teaching effects between different teaching methods, which leads to the distress of full-time teachers of mechanics for the choice of new types of teaching methods in practice.

Network Meta is a new type of systematic evaluation method based on the evolution of traditional Network Meta which realizes the indirect quantitative comparison of different interventions by meta-analyzing the results of many previous studies and can be ranked according to the value of a certain outcome index to screen out the optimal interventions [14-15]. This method has gained wide application in the medical field [16-18], but has been less used in the educational field. In this study, we used Net Meta-analysis to systematically collect and sort out the relevant literature on the evaluation of teaching effectiveness of different teaching methods in mechanics courses, and screened out eight representative new teaching methods. Through in-depth integration and analysis of the teaching implementation effect of these teaching methods in mechanics courses, it aims to provide theoretical support and practical reference for the optimization of the teaching mode and teaching innovation and reform of mechanics courses.

2. Information and methods

2.1 Incorporation of literature

The inclusion criteria for the literature were: type of study: randomized controlled trial (RCT); study population: undergraduate and specialist college students involved in the teaching of mechanics courses; intervention: teaching effectiveness of different novel teaching methods; and outcome indicator: quantitative indicator of quiz or exam scores.

2.2 Retrieval Strategy

Use of computerized search of domestic databases such as CNKI, Wanfang Database, and VIP Database and foreign databases such as Web of Science and PubMed was used until January 2024. Using a combination of subject terms and free words, retrieval of a randomized controlled study on the effect of different teaching methods on the effectiveness of a mechanics course. Search terms in English and Chinese include: mechanical, education, method and teaching method. Carefully study the literature that meet the requirements.

2.3 Literature exclusion criteria

Literature was excluded for the presence of the following [19]: repeated reporting of the same group

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of data; inconsistent with the type of study, such as no controlled trials and observational studies, etc. The study design was flawed and not fully consistent with randomization.

2.4 Literature screening and Extraction of information

Based on the purpose of the study and the criteria for inclusion of literature, two researchers with background in the basics of the study area were selected to perform an initial screening of the titles and abstracts of the literature, respectively. The included literature was read through the full text and screened again to extract informative material. For dissenting literature, it was discussed individually to decide whether it should be included in the study or not [20]. Literature information to be extracted includes: title, author, year of publication, test sample size, control sample size, test teaching method, and control teaching method. The ending metrics are final quiz/exam mean scores and standard deviations, using percentages by default, normalized for non-percentage scores, and no restrictions on question types.

2.5 Evaluation of literature quality

Literature bias was evaluated using the Cochrane Risk of Bias Evaluation Tool (5.1.0) for the 42 papers finally included in this study [21]. The tool consists of seven evaluation components, which include: whether a randomized sequence was generated; whether allocation was concealed; whether subjects and intervention providers were blinded; whether the outcome evaluator was blinded; whether the outcome data were complete; whether outcome reporting was selective; and other biases. Each element of the evaluation resulted in three levels of “low risk of bias”, “unclear” and “high risk of bias”. If a single document studied fully met the above criteria, the quality evaluation result was grade A; if it partially met the above criteria, it was grade B; if it did not meet the above criteria at all, it was grade C.

2.6 Methods of statistical analysis

Revman5.3 software was used for literature quality assessment. Stata 14.0 software was used for data analysis and graphing, standardized mean difference (SMD) was used as an indicator of effect size and 95% confidence interval (95% CI) was calculated. The network program package developed and applied by White [22] et al. was loaded for net Meta-analysis. The likelihood of each intervention producing the best intervention was presented using the Surface under the cumulative ranking probability map (SUCRA) module [23]. Inconsistency was usually detected by comparing the difference (p-value) between direct and indirect comparisons. When $P > 0.05$, there is agreement between direct and indirect comparisons [24].

3. Results and Analysis

3.1 Literature search results and network relationship maps

Combined with the results of the inclusion literature strategy and exclusion criteria, through two rounds of literature screening, 42 pieces of literature were finally identified and 82 groups of randomized controlled data were included in this research study, involving 8 new teaching methods, all of which were directly compared with traditional teaching methods, no direct comparison between different new teaching methods, which belonged to a two-armed study. Among them, 42 groups were compared between blended teaching method and traditional teaching method; 4 groups were compared between simulation teaching method and traditional teaching method; 3 groups were compared between problem-oriented teaching method and traditional teaching method; 10 groups were compared between diversified teaching method and traditional teaching method; 4 groups were compared between discussion teaching method and traditional teaching method; 14 groups were compared between flipped classroom and traditional teaching method; 1 group was compared between asynchronous teaching method and traditional teaching method; and 4 groups were compared between thinking cultivation teaching method 4 groups compared with traditional teaching methods. In order to visualize the comparative relationship between various teaching methods, a mesh relationship diagram of different teaching methods was drawn, as shown in Figure 1. Where a line indicates the existence of direct comparative evidence, no line indicates the absence of direct comparative evidence.

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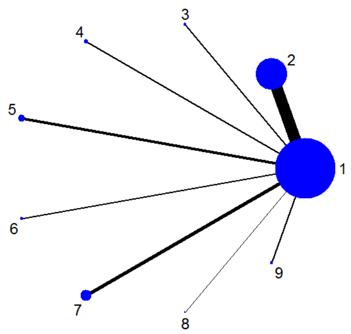

Figure 1: Mesh of different teaching methods

Where: 1 denotes traditional pedagogy; 2 denotes blended pedagogy, 3 denotes simulation-based pedagogy, 4 denotes problem-oriented pedagogy, 5 denotes diversified pedagogy, 6 denotes discussion-based pedagogy, 7 denotes flipped classroom, 8 denotes asynchronous pedagogy and 9 denotes thought development pedagogy.

3.2 Quality assessment of the included literature

All 42 papers included in this study were randomized controlled trials, and the quality assessment results were all grade B, indicating a moderate likelihood of bias in the literature. A total of 39 (92.86%) literatures mentioned the specific method of random sequence generation, mainly the randomized numeric table method; 33 literatures mentioned whether the allocation was hidden; none of the literatures mentioned whether subjects and intervention providers were blinded or not and whether outcome evaluators were blinded or not; 23 literatures had good completeness of the outcome data; and none of the literatures had selective reporting of the outcomes.

3.3 Comparison of teaching effectiveness of different teaching methods

The results of reticulated Meta-analysis of the teaching effect of different teaching methods on mechanics courses are shown in Table 1. The results show that hybrid teaching method, simulation teaching method, problem-oriented teaching method, diversified teaching method and flipped classroom are significantly better than traditional teaching method, and the differences are statistically significant ($P < 0.05$). The differences between the teaching effect of discussion-based teaching method, asynchronous teaching method and thinking cultivation method and traditional teaching method are not statistically significant ($P > 0.05$). Comparing different new teaching methods with each other, there is no statistically significant difference in the teaching effect of mechanics courses ($P > 0.05$).

Table 1: Results of Net Meta-analysis of Teaching Effectiveness of Different Teaching Methods

No.	New teaching methods	Contrasting teaching methods	Effect size	95% confidence interval		P-value
1	Blended Approach	Traditional Teaching Method	1.313	1.054	1.571	0.000
2	Simulation Teaching Method	Traditional Teaching Method	1.510	0.637	2.382	0.001
3	Problem-oriented Teaching Method	Traditional Teaching Method	1.989	1.004	2.974	0.000
4	Diversified Teaching Method	Traditional Teaching Method	1.001	0.479	1.524	0.000
5	Discussion Teaching Method	Traditional Teaching Method	0.341	-0.493	1.175	0.423
6	Flipped Classroom	Traditional Teaching Method	1.142	0.694	1.590	0.000
7	Asynchronous Teaching Method	Traditional Teaching Method	1.169	-0.487	2.825	0.167
8	Mindset Development Method	Traditional Teaching Method	0.573	-0.260	1.406	0.178

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3.4 SUCRA cumulative probability ranking

The sorting of area under the cumulative ranked probability plot (SUCRA) is an important method for comparing the effectiveness of different interventions. For this study, the larger the SUCRA value of different teaching methods, the more effective the teaching method is in improving the teaching effectiveness of the mechanic course. The analysis results of this study show that the problem-oriented teaching method can be the optimal teaching method, which has the greatest probability of being located in the first rank, with a SUCRA probability value of 91.5%; followed by the simulation teaching method, with a SUCRA probability value of 75.2%; followed by the blended teaching method, the asynchronous teaching method, the flipped classroom, the diversified teaching method, the thinking cultivation method, and the discussion method in the following order; the traditional teaching method ranked last with a SUCRA probability value of 4.8%.

4. Discussion

4.1 Analysis of teaching effectiveness of different teaching methods

In the early stage of China's large population base and relative lack of educational resources, the traditional teaching method can achieve the teaching effect of low educational input and high educational output. With the continuous development of science and technology, new teaching methods have emerged, reflecting unique advantages different from traditional teaching methods, and have achieved good teaching results. This study realizes the indirect comparison of the teaching effect between different teaching methods through the net Meta-analysis method, which helps teachers to choose the teaching method suitable for corresponding students among many teaching methods.

A total of eight novel teaching methods were included in this study through multiple rounds of literature search and screening. All such novel teaching methods have improved the teaching effectiveness of mechanics courses compared to traditional teaching methods, and the degree of improvement varies in all of them. For this reason, this study used the SUCRA tool to derive a ranking of the teaching effectiveness of different teaching methods. The ranking results show that the problem-based teaching method has a SUCRA probability value of 91.5%, which is the most effective for teaching mechanics courses and has a significant improvement on students' final grades. The reason for this is that the method can improve students' initiative and participation in learning, can cultivate students' ability to think and solve problems independently, promote teamwork and communication, and increase students' level of understanding and application of knowledge [12].

For mechanics courses, the content of the textbook is mostly basic theoretical knowledge, and less related to the combination of practical knowledge. The problems involved in the problem-oriented method can be echoed as the problems closely related to the theoretical knowledge and real life, which can cause students to resonate with the phenomena presented in the problem, stimulate the exploration potential of solving practical problems, and realize the teaching goal of combining science and reality. Therefore, it is recommended to use the problem-oriented teaching method in the future mechanics courses. The teaching effect of the simulation teaching method for mechanics courses is second only to the problem-oriented method. The reason may be that the simulation method can provide students with a platform and learning scenarios that link theory with engineering practice, effectively stimulate students' interest in learning and increase their practical hands-on ability. This is also a form of combination of basic theoretical knowledge and practical application in the textbook.

4.2 Exploration of a multi-track pedagogy

Multi-track teaching method is a kind of teaching method that integrates many different teaching methods, and it is also a direction of optimization of teaching effect that is worth trying and exploring. Single teaching methods each have their unique advantages and disadvantages, and the multi-track teaching method emphasizes the integrated application of these different teaching modes according to the characteristics of the content of the lecture and the target audience, in order to complement each other's strengths and complement each other's weaknesses, to further improve the teaching effect and to promote the enhancement of the quality of talent cultivation. For this study, the integrated application of the problem-oriented method and simulation teaching method may achieve better teaching results. For example, the set problem involves simulation and simulation type of problems, which is used as a guide to teach the course. Further, the blended approach or the rest of the pedagogies may also be appropriately

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incorporated into the actual teaching. In the process of implementing the multi-track teaching method, it may be necessary to consider the constraints of the amount of course hours, and rationally integrate and allocate the time required for each section to achieve the optimal teaching effect as much as possible.

5. Conclusion

Under the background of new engineering construction, mechanics courses are characterized by strong theory and high applicability. In recent years, a variety of new teaching methods have emerged, and after the practical verification of the previous generation, they all show better teaching effect than the traditional teaching methods and improve students' learning performance. Choosing the optimal teaching method can significantly improve the teaching effect of the course, so that students can get the comprehensive improvement of knowledge, ability and quality. The results of this study prove that the problem-oriented teaching can significantly improve students' learning performance and achieve the optimal teaching effect compared with other teaching methods. Problem-oriented teaching can be used in future mechanics courses in accordance with the actual learning situation. At the same time, given that different teaching methods have their own advantages and disadvantages, we can also explore the effective integration of the problem-oriented approach with other teaching methods to form a dual-track or multi-track teaching, in order to further improve the teaching effect.

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