Online-Journals.org

iJET International Journal of Emerging Technologies in Learning

iJET | eISSN: 1863-0383 | Vol. 18 No. 20 (2023) | OPEN ACCESS

https://doi.org/10.3991/ijet.v18i20.43875

PAPER

Teaching Effect Evaluation of Flipped Classrooms in Engineering Management Colleges: A Multivariate Ordered Logit Model

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ABSTRACT

Adapting traditional classroom teaching methods to students' personalized learning styles and needs can be challenging, resulting in passive learning, low teaching quality, and insufficient support for students' learning and development. The flipped classroom teaching model integrates information technology (IT) into education, enriches teaching approaches, and emphasizes a student-oriented concept. The flipped classroom can help students deeply understand the content by building upon shallow learning guided by effective teaching strategies. In turn, it facilitates the development of higher-order thinking skills and promotes students' physical and mental well-being. In this study, five engineering management colleges in Henan Province, China, were surveyed using a questionnaire distributed during the fall semester of 2022–2023. The factors influencing the teaching effect of the flipped classroom were analyzed using a multivariate ordered logit model. Results demonstrated that the questionnaire had a reliability coefficient of 0.844, a KMO value of 0.788, and a Bartlett sphericity test with a corresponding P value of less than 0.01. Several factors, including gender (P = 0.054), self-study ability (P = 0.064), campus network (P = 0.000), teaching resources (P = 0.085), and classroom interaction (P = 0.036), significantly influence the teaching effect of the flipped classroom. The findings of this study provide valuable insights for enriching the teaching management theory of the flipped classroom, helping teachers enhance their management abilities in implementing the flipped classroom, and facilitating convenient teaching and learning experiences for both teachers and students in information technology.

KEYWORDS

engineering management colleges, flipped classroom, teaching effect, effect evaluation, multivariate ordered logit model

Jia, J., Yang, J., Xue, L. (2023). Teaching Effect Evaluation of Flipped Classrooms in Engineering Management Colleges: A Multivariate Ordered Logit Model. *International Journal of Emerging Technologies in Learning (iJET)*, 18(20), pp. 72–82. https://doi.org/10.3991/ijet.v18i20.43875

Article submitted 2023-06-08. Revision uploaded 2023-08-10. Final acceptance 2023-08-14.

1 INTRODUCTION

The rapid development of information technology (IT) in today's society has enabled the digitization and informatization of educational resources, resulting in multimedia teaching methods replacing traditional chalk and blackboard-based teaching in schools. Information-based teaching forms offer a richer and more engaging learning experience compared to the monotonous traditional classroom. Students now gain knowledge not only from teachers but also through various information-based learning platforms. As students become more autonomous, self-directed learning has gained prominence. To adapt to these changes, teachers need to adjust their teaching concepts, methods, and roles to provide students with a learning environment and mode that align with the current era. New teaching models can integrate IT to facilitate teaching, provide access to a wide range of teaching resources, and create conditions conducive to students' all-round development. With the deep integration of IT and education, information-based teaching models have emerged. In the era of "Internet +," the Internet has permeated all aspects of life. In higher education, college students can access abundant learning materials online. Consequently, higher expectations are placed on the teaching and learning methods used by university teachers. Educational institutions in China and abroad have adjusted their teaching models and methods accordingly.

The flipped classroom, a product of the "Internet + Education" era, is supported primarily by network IT. The flipped classroom teaching model shifts the focus of classroom teaching from "imparting book knowledge" to "enhancing students' comprehensive quality." Compared with conventional classroom teaching, the flipped classroom reverses the teaching process, involving knowledge previewing inside and outside the classroom, in-class and out-of-class discussions, and knowledge application and guidance. Through discussions, practice, and consultations, teachers and students engage in more interactive exchanges. Teaching objectives have transitioned from cognitive, memorization, and application levels to analysis, evaluation, and creation, allowing for the realization of these objectives through interactions. Classroom interactions play a significant role in flipped classroom teaching with extended durations. Effective communication during these interactions helps maintain students' enthusiasm for learning. Through communication, students can grasp knowledge, enhance their learning abilities, and develop problem-solving skills independently. Effective interaction is a crucial factor in improving teaching quality. The flipped classroom, with its flexible learning time and place and abundant learning resources, breaks the constraints of traditional teaching methods, highlighting the advantages of student autonomy and active learning. It effectively addresses the shortcomings of traditional teaching and brings new vitality to education. However, despite the increasing popularity of the flipped classroom, its teaching effect is not always ideal. The reasons are not only related to teachers' limited educational concepts, insufficient digital application skills, and weak management abilities, but also to the lack of comprehensive teaching management systems. The current teaching management system is formulated based on the traditional classroom teaching mode and is not entirely suitable for effectively supporting the implementation of the flipped classroom in engineering management colleges.

2 LITERATURE REVIEW

As a novel teaching approach, the flipped classroom overcomes the constraints of time and space and emphasizes the flexibility of learning environments

and resources. It highlights the importance of students' autonomy and active learning. Evaluating the teaching effectiveness of the flipped classroom has become a research focus.

Jdaitawi [1] concluded that the flipped classroom model improves students' academic performance and provides relevant teaching suggestions. Wei et al. [2] discussed the management method of the flipped classroom in the Chinese context and proposed an approach to enhance middle school students' mathematics learning performance. The results indicated a significant improvement in students' mathematics academic performance, particularly at the middle level. Leis et al. [3] found that students using the flipped classroom spent more time preparing lessons compared with those using the traditional teaching method, and their post-test composition showed a higher word count. Sun et al. [4] explored the influence of the flipped classroom on students' self-regulation abilities in open-course teaching. The findings indicated that the flipped classroom model creates a learning environment that encourages learners to actively seek external help. Gren [5] asserted that the flipped classroom method enhances learning by allowing more time for classroom activities and improving performance while teaching software engineering topics. Subramaniam et al. [6] employed a quasi-experimental design and reported high student participation in the flipped classroom group based on questionnaire survey results. Yaroslavova et al. [7] indicated that the flipped classroom method positively affects the development of English learners' communicative competence, providing strategic insights for promoting language development. Hashemifardnia et al. [8] examined the influence of the flipped classroom on Iranian junior high school students' reading comprehension. The post-test scores of the experimental group were better than those of the control group. Debbağ et al. [9] used a quasi-experimental design and found that the flipped classroom provides trained teachers with the opportunity to apply their knowledge, improve their teaching skills, and actively participate in the course. Empirical results from Murillo-Zamorano et al. [10] emphasized four fundamental dimensions of the flipped classroom and its positive impact on students' knowledge, skills, and participation. Talan et al. [11] observed that students who experienced the flipped classroom teaching model achieved higher academic performance and investment compared with the control group, expressing general satisfaction with the approach. Hotle et al. [12] identified that the only disadvantage of the flipped classroom is the limited opportunity for students to ask questions during class. Whether this impacts students' learning outcomes is suggested for future research. Jaiprakash [13] demonstrated that the intelligent flipped classroom teaching model enhances students' academic performance, stimulates learning initiative, and improves satisfaction. Afrilyasanti et al. [14] found statistical differences in post-test scores between the experimental group using the flipped classroom model and the control group using traditional teaching methods. Wang et al. [15] showed that the flipped classroom enhances students' learning interest and motivation, indicating its positive effect on college teaching.

Existing literature reveals that the flipped classroom is a digital teaching application model consisting of two stages. Before class, teachers prepare engaging, concise, and easy-to-understand digital learning resources delivered through the Internet and IT, and students complete online learning tasks. In class, teachers assist students in exploring key and challenging concepts from pre-class learning, providing inspiration and guidance. Therefore, it is essential to deeply explore the factors that affect the evaluation of the flipped classroom teaching effect among engineering management college students to inform curriculum teaching reform and enhance teaching quality in higher engineering education.

3 METHODOLOGY

3.1 Model introduction

The multivariate ordered logistic regression analysis is employed to investigate the effects of different influencing factors (explanatory variables) on ordered multi-class variables (explained variables). It involves fitting several logistic regression models at the level of dependent variables to form a cumulative logit model.

Assuming the values of the dependent variables are 1, 2, 3, and 4, and the probabilities of the corresponding values are π_1, π_2, π_3, and π_4. The three models are fitted for n independent variables as shown in (1)–(3):

$$Logitp_1 = Logit\frac{\pi_1}{1-\pi_1} = Logit\frac{\pi_1}{\pi_2+\pi_3+\pi_4} = -\alpha_1 + \beta_1 x_1 + \ldots + \beta_n x_n \tag{1}$$

$$Logitp_2 = Logit\frac{\pi_1+\pi_2}{1-(\pi_1+\pi_2)} = Logit\frac{\pi_1+\pi_2}{\pi_3+\pi_4} = -\alpha_2 + \beta_1 x_1 + \ldots + \beta_n x_n \tag{2}$$

$$Logitp_3 = Logit\frac{\pi_1+\pi_2+\pi_3}{1-(\pi_1+\pi_2+\pi_3)} = Logit\frac{\pi_1+\pi_2+\pi_3}{\pi_4} = -\alpha_3 + \beta_1 x_1 + \ldots + \beta_n x_n \tag{3}$$

Compared with the traditional logistic regression in which the dependent variable is binomial, those subjected to logit transform are π_1, $\pi_1+\pi_2$, and $\pi_1+\pi_2+\pi_3$, that is, the cumulative probability for the ordered values of dependent variables.

Hence, π_1, $\pi_1+\pi_2$, and $\pi_1+\pi_2+\pi_3$ can be solved according to the three regression equations, and π_4 is obtained through conversion, as shown in (4).

$$\begin{aligned}
\pi_1 &= \frac{\exp(-\alpha_1 + \sum_{i=1}^{n}\beta_i x_i)}{1+\exp(-\alpha_1 + \sum_{i=1}^{n}\beta_i x_i)} \\
\pi_2 &= \frac{\exp(-\alpha_2 + \sum_{i=1}^{n}\beta_i x_i)}{1+\exp(-\alpha_2 + \sum_{i=1}^{n}\beta_i x_i)} - p_1 \\
\pi_3 &= \frac{\exp(-\alpha_3 + \sum_{i=1}^{n}\beta_i x_i)}{1+\exp(-\alpha_3 + \sum_{i=1}^{n}\beta_i x_i)} - p_1 - p_2 \\
\pi_4 &= 1-\pi_1-\pi_2-\pi_3
\end{aligned} \tag{4}$$

The model essentially divides the dependent variables into two levels based on their different values and establishes a binary logistic regression model for these two levels. The resulting odds ratio (OR) indicates the ratio of the unit change in the independent variable to the increment of the dependent variable by one level. The advantage of the multivariate ordered logistic model is its ability to handle multiple categories of dependent variables without losing substantial data information. Additionally, this model considers the orderliness of the variables, ensuring consistent parameter estimation results even when different values are assigned. This prevents varying parameter estimation results from the use of a linear probability model, thereby ensuring the stability of research findings. In comparison to the binary logistic model, the ordered logit regression model allows testing for the significant impact of different sequences of independent variables on dependent variables.

3.2 Data source

Henan Province in China is a region known for its highly developed higher engineering education. The education authorities in Henan Province have emphasized the importance of abundant information resources and have encouraged students to become active participants in their studies, promoting the widespread adoption of the flipped classroom in colleges and universities. Engineering colleges play a vital role in fostering the development of China's manufacturing industry, considering China as major manufacturing country. For this study, the research subjects consisted of students majoring in management from five universities in Henan Province: Zhengzhou University of Aeronautics, Zhengzhou Technology and Business University, Henan University of Engineering, Henan University of Economics and Law, and Henan University of Science and Technology. A questionnaire survey was conducted on the spot during the autumn semester of the academic year 2022–2023, using paper questionnaires. The dependent variable and the teaching effect of the flipped classroom were defined based on previous research by Jdaitawi [1], Ayçiçek [16], and Subramaniam [6], which identified five dimensions: classroom cognition, process experience, classroom acceptance, the flipped classroom environment, and difficulty coping. The specific questionnaire items related to the teaching effect of the flipped classroom are presented in Table 1. Explanatory variables were chosen based on research findings by Liu [17], Cheng [18], and Lai [19], and included gender, self-study ability, campus network, teaching resources, flipping process, classroom interaction, coping ability, and after-class mutual evaluation.

Table 1. Questionnaires on the teaching effect of flipped classroom

Variable	Measurement Problem	Problem No.
Classroom cognition	Flipped classroom can improve the classroom learning effect	A1
	Flipped classroom can improve the learning efficiency	A2
	Flipped classroom is conducive to students' autonomous learning	A3
Process experience	Flipped classroom enhances learning interest	B1
	Flipped classroom arouses students' curiosity	B2
	Flipped classroom enhances teacher-student interactions	B3
	Flipped classroom can drive students to explore	B4
Classroom acceptance	I am willing to implement flipped learning using teaching resources	C1
	I am willing to accept flipped classroom in different courses	C2
	I am willing to recommend flipped classroom to other students for learning	C3
	I am willing to persist in studying under the flipped classroom mode	C4
Flipped classroom environment	The attitude of surrounding students over flipped classroom has a great influence on me	D1
	I can search the Internet thanks to network coverage in the school	D2
	The network learning resources purchased by the school are ich	D3
	Teachers possess very abundant teaching resources that can be utilized by students	D4
Difficulty coping	I can be timely helped when encountering any difficulty in flipped classroom	E1
	I believe that I can effectively cope with difficulties encountered in flipped classroom	E2

4 RESULTS

4.1 Reliability and validity tests

As shown in Table 2, the reliability coefficient of the questionnaire is 0.844, which indicates high reliability of the research data since it exceeds the threshold of 0.8. The "item deleted α coefficient" reveals that deleting any item does not increase the reliability coefficient, suggesting that none of the items should be deleted.

Table 2. Reliability test result

Name	Corrected Item Total Correlation (CITC)	Item Deleted α Coefficient	Cronbach α Coefficient
A1	0.453	0.836	0.844
A2	0.442	0.837	
A3	0.470	0.835	
B1	0.531	0.832	
B2	0.523	0.832	
B3	0.588	0.829	
B4	0.627	0.827	
C1	0.470	0.835	
C2	0.480	0.835	
C3	0.394	0.839	
C4	0.279	0.844	
D1	0.294	0.843	
D2	0.302	0.843	
D3	0.284	0.844	
D4	0.492	0.834	
E1	0.473	0.835	
E2	0.540	0.831	
Standardized Cronbach α coefficient: 0.843			

Table 3. KMO and Bartlett tests

KMO Value		0.788
Bartlett sphericity test	Approximate chi-square	2379.814
	df	136
	P value	0.000

Table 3 displays a KMO value of 0.788 and a corresponding P value from the Bartlett sphericity test that is less than 0.01. These results indicate excellent validity for the questionnaire used in this study.

4.2 Multivariate ordered logit regression results

The factors influencing the flipped classroom teaching effect were subjected to regression analysis using the multivariate ordered logit model in Stata software (StataMP-64). The results of the analysis are presented in Table 4.

Table 4. Results of the multivariate ordered logit regression model

Explanatory Variable	Regression Coefficient	Standard Error	z Value	Wald χ^2	P Value	OR Value
Gender	0.432	0.224	1.925	3.708	0.054	1.540
Self-study ability	0.266	0.144	1.850	3.423	0.064	0.767
Campus network	0.387	0.075	5.196	26.997	0.000	1.473
Teaching resource	0.217	0.126	1.723	2.970	0.085	1.242
Flipping process	0.051	0.217	0.233	0.054	0.816	1.052
Classroom interaction	0.319	0.152	2.095	4.388	0.036	0.727
Coping ability	0.067	0.218	0.307	0.094	0.759	0.935
After-class evaluation	0.023	0.132	0.172	0.029	0.864	0.978

Table 4 reveals the following:

1. Gender influences the flipped classroom teaching effect in engineering management colleges, with a significant regression coefficient at the 10% level. The probability of achieving a positive flipped classroom teaching effect among males is higher than that among females. This suggests that males are more engaged in discussion, interaction, and communication within the flipped classroom environment. This trend is likely due to the focus on manual operations in engineering management colleges, which are particularly suited for male students. The flipped classroom model, with its emphasis on independent learning and practical ability, aligns well with male students' learning preferences.
2. Self-study ability has a significant impact on the flipped classroom teaching effect in engineering management colleges, with a significant regression coefficient at the 10% level. Students who possess better self-control and self-study abilities are more likely to benefit from the student-centered approach of the flipped classroom. The model encourages autonomous learning, the application of knowledge to real or simulated situations, and the cultivation of higher-order thinking skills. By implementing heuristic teaching methods, fostering students' autonomous inquiry skills, and providing positive feedback and expectations, teachers can effectively enhance students' comprehensive quality and intrinsic motivation.
3. The campus network has a significant impact on the flipped classroom teaching effect in engineering management colleges, with a significant regression coefficient at the 1% level. Effective communication between learners and teachers is essential in a flipped classroom environment. In China, platforms such as Superstar Fanya and Tencent Conference are widely used for implementing flipped classroom reforms. Teachers utilize these platforms to upload teaching resources, publish tasks, receive feedback, facilitate discussions, answer questions, and record student interactions. A reliable campus network is crucial for achieving the expected teaching effect of the flipped classroom.

4. Teaching resources have a significant impact on the flipped classroom teaching effect in engineering management colleges, with a significant regression coefficient at the 10% level. The blended learning approach embodied in the flipped classroom aligns with cognitive laws and promotes the efficient utilization and development of teaching resources. The integration of IT and the physical classroom in the flipped classroom fosters a student-oriented teaching model that focuses on cultivating application ability. A flipped classroom provides flexibility, overcoming limitations of time and space, and enables teachers to leverage teaching resources effectively. This approach has the potential to play a valuable role in most higher education scenarios.
5. The flipping process has no significant influence on the flipped classroom teaching effect in engineering management colleges. However, it poses a challenge for teachers to select course content and effectively control all teaching links. Some teachers overlook the importance of reasonable control throughout the flipped classroom teaching process, prioritizing the teaching form over guiding students to complete tasks and focusing on optimizing the teaching process to improve the teaching effect.
6. Classroom interaction has a significant impact on the flipped classroom teaching effect in engineering management colleges, with a significant regression coefficient at the 5% level. Communication within the classroom is an essential teaching activity involving mutual dialogue between teachers and students. Under the flipped classroom model, classroom interaction becomes an integral part of teaching. It can be categorized into teacher-student interaction and student-student interaction. Teacher-student interactions can take various forms, whereas student-student interactions occur at the individual and group levels. Flipped classrooms integrate teaching content and IT, emphasizing the importance of classroom interaction.
7. Coping ability has no significant influence on the flipped classroom teaching effect in engineering management colleges. This may be because the overall implementation of the flipped classroom model in some courses has not yielded ideal results. Many teachers treat flipping as a mere formality and fail to grasp its core principles. Teaching remains teacher-dominated, and students' interest and initiative in learning are not sufficiently enhanced. This finding suggests that teachers should focus on problem-based teaching to spark students' curiosity and combine effective guidance to cultivate their problem-solving skills in real-life situations.
8. After-class evaluation has no significant influence on the flipped classroom teaching effect in engineering management colleges. This is mainly because when students encounter cognitive conflicts between their existing concepts and new knowledge, they need to engage in reflection. While in-class comments from teachers and classmates can partially correct cognitive biases, independent problem-solving may still lead to cognitive conflicts. Students need to reflect continuously after class, assimilate new ideas comprehensively, put them into practice, and achieve knowledge transfer. However, many teachers and students tend to overlook the importance of post-class evaluation. They fail to recognize that post-class evaluation is a crucial step, requiring teachers to provide targeted feedback based on students' mastery and design diverse assignments that cater to students' varying levels of understanding.

5 DISCUSSION

The emergence of the flipped classroom has transformed the way students learn core curriculum content independently before class [20]. Class time has become

dedicated to exploring their preparedness and collaboratively solving key problems. This study identified key factors that influence the implementation of the flipped classroom in engineering management colleges. The flipped classroom model enhances classroom participation, learning initiative, and the subjective initiative of students through an optimized teaching atmosphere. By understanding students' pre-class questions, teachers can clarify key and challenging points, design teaching that meets students' needs, and facilitate collaborative problem-solving during class. Attention should be given to continuously improving teachers' abilities and qualities, optimizing teaching methods, and providing updated teaching resources to foster student interest and facilitate enjoyable learning experiences. Establishing a comprehensive teaching platform and strengthening its applicability, information accessibility, and functionality are crucial for the success of the flipped classroom model. It should support uploading teaching materials, facilitating teacher-student and student-student discussions, monitoring course progress, presenting teaching summaries, and evaluating learning outcomes. These measures stimulate students' interest in professional knowledge, foster communication between teachers and students, guide students to enhance their learning consciousness and self-confidence, and achieve the goals of effective course teaching.

6 CONCLUSION

With the integration of IT and education, information elements have become integral to teaching and learning activities. The flipped classroom is a representative model of information-based teaching. It facilitates a transition from teaching book knowledge to enhancing students' comprehensive quality and promotes students' overall development. The flipped classroom significantly improves students' manual operation ability and enhances their higher-order thinking skills to a certain extent. This research surveyed five engineering management colleges in Henan Province, China, using a questionnaire distributed during the autumn semester of the 2022–2023 academic year. The study analyzed the factors affecting the teaching effect of the flipped classroom using a multivariate ordered Logit model. The following conclusions were drawn: (1) The reliability coefficient of this questionnaire was 0.844, the KMO value was 0.788, and the corresponding p value of the Bartlett sphericity test was less than 0.01. (2) Five factors, i.e., gender ($P = 0.054$), self-study ability ($P = 0.064$), campus network ($P = 0.000$), teaching resources ($P = 0.085$), and classroom interaction ($P = 0.036$), all had a significant influence on the teaching effect of a flipped classroom. (3) The flipping process, coping ability, and after-class evaluation did not have notable effects on flipped classroom teaching. Further research is recommended to explore the relationship between flipped classroom teaching content and teaching processes, stimulate students' interest in professional knowledge within the flipped classroom model, and optimize the implementation process of the flipped classroom teaching model.

7 ACKNOWLEDGMENT

This study was supported by the Graduate Quality Improvement Engineering Project of Zhengzhou University of Aeronautics (No. 2022YJSKC01), the Education and Teaching Reform Research and Practice Project of Zhengzhou University of Aeronautics (No. zhjy22-48), and the 2021 university-level online open courses of Zhengzhou University of Aeronautics.

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