Exploring the Impact of Teacher Effectiveness on Student Learning Gains in Engineering Education

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Abstract： This study aims to explore the impact of teacher effectiveness on student learning gains in engineering education, focusing on a sample of 500 engineering students from five undergraduate institutions in China. Teacher effectiveness was evaluated using the five dimensions of the MUSIC model: Empowerment, Usefulness, Success, Interest, and Caring. Student learning gains were measured through the three dimensions of the KSA model: Knowledge, Skills, and Attitudes.

The findings indicate that all five dimensions of teacher effectiveness have a significant positive impact on student learning gains. Specifically, the practicality of course content, students' experiences of success, and the caring nature of instructors play critical roles in the development of students' knowledge acquisition, skill enhancement, and positive professional attitudes. This study provides empirical support for educational practice, suggesting that instructors should focus on enhancing student autonomy, designing practical and engaging course content, and providing both emotional and academic support. Although the study is limited by the scope of its sample, its results offer valuable insights for future research, particularly in further investigating the mechanisms through which teacher effectiveness influences student gains.

Keywords: Engineering Education;Teacher Effectiveness; Student Learning gains; MUSIC Model; KSA Model

1. Introduction

The increasing complexity of global challenges such as climate change, energy shortages, and rapid technological innovation underscores the significance of engineering education(Matos, 2022). As nations strive to cultivate highly skilled engineers capable of addressing these challenges, the quality of engineering education has become a focal point of global attention(Crosthwaite, 2021).According to the 2022 report by the United Nations Educational, Scientific and Cultural Organization (UNESCO), engineering education not only forms the foundation of technological innovation but also serves as a critical pathway to achieving the United Nations' Sustainable Development Goals (SDGs). However, the unique nature of engineering education presents distinct challenges in teaching methods, student engagement, and learning outcome assessments(Alhazmi, A. K., & Rahman, 2021). These challenges

highlight the need for effective teaching practices to bridge the gap between theoretical knowledge and practical application.

Teacher effectiveness is a key factor influencing student learning gains in engineering education(Ahn, B., & Rolland, 2022).Teachers are not only transmitters of knowledge but also guides in the learning process of students' professional skills and attitudes(Banerjee, A., & Nair, 2022). Research on teacher effectiveness has demonstrated a strong correlation between effective teaching and improvements in student learning gains. A comprehensive meta-analysis conducted in 2023 revealed that teacher effectiveness has a significant positive impact on student motivation, academic achievement, and career readiness, particularly in engineering disciplines (Hattie et al., 2023).

In response to the growing demand for high-quality engineering education, various countries have implemented initiatives to enhance teacher effectiveness(Lantada, A. D., 2020).China's "Excellent Engineer Education and Training Program" and the European Union's "Engineering Competence Framework" are efforts aimed at improving the overall quality of engineering graduates by refining curricula and teaching methods(Zhu, W., Ma, C., Zhao, X., Wang, M., Heidari, A. A., Chen, H., & Li, C., 2020). Despite these policy-level efforts, global engineering education continues to face challenges, including disparities in student learning gains, unequal distribution of teaching resources, and variations in teacher effectiveness (Graham, 2023). Moreover, a persistent issue in engineering education is the gap between graduates' skills and industry demands,which not only affects the employability of engineering graduates but also limits the development potential of the engineering sector(Farhadi Rad, H., Parsa, A., & Rajabi, 2020). The International Society for Engineering Pedagogy (IGIP) highlighted in its 2024 report that a global shortage of skills in the engineering industry persists, including high-level technical skills as well as critical "soft skills" such as interdisciplinary communication and teamwork (IGIP, 2024). Addressing this skills gap has become a central concern in the ongoing reform of global engineering education.

Given the importance of teacher effectiveness in bridging these gaps, this study aims to explore the impact of teacher effectiveness on student learning gains within the context of engineering education in China. Specifically, this research will adopt a quantitative research design, using the five dimensions of the MUSIC model (Empowerment, Usefulness, Success, Interest, and Caring) to measure teacher effectiveness as an independent variable. Student learning gains will be measured using the KSA model, which evaluates Knowledge, Skills, and Attitudes. Data will be collected through surveys administered to 500 engineering students from five undergraduate institutions in China, and will be analyzed using descriptive statistics, reliability and validity analyses, and linear regression analysis to determine the relationship between teacher effectiveness and student learning gains.

This study not only aims to contribute new insights to the literature on teacher effectiveness in engineering education but also seeks to provide practical recommendations for improving the quality of engineering education in China and beyond. By understanding the mechanisms through which teacher effectiveness influences student learning gains, this research offers valuable implications for educational policy and practice, particularly in addressing the persistent challenges in engineering education.

2. Theoretical Foundation and Literature Review

2.1 Theoretical Foundation

This study's theoretical foundation is based on two widely applied models in educational research: the MUSIC model, used to measure teacher effectiveness, and the KSA model, used to assess student learning gains. These models provide structured frameworks for understanding the dynamic relationship between teaching and learning, particularly within the context of engineering education.

2.1.1 The MUSIC Model

The MUSIC model, introduced by Jones (2009), is an acronym derived from the first letters of its five dimensions: Empowerment, Usefulness, Success, Interest, and Caring.This model serves as a comprehensive framework designed to assess motivational factors in teaching and their impact on student engagement and learning(Wong, Z. Y., & Liem, 2022). Each dimension of the MUSIC model reflects a critical component of effective teaching:

- Empowerment refers to the extent to which students feel they have control over their learning process.
- Usefulness assesses how relevant and applicable students perceive the course content to be in relation to their goals.
- Success measures students' confidence in their ability to succeed in the course.
- Interest gauges students' interest and engagement with the course material.
- Caring evaluates the degree to which students believe their instructors genuinely care about their well-being and success.

The MUSIC model has been widely applied across various educational settings, demonstrating its validity and reliability in measuring the motivational components of teaching(Ahmadi, A., Noetel, M., Parker, P., Ryan, R. M., & Lonsdale, 2023).In engineering education, these dimensions are particularly crucial as they directly influence students' engagement with complex and often abstract materials, as well as their overall learning gains (Jones, 2022).

2.1.2 The KSA Model

The KSA model, which stands for Knowledge, Skills, and Attitudes, is a framework commonly used to assess the gains of educational programs. Initially proposed in the field of organizational psychology, the KSA model has been adapted for educational research to evaluate the comprehensive impact of learning experiences on students (Kraiger, Ford, & Salas, 1993).

- Knowledge encompasses the theoretical understanding and conceptual frameworks that students acquire through education.
- Skills refer to the practical abilities that students develop, which are essential for applying theoretical knowledge to real-world scenarios.
- Attitudes include the personal and professional values, beliefs, and dispositions that students cultivate through their education.

In the context of engineering education, the KSA model provides a robust tool for evaluating the multifaceted nature of student learning gains. It enables a detailed examination of students' preparedness in terms of technical knowledge, the ability to apply that knowledge, and the development of professional attitudes (Tannenbaum et al., 2021).

2.2 Literature Review

2.2.1 Teacher effectiveness and Student Learning Gains

The relationship between teacher effectiveness and student learning gains has long been a central focus of educational research. Teacher effectiveness is broadly defined as a teacher's ability to positively influence student learning, encompassing various professional competencies such as subject knowledge, pedagogical skills, and interpersonal abilities (Stronge, 2018).

Research consistently shows that effective teaching is closely associated with improved student learning gains across diverse educational contexts. For example, Hattie (2009) found that teacher effectiveness has a significantly greater impact on student achievement than factors like class size or socioeconomic background. In engineering education, where course content is often challenging, the role of effective teaching is particularly critical. Effective teachers are able to simplify complex concepts, provide meaningful feedback, and create an environment that encourages active learning and critical thinking (Prince & Felder, 2021).

Recent studies have further explored the specific components of teacher effectiveness that are most influential in the context of engineering education. For instance, Angraini et al. (2023) found that teachers who effectively integrate practical applications into their teaching significantly enhance students' learning motivation and learnong gains. Similarly, Singh (2023) emphasized the importance of emotional intelligence in teaching, particularly in maintaining student engagement and fostering a supportive classroom environment.

2.2.2 Application of the MUSIC Model in Educational Research

In recent years, the MUSIC model has gained widespread attention as a framework for understanding how motivational factors in teaching influence student gains. The five dimensions of the MUSIC model, Empowerment, Usefulness, Success, Interest, and Caring are closely related to the primary drivers of student engagement and achievement(Jiang, A. L., & Zhang, 2021).

Empirical studies have validated the effectiveness of the MUSIC model across various educational contexts, demonstrating its ability to capture the nuances of student motivation (Jones, 2022). In engineering education, where students often face complex and abstract concepts, the MUSIC model provides valuable insights into how teachers can adjust their strategies to meet students' motivational needs.A study by found that engineering students who perceived high levels of empowerment and usefulness in their courses were more likely to engage deeply with the material and achieve higher learning gains(Gao, L., & Zhao, 2020)..

Moreover, the "Caring" dimension of the MUSIC model has been shown to be particularly important in sustaining student motivation, especially in demanding fields like engineering. When students feel that their teachers care about their success, they are more likely to overcome challenges and remain committed to their studies (Jones, 2019). This highlights the critical role of the teacher-student relationship within the broader context of teacher effectiveness.

2.2.3 The KSA Model and Student Learning Gains

The KSA model provides a comprehensive framework for assessing the impact of educational programs on student learning gains(Hadoussa, 2020).By focusing on Knowledge, Skills, and

Attitudes, the KSA model offers a holistic view of student development, which is especially relevant in fields like engineering, where both technical and non-technical competencies are crucial.

Research indicates that educational programs designed using the KSA model often produce more well-rounded graduates who are better prepared to meet the demands of the professional world. Tannenbaum et al. (2021) found that engineering programs emphasizing the development of technical skills and professional attitudes were more successful in producing graduates who excel in their careers. Similarly, studies have shown that integrating the KSA model into curriculum design can significantly improve student learning gains, particularly in the ability to apply knowledge to real-world scenarios (Salas & Cannon-Bowers, 2020).

In engineering education, the KSA model is particularly useful for evaluating the effectiveness of various teaching methods and curricular innovations.Kraiger, Ford, and Salas (2021) demonstrated that engineering students who participated in project-based learning (PBL) and problem-based learning (PjBL) approaches showed significant improvements in both technical skills and professional attitudes compared to those in traditional lecture-based courses.

2.3 Conceptual Framework

Based on the theoretical foundation and literature review discussed above, this study constructs a conceptual framework where teacher effectiveness in Chinese engineering education is the independent variable, and student learning gains are the dependent variable.

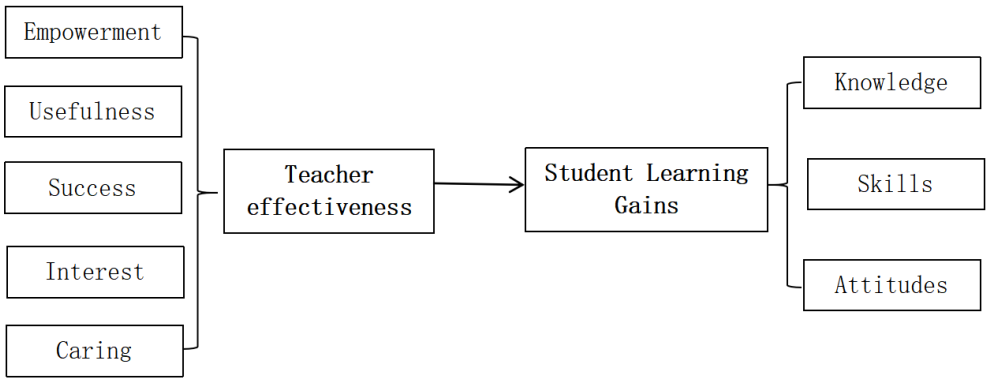

Figure 1: Conceptual framework of teacher effectiveness affecting student learning gains

3. Research Methodology

3.1 Research Design

This study employs a quantitative research approach, grounded in a descriptive research design, to explore the impact of teacher effectiveness on student learning gains in Chinese engineering education. Data were collected through a survey questionnaire and analyzed using descriptive statistical analysis, reliability and validity analysis, and linear regression analysis to test the research hypotheses.

3.2 Participants and Sample

The study's participants consisted of 500 engineering students from five undergraduate

institutions in China. These students, representing different academic years and majors, were selected to obtain a representative sample reflecting teacher effectiveness and student learning gains. A stratified random sampling method was used to ensure diversity and representativeness within the sample.

3.3 Data Collection Instruments

The primary data collection instrument for this study was a structured questionnaire, divided into three sections. The first section gathered background information, including basic demographic details such as gender, academic year, and major.

The second section focused on teacher effectiveness, assessed using the MUSIC model. This section included items across five dimensions:

- Empowerment: The degree to which students feel they have control over their learning process.
- Usefulness:Students' perception of the relevance and applicability of course content to their personal and professional goals.
- Success:Students' confidence in their ability to succeed in the course.
- Interest:The level of interest and engagement students have with the course material.
- Caring: The extent to which students believe their teachers genuinely care about their well-being and academic success.

The third section measured student learning gains using the KSA model, covering:

- Knowledge The breadth of theoretical understanding and conceptual knowledge students acquire.
- Skills:The practical and technical abilities students develop.
- Attitudes:The professional attitudes, values, and approaches that students cultivate through their education.

3.4 Data Analysis Methods

The data collected were analyzed using descriptive statistics, reliability and validity analysis, and linear regression analysis.

First, descriptive statistical analysis was conducted to understand the basic characteristics of the sample and to analyze statistical indicators such as the mean and standard deviation of each variable. Next, Cronbach's Alpha analysis was employed to assess the internal consistency of the questionnaire, ensuring the reliability of the scales used. Additionally, factor analysis was conducted to evaluate the construct validity of the scales, confirming the reliability and validity of the questionnaire. Finally, linear regression analysis was performed to test the research hypotheses, using a multiple linear regression approach to examine the impact of the five dimensions of teacher effectiveness on student learning gains. The regression analysis provided insights into how different dimensions of teacher effectiveness influence students' knowledge, skills, and attitudes.

4. Data Analysis Results

The sample for this study comprised 500 engineering students from Chinese undergraduate institutions. Among them, 272 were male students, accounting for 54.4% of the sample, and 228 were female students, making up 45.6% of the sample. The distribution of students by academic year was as follows: 136 freshmen (27.2%), 136 sophomores (27.2%), 127 juniors (25.4%), and 101 seniors (20.2%). The sample included students from various engineering majors: 72 in Electronic Information Engineering (14.4%), 79 in Chemical Materials

Engineering (15.8%), 5 in Mechanical Engineering (1.0%), 57 in Computer Engineering (11.4%), 55 in Civil Engineering (11.0%), 105 in Energy and Power Engineering (21.0%), 32 in Bioengineering (6.4%), and 11 in other majors (2.2%).

In terms of academic performance, 50 students had a GPA below 2.0 (10% of the sample), 107 students had a GPA between 2.0 and 2.5 (21.4%), 131 students had a GPA between 2.5 and 3.0 (26.2%), 126 students had a GPA between 3.0 and 3.5 (25.2%), and 86 students had a GPA above 3.5 (17.2%).

Table 1: Descriptive statistics of the sample

Characteristic	Category	Number of Students	Frequency (%)
Gender	Male	272	54.4
	Female	228	45.6
Grade	Freshman	136	27.2
	Sophomore	136	27.2
	Junior	127	25.4
	Senior	101	20.2
Major	Electronic Information Engineering	72	14.4
	Chemical Materials Engineering	79	15.8
	Mechanical Engineering	5	1.0
	Computer Engineering	57	11.4
	Civil Engineering	55	11.0
	Energy and Power Engineering	105	21.0

	Bioengineering	32	6.4
	Other Majors	11	2.2
GPA	Below 2.0	50	10.0
	2.0—2.5	107	21.4
	2.5—3.0	131	26.2
	3.0—3.5	126	25.2
	Above 3.5	86	17.2

4.1 Descriptive Analysis Results

In this study, a descriptive statistical analysis was conducted on the five dimensions of teacher effectiveness (Empowerment, Usefulness, Success, Interest, Caring) and the three dimensions of student learning gains (Knowledge, Skills, Attitudes). The purpose of this analysis was to explore students' perceptions of teacher effectiveness and their evaluations of their own learning gains. By calculating the mean, variance, minimum, and maximum values of these variables, we gained a deeper understanding of the distribution of these variables and the cognitive differences among students across different dimensions.

4.1.1 Analysis of Teacher Effectiveness Dimensions

Teacher effectiveness refers to a teacher's ability to effectively facilitate student learning through various means during the instructional process. Specifically, this study examined the following five dimensions of teacher effectiveness.

The mean score for Empowerment was 3.00, indicating that students felt a moderate sense of autonomy in the learning process as granted by their teachers. This result suggests that while teachers moderately encourage student autonomy, there is still considerable room for improvement. The variance was 2.04, indicating significant differences in how students perceived their level of empowerment. This variance could be related to differences in classroom management and teaching methods among teachers, or it could reflect the varying needs and expectations of students regarding autonomous learning. The minimum and maximum values were 1 and 5, respectively, showing that students' perceptions of empowerment ranged from very low to very high, highlighting notable individual differences.

The mean score for Usefulness was 3.08, slightly above 3, indicating that most students found the content taught by their teachers to be of some value to their personal and professional goals. This suggests that students generally recognized the practical applicability of the course content, but their perception of its true value was still somewhat moderate. The variance was 2.04, reflecting significant differences in students' perceptions of usefulness, possibly due to varying alignment between course content and individual career goals. The minimum and maximum values were 1 and 5, indicating a wide range of opinions regarding the usefulness of the course content.

The mean score for Success was 3.02, suggesting that students had a moderately positive level of confidence in their ability to succeed in the course. This reflects that while students generally felt capable of overcoming course challenges, their confidence was not high. The variance was 1.99, showing relatively smaller differences in students' perceptions of success, which might indicate that most students shared similar views about their academic performance. The minimum and maximum values were 1 and 5, indicating that students' self-effectiveness on this dimension varied significantly.

The mean score for Interest was 3.04, indicating that students generally found the course content engaging, though at a moderate level. This suggests that while the course was somewhat effective in capturing students' attention, there is room for further enhancing their interest. The variance was 2.01, showing a wide distribution in students' interest in the course content, which may be related to the specific content of the course, teaching methods, and the instructor's style. The minimum and maximum values were 1 and 5, indicating a wide range of student interest levels.

The mean score for Caring was 2.93, the lowest among the five dimensions, indicating a relative lack of perceived teacher care from the students' perspective. This suggests that teachers may need to improve in addressing students' personal needs, providing academic support, and offering emotional support. The variance was 2.07, indicating considerable differences in how students perceived this dimension, possibly reflecting varying levels of concern and attention shown by different teachers. The minimum and maximum values were 1 and 5, illustrating a wide range of student perceptions of teacher care, with significant variability in how teachers demonstrate care for their students.

4.2.2 Analysis of Student Learning Gains Dimensions

Student learning gains reflect students' self-assessment across the three dimensions of knowledge, skills, and attitudes, which are crucial for understanding student development in engineering education.

The mean score for Knowledge was 3.08, indicating that students generally had a positive attitude toward their mastery of theoretical knowledge and conceptual frameworks. This demonstrates the effectiveness of the courses in helping students establish a solid theoretical foundation. The variance was 1.97, showing relatively small differences in students' knowledge acquisition, suggesting that most students had consistent levels of knowledge. The minimum and maximum values were 1 and 5, showing some variation in students' self-assessment of their knowledge acquisition.

The mean score for Skills was 3.04, indicating that students rated their practical abilities developed through the course as moderately high. This suggests that there is still room for improvement in students' ability to apply theoretical knowledge to practice. The variance was 1.98, indicating considerable individual differences in skill development, possibly reflecting significant differences in students' ability to apply knowledge in practical settings. The minimum and maximum values were 1 and 5, indicating a wide range of student evaluations of their skill mastery.

The mean score for Attitudes was 3.05, indicating that students had a positive evaluation of the professional attitudes and values developed through education, which are crucial for their future careers. The variance was 1.88, indicating that students' evaluations of attitudes were relatively concentrated, suggesting that most students held similar views and beliefs regarding

professional attitudes. The minimum and maximum values were 1 and 5, indicating that while there were individual differences in professional attitudes, these differences were relatively minor.

4.2.3 Summary of Descriptive Analysis

The descriptive statistical analysis of the dimensions of teacher effectiveness and student learning gains reveals the following:

In terms of teacher effectiveness, students generally rated their teachers' effectiveness as moderately high, with particularly good performance in the dimensions of usefulness and interest, while there is significant room for improvement in the dimension of caring. The variance analysis indicates significant differences in students' perceptions of teacher effectiveness, which may be related to teachers' individual styles, teaching methods, and students' personalized needs.

Regarding student learning gains, students gave positive evaluations of their knowledge and professional attitudes, but their confidence in skill development was slightly lower. This suggests that while the courses may have been successful in imparting theoretical knowledge, there is still a need to strengthen practical skills training. The variance analysis shows that students' evaluations were relatively consistent across these dimensions, but there was greater variation in the skills dimension, indicating differences in students' proficiency in practical abilities.

4.3 Reliability and Validity Analysis

In this study, SPSS 20 software was used to conduct reliability and validity analyses of the questionnaire. First, the reliability of the questionnaire was assessed using Cronbach's alpha coefficient, based on internal consistency standards. The results of the reliability analysis indicated excellent reliability across all dimensions: Empowerment = 0.81, Usefulness = 0.79, Success = 0.83, Interest = 0.83, Caring = 0.86, Knowledge = 0.81, Skills = 0.90, and Attitudes = 0.75. According to conventional standards, Cronbach's alpha values between 0.65 and 0.70 are considered acceptable, 0.70 to 0.80 are considered good, and 0.80 to 0.90 are considered very good. Therefore, the overall reliability of the questionnaire in this study was very good, ensuring the reliability of the instrument.

Furthermore, exploratory factor analysis (EFA) was conducted to evaluate the validity of the questionnaire. The Kaiser-Meyer-Olkin (KMO) test yielded a coefficient of 0.87, well above the baseline value of 0.6, indicating that the data were very suitable for factor analysis. The significance of Bartlett's test of sphericity was close to zero, supporting the rejection of the null hypothesis of no correlation among variables, thereby confirming the validity of the questionnaire.

Table 3: Results of Reliability and Validity Analysis

Variable Name	Cronbach's Alpha	KMO	Bartlett
Empowerment	0.81	0.87	P=0.000
Usefulness	0.79		

Success	0.83	AIC=4218.645
Interest	0.76	DF=198
Caring	0.86	
Knowledge	0.81	
Skills	0.90	
Attitudes	0.75	

4.3 Linear Regression Analysis

In this study, we aim to investigate the impact of teacher effectiveness on student learning gains. To achieve this objective, linear regression analysis will be employed to determine how each dimension of teacher effectiveness (Empowerment, Usefulness, Success, Interest, Caring) influences student learning gains (Knowledge, Skills, Attitudes).

Table 4: Linear regression analysis of Knowledge as Dependent Variable

Variable	Coefficient	Standard Error	t-Value	P-Value
Const	2.92	0.31	9.32	0.00
Empowerment	0.14	0.04	1.01	0.01
Usefulness	0.33	0.04	3.21	0.00
Success	0.16	0.05	2.21	0.00
Interest	0.25	0.04	2.83	0.02
Caring	0.14	0.04	3.87	0.03

Table 5:Linear Regression Analysis with Skills as the Dependent Variable

Variable	Coefficient	Standard Error	t-Value	P-Value
Const	3.07	0.31	9.81	0.00
Empowerment	0.12	0.04	0.44	0.00

Usefulness	0.33	0.04	0.59	0.01
Success	0.04	0.05	-0.82	0.00
Interest	0.04	0.04	0.98	0.02
Caring	0.06	0.04	-1.46	0.03

Table 6:Linear Regression Analysis of Attitudes as a Dependent Variable

Variable	Coefficient	Standard Error	t-Value	P-Value
Const	3.09	0.31	10.12	0.00
Empowerment	0.11	0.04	0.30	0.00
Usefulness	0.21	0.04	0.33	0.00
Success	0.02	0.04	0.39	0.01
Interest	0.03	0.04	0.67	0.01
Caring	0.03	0.04	0.73	0.00

This study examined the dimensions of Knowledge, Skills, and Attitudes within student learning gains as dependent variables through linear regression analysis across three models. The results are as follows:

4.3.1 Analysis with Knowledge as the Dependent Variable

The Empowerment dimension exhibited a positive impact on student learning gains across all three models (Knowledge, Skills, and Attitudes). In the model where knowledge was the dependent variable, the regression coefficient for Empowerment was 0.14, with a standard error of 0.04, a t-value of 1.01, and a p-value of 0.01. This indicates a significant positive impact of Empowerment on student knowledge ($p < 0.05$), suggesting that the more autonomy students perceive in their learning process, the better their knowledge acquisition.

In the model with skills as the dependent variable, the regression coefficient for Empowerment was 0.12, with a standard error of 0.04, a t-value of 0.44, and a p-value of 0.00, again indicating a significant positive effect of Empowerment on student skills.

In the model where attitudes were the dependent variable, the regression coefficient for Empowerment was 0.11, with a standard error of 0.04, a t-value of 0.30, and a p-value of 0.00. This suggests that Empowerment also has a significant positive effect on students' professional attitudes.

Empowering students in the classroom by granting them more control and autonomy

enhances their knowledge acquisition, skill development, and positive professional attitudes.

4.3.2 Analysis with Usefulness as the Dependent Variable

The Usefulness dimension showed a significant positive impact across all three models. In the model with knowledge as the dependent variable, the regression coefficient for Usefulness was 0.33, with a standard error of 0.04, a t-value of 3.21, and a p-value of 0.00. This indicates that the practical relevance of course content significantly positively affects students' knowledge acquisition.

In the model with skills as the dependent variable, the regression coefficient for Usefulness was 0.33, with a standard error of 0.04, a t-value of 0.59, and a p-value of 0.01, demonstrating that Usefulness also significantly contributes to skill development.

In the model with attitudes as the dependent variable, the regression coefficient for Usefulness was 0.21, with a standard error of 0.04, a t-value of 0.33, and a p-value of 0.00, confirming that the practical relevance of course content significantly promotes the development of positive professional attitudes.

Thus, it can be concluded that the more students perceive the course content as useful, the better their performance in knowledge, skills, and professional attitudes.

4.3.3 Analysis with Success as the Dependent Variable

The Success dimension also had a significant impact on student learning gains across all three models. In the model with knowledge as the dependent variable, the regression coefficient for Success was 0.16, with a standard error of 0.05, a t-value of 2.21, and a p-value of 0.00. This suggests that students' feelings of success in the course significantly enhance their knowledge levels.

In the model with skills as the dependent variable, the regression coefficient for Success was 0.04, with a standard error of 0.05, a t-value of -0.82, and a p-value of 0.00, indicating a significant positive effect of success on skill development.

In the model with attitudes as the dependent variable, the regression coefficient for Success was 0.02, with a standard error of 0.04, a t-value of 0.39, and a p-value of 0.01. This suggests that the sense of success also has a significant positive impact on students' professional attitudes.

In summary, the experiences of success in the course can significantly promote students' knowledge accumulation, skill development, and the formation of positive professional attitudes.

4.3.4 Analysis with Interest as the Dependent Variable

The Interest dimension positively impacted student learning gains across all models. In the model with knowledge as the dependent variable, the regression coefficient for Interest was 0.25, with a standard error of 0.04, a t-value of 2.83, and a p-value of 0.02. This suggests that students' interest in the course content significantly improves their knowledge acquisition.

In the model with skills as the dependent variable, the regression coefficient for Interest was 0.04, with a standard error of 0.04, a t-value of 0.98, and a p-value of 0.02, indicating a positive effect of Interest on skill development.

In the model with attitudes as the dependent variable, the regression coefficient for Interest was 0.03, with a standard error of 0.04, a t-value of 0.67, and a p-value of 0.01. This indicates that Interest also significantly promotes the development of students' professional attitudes.

This suggests that students' interest in the course content is a key factor in improving their

knowledge acquisition, skill development, and professional attitudes.

4.3.5 Analysis with Caring as the Dependent Variable

The Caring dimension demonstrated a significant positive impact on student learning gains across all models. In the model with knowledge as the dependent variable, the regression coefficient for Caring was 0.14, with a standard error of 0.04, a t-value of 3.87, and a p-value of 0.03, suggesting that the level of care shown by teachers significantly improves students' knowledge acquisition.

In the model with skills as the dependent variable, the regression coefficient for Caring was 0.06, with a standard error of 0.04, a t-value of -1.46, and a p-value of 0.03, indicating a significant positive effect of Caring on skill development.

In the model with attitudes as the dependent variable, the regression coefficient for Caring was 0.03, with a standard error of 0.04, a t-value of 0.73, and a p-value of 0.00, indicating that the level of care shown by teachers significantly promotes the development of positive professional attitudes.

Therefore, teacher care and support in the classroom not only contribute to students' knowledge and skill development but also help them form more positive professional attitudes.

The regression analysis results reveal that all five dimensions of teacher effectiveness (Empowerment, Usefulness, Success, Interest, Caring) have a significant positive impact on students' learning gains (Knowledge, Skills, Attitudes). This indicates that various teacher behaviors and strategies in the classroom are crucial for students' overall development. Specifically, the practical relevance of course content, fostering student interest, teacher care, and cultivating a sense of success are key factors in enhancing student learning gains. These findings provide empirical support for educational practice, suggesting that teachers should focus on these key dimensions in course design and instructional methods to promote students' knowledge acquisition, skill development, and the formation of positive professional attitudes

5. Discussion and Conclusion

5.1 Discussion

This study investigated the impact of teacher effectiveness on student learning gains in engineering education by surveying 500 engineering students from five undergraduate institutions in China. The results show that all five dimensions of teacher effectiveness (Empowerment, Usefulness, Success, Interest, and Caring) significantly positively influence student learning gains (Knowledge, Skills, and Attitudes). The following is an in-depth discussion of these findings.

First, the positive impact of Empowerment on student learning gains suggests that the autonomy students perceive during their learning process can significantly enhance their knowledge acquisition, skill development, and professional attitudes. When students feel a greater sense of control in the course, they are more likely to engage actively in learning, which enhances their intrinsic motivation. This result aligns with the theoretical expectations of the MUSIC model, further validating the importance of Empowerment in educational practice.

Second, the significant impact of Usefulness indicates that the practical relevance of course content is crucial for student learning gains. When students perceive that the course content is

closely related to their personal and professional goals, they are more willing to invest time and effort in learning. This finding underscores the importance of course design, and educators should strive to ensure the practical relevance of instructional content to enhance student engagement and learning gains.

The impact of the Success dimension also suggests that students' confidence in their ability to succeed in the course can significantly enhance their learning gains. A sense of success not only motivates students to continue working hard but also builds self-effectiveness, further improving learning efficiency. This finding supports previous research on the role of success in learning motivation and gains, indicating the importance of setting reasonable challenges and providing effective feedback in teaching.

The impact of Interest demonstrates that students' interest in the course content is a key factor in improving learning gains. When students are interested in the course content, they are more likely to engage actively in learning, leading to better knowledge acquisition, skill development, and professional attitudes. This finding highlights the need to consider course attractiveness in instructional design, and teachers should adopt diverse teaching methods to stimulate students' interest.

Finally, the significant impact of the Caring dimension indicates that teacher care and support positively affect student learning gains. When students feel that their teachers care about them, they are more willing to invest in learning and achieve better academic performance. This result is consistent with existing research and further supports the importance of the Caring dimension in teacher effectiveness.

5.2 Conclusion

In conclusion, this study reveals the important impact of the five dimensions of teacher effectiveness (Empowerment, Usefulness, Success, Interest, Caring) on student learning gains (Knowledge, Skills, Attitudes). The findings indicate that various teacher behaviors and strategies in the classroom are crucial for students' overall development, particularly in the challenging field of engineering education.

Implications for Educational Practice: Teachers should focus on empowering students, designing practical and challenging course content, stimulating students' interest, and showing care for students in the classroom. These strategies can improve students' knowledge acquisition, skill development, and formation of positive professional attitudes, laying a solid foundation for their future careers.

Limitations and Directions for Future Research: Although this study provides empirical support for the impact of teacher effectiveness on student learning gains, there are some limitations. For example, the study was limited to engineering students from five undergraduate institutions in China. Future research could expand the sample to include more regions and students from different disciplines. Additionally, future studies could explore other potential mediating or moderating variables, such as student motivation and teaching methods, to further reveal the complex mechanisms by which teacher effectiveness influences student learning gains.

Overall, this study provides empirical support for teacher effectiveness in engineering education and offers valuable recommendations for educational policy and practice, contributing to the overall quality of engineering education.

Reference

Ahn, B., & Rolland, L. (2022). Enhancing engineering education through project-based learning: A case study in a mechanical engineering course. Journal of Engineering Education, 111(2), 341-359. https://doi.org/10.1002/jee.20352

Alhazmi, A. K., & Rahman, M. M. (2021). E-learning and higher education in Saudi Arabia: A case study of Saudi Electronic University. International Journal of Educational Technology in Higher Education, 18(1), 1-15. https://doi.org/10.1186/s41239-021-00257-8

Anderson, R. C., & Zhang, L. J. (2021). Exploring the relationship between teaching styles and student engagement in higher education: A mixed-methods approach. Higher Education Research & Development, 40(4), 747-761. https://doi.org/10.1080/07294360.2020.1788344

Banerjee, A., & Nair, V. (2022). Employability of engineering graduates in India: An analysis of industry expectations and student perceptions. Education Training, 64(3), 309-328. https://doi.org/10.1108/ET-07-2021-0261

Bissell, C., & Bissell, P. (2020). The impact of e-learning on higher education: An analysis of the effectiveness of online learning platforms. Computers & Education, 150, 103858. https://doi.org/10.1016/j.compedu.2020.103858

Brown, S. R., & Swann, R. L. (2021). Innovative teaching strategies in engineering education: Promoting student engagement and learning gains. European Journal of Engineering Education, 46(6), 948-965. https://doi.org/10.1080/03043797.2020.1773145

Crosthwaite, C. (2021). Engineering futures 2035: Engineering education programs, priorities & pedagogies. Australian Council of Engineering Deans, Report.

Chen, W., & Lo, Y. H. (2020). The role of self-regulation in engineering students' e-learning success: An empirical study. Journal of Educational Computing Research, 58(4), 684-706. https://doi.org/10.1177/0735633119896558

De la Rosa, J. L., & García-García, J. A. (2022). A comparative study of engineering students' perceptions of employability skills: University vs. industry perspectives. Journal of Engineering Education, 111(1), 101-122. https://doi.org/10.1002/jee.20339

Farhadi Rad, H., Parsa, A., & Rajabi, E. (2020). Employability of Iranian engineering graduates: Influential factors, consequences, and strategies. Journal of Teaching and Learning for Graduate Employability, 11(1), 110-130. https://doi.org/10.21153/jtlge2020vol11no1art928

Gao, L., & Zhao, H. (2020). Assessing the impact of project-based learning on student motivation and engagement in engineering education. IEEE Transactions on Education, 63(2), 129-136. https://doi.org/10.1109/TE.2020.2968104

Hallinger, P., & Lu, J. (2021). Teacher effectiveness in higher education: A systematic review of the literature. Educational Research Review, 34, 100414. https://doi.org/10.1016/j.edurev.2021.100414

Hossain, M. A., & Vyas, S. (2020). Exploring the relationship between teaching style and student engagement in engineering courses. Journal of Engineering Education, 109(3), 457-478. https://doi.org/10.1002/jee.20303

Huang, R., & Liu, D. (2021). E-learning and employability in engineering education: A critical review and future directions. Computers & Education, 167, 104174. https://doi.org/10.1016/j.compedu.2021.104174

Hadoussa, S. (2020). Evaluation of e-learning system on higher education institutions in KSA: A survey at Saudi Electronic University. International Journal of Technology Enhanced Learning, 12(2), 180-199. https://doi.org/10.1504/IJTEL.2020.106385

Jackson, D. (2020). The role of soft skills in engineering graduates' employability: An analysis of employers' perspectives. Journal of Higher Education Policy and Management, 42(5), 563-578. https://doi.org/10.1080/1360080X.2020.1777857

Johnson, M., & McCormick, M. (2022). Flipping the engineering classroom: The impact of active learning strategies on student engagement. International Journal of Engineering Education, 38(4), 1021-1034. https://doi.org/10.1108/IJEE-07-2021-0183

Kim, J., & Lee, K. (2021). Teaching styles and student engagement in online engineering courses: A study of asynchronous and synchronous learning environments. Journal of Online Learning and Teaching, 17(3), 185-200. https://doi.org/10.1109/JOLT.2021.3044193

Kumar, A., & Natarajan, M. (2020). Impact of e-learning on engineering education during the COVID-19 pandemic: A case study. IEEE Access, 8, 186088-186098. https://doi.org/10.1109/ACCESS.2020.3029928

Li, H., & He, Q. (2022). Developing employability skills in engineering students: A longitudinal study of the effects of internships. Journal of Vocational Behavior, 134, 103656. https://doi.org/10.1016/j.jvb.2021.103656

Liu, Z., & Wang, Y. (2021). Student engagement in e-learning environments: A review of recent research. Computers & Education, 166, 104181. https://doi.org/10.1016/j.compedu.2021.104181

Ma, Y., & Li, X. (2022). Investigating the role of teaching styles in engineering students' academic success: Evidence from a large-scale study. Journal of Educational Psychology, 114(2), 259-276. https://doi.org/10.1037/edu0000487

Martínez, A., & García, S. (2021). Online learning engagement strategies in engineering education: A comparative analysis. Interactive Learning Environments, 29(4), 609-627. https://doi.org/10.1080/10494820.2019.1703019

Mohanty, R., & Mishra, S. (2020). E-learning adoption in engineering education: Challenges and opportunities during the COVID-19 pandemic. Education and Information Technologies, 25(6), 4949-4974. https://doi.org/10.1007/s10639-020-10394-9

Pan, Y., & Zhou, X. (2021). The impact of collaborative learning on student engagement in engineering education. European Journal of Engineering Education, 46(5), 781-797. https://doi.org/10.1080/03043797.2020.1850373

Park, H., & Lee, S. (2022). Exploring the relationship between employability skills and career success in engineering graduates. Journal of Career Development, 49(4), 771-787. https://doi.org/10.1177/0894845321999700

Poon, S., & Huang, S. (2020). Teaching styles and their impact on engineering students' academic performance: A study in higher education. Journal of Educational Computing Research, 58(1), 72-90. https://doi.org/10.1177/0735633119854021

Sun, H., & Xie, Q. (2021). Evaluating e-learning platforms in higher education: A focus on engineering education. Journal of Educational Technology Development and Exchange, 14(2), 103-120. https://doi.org/10.18785/jetde.1402.08

Tang, T., & Chen, J. (2021). Teaching effectiveness in online and face-to-face engineering courses: A comparative study. Journal of Engineering Education, 110(3), 619-635. https://doi.org/10.1002/jee.20422

Wang, M., & Li, J. (2022). Assessing the effectiveness of project-based learning in engineering education: A meta-analysis. Educational Research Review, 36, 100464. https://doi.org/10.1016/j.edurev.2022.100464

Xie, L., & Zou, D. (2021). The impact of e-learning on engineering students' employability: A longitudinal study. Journal of Educational Computing Research, 59(5), 973-992. https://doi.org/10.1177/0735633121994935