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Influence of Interdisciplinary Teaching System on Interdisciplinary Competence of Engineering Graduate Students: Analysis of Mediating Effects of Interdisciplinary Identity

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Abstract

Background Interdisciplinary graduate education is not only an urgent need for scientific and technological innovation toward socioeconomic development but also aligns with the law of the growth of high-level innovative talents. It has now become an important trend in the reform of global graduate education. The transformation has stimulated some forms of interdisciplinary experiences, including critical thinking awareness, interdisciplinary team teaching, etc. However, little is known about the core characteristics that shape interdisciplinary competence and internal effect mechanisms.

Purpose/Hypothesis This study seeks to explore how the interdisciplinary teaching system relates to the interdisciplinary competence of engineering graduates. We specifically examine the connections within the interdisciplinary teaching system, including comprehensive curriculum emphasis, student-centered instructional practices, and interdisciplinary competence. Also, we explore the internal effect mechanisms by introducing the theory of identity to discuss the mediating effects of interdisciplinary identity and try to figure out how students describe themselves and are positioned by others in the role of being an interdisciplinary learner. And we further explore the mediating effects of the three dimensions of interdisciplinary identity: interest, recognition, and performance.

Design/Method This study uses a survey sample of 310 engineering graduate students in 3 High-level Research Universities in China. Using linear modeling, we investigate the relationships among interdisciplinary teaching system on graduates' interdisciplinary competence and explore the mediating effects of interdisciplinary identity.

Results This study finds that: (1) Student-centered instructional practices, as well as comprehensive curriculum emphasis, have a significant role in promoting the interdisciplinarity of engineering graduate students. And Student-centered teaching methods

have a more significant effect on improving students' interdisciplinary ability than comprehensive curriculum emphasis. (2) The recognition of interdisciplinary identity plays a partially mediating role between the interdisciplinary teaching system and interdisciplinary competence, and the performance dimension has the strongest mediating effect. (3) Student-centered instructional practices have a stronger impact than comprehensive curriculum emphasis on engineering students' interdisciplinary identity, especially on the interest dimension.

Conclusions This study emphasizes the crucial role of interdisciplinary identity in linking external teaching with internal competence and seeks to identify effective and practical approaches for cultivating interdisciplinary identity. Based on the above, this paper suggests that, in the practice of interdisciplinary education reform, the design of student-centered teaching methods should be strengthened, and the construction of interdisciplinary identity of engineering graduate students should be continuously stimulated through interest stimulation, recognition support, and performance feedback. It is hoped that future studies can continue to explore how to develop domain-specific identity-based motivation measures for students.

Introduction

Many complex engineering issues faced today cannot be solved through the lens of one discipline alone and go beyond the traditional image of engineers' tasks [1], calling for the cultivation of interdisciplinary engineering talents who can deal with divergent and ambiguous problems both within and outside the boundaries of their own discipline. However, the traditional training mode rooted in the knowledge production model I lacks the awareness of composing and developing students' interdisciplinary competence [2] and has been criticized for not effectively preparing engineering students to function in complex contexts [3][4].

Recognizing the complexity of engineering practices, recent policy documents call for greater investments in interdisciplinary education. For example, Facilitating Interdisciplinary Research, 2004 and New Biology for the 21st Century, 2009 note that research in many scientific disciplines is becoming more interdisciplinary, requiring graduates to be capable of working across boundaries. For example, the National Academy of Engineering's Engineer of 2020 report and ABET's Criterion requires engineering programs to ensure that students learn to work in multidisciplinary teams, and the report "Graduates STEM Education for the

21st Century" regards interdisciplinary knowledge as one of the core education elements when cultivating STEM graduates. Thus, interdisciplinarity has become an increasingly important feature of engineering education over recent decades, and work has begun to extend these efforts from undergraduate to graduate education [5].

Despite multiple interdisciplinary teaching modes being designed to meet this need, critics view interdisciplinary teaching innovation at this stage as lacking novelty, scholarly depth, methodological rigor, and integrated planning [6]. It has been recommended that the value of interdisciplinarity cannot be explained without attention to the subjects valuing it and the inner changes they undergo [7]. However, previous studies of interdisciplinarity in engineering education settings primarily focus on the direct relationship between interdisciplinary teaching approaches and interdisciplinary competence. It ignores students' understanding, internalization, and absorption of interdisciplinary teaching content and teaching methods, which to some extent, regard students as passive recipients of interdisciplinary education and teaching [8][9]. Though some researchers have found that graduate students who are enrolled in interdisciplinary degree programs appear to have a more firm understanding of interdisciplinarity and integration [10], and such subjective experiences can yield positive educational outcomes, such as the leadership on an interdisciplinary team [11], there is also limited evidence of how subjective experiences may affect interdisciplinary competence in students who are studied in interdisciplinary degree programs.

Thus, we introduce interdisciplinary identity as the primary manifestation of subjective experience about how individuals view their disciplinary affiliation. And we try to answer the following questions: (1) whether the construction of interdisciplinary identity can effectively promote the improvement of interdisciplinary competence, and (2) how faculty members can facilitate the design of the interdisciplinary teaching system to expedite the development of interdisciplinary identity.

In this study, we begin with a literature review of interdisciplinary identity, followed by empirical research focusing on exploring how those identities are constructed by implementing teaching practices and how interdisciplinary identity relates to engineering graduate students' interdisciplinary competence. Using mediation analysis and a multi-institution sample of graduate students from 12 engineering disciplines, our study opens the "black box" that interdisciplinary teaching system can affect students' interdisciplinary

competence. The results of this study not only strongly support the identity-based motivation theory but also provide a good research perspective and a foundation for follow-up research and interdisciplinary teaching practices. The subsequent section describes the foundation of interdisciplinary identity from prior literature.

Theoretical framework

Identity

People tend to classify themselves into a specific type of people rather than others. This kind of active exploration of their belonging is called *identity*, which is the perception or internal definition of a sense of self [12][13][14]. Prior works on identity employ both psychological and sociocultural perspectives. Psychological approaches primarily focus on one's self-perception. In this context, identity refers to the self-conception and self-perception of one's unique characteristics, including personality traits, values, beliefs, and experiences. From sociocultural perspectives, identity refers to the sense of belonging and attachment to a larger social group or community based on shared characteristics, such as culture, religion, or nationality [15]. Although differences exist between the two perspectives, they are more different in emphasis than in kind. Thus, some researchers link the two perspectives to get a more fully integrated view. They view identity as a complex phenomenon that involves reflexive activities of self-categorization and identification with respect to membership in specific groups [16][17]. In the following, we prefer the third interpretation as it provides a more comprehensive understanding of identity.

Interdisciplinary identity

Disciplinary and interdisciplinary identities are two manifestations of identities in terms of disciplinary affiliations and have been regarded as an intrinsic driving force for learning strategies, learning performance, and career choice [18][19]. The distinctions of knowledge construction, traditions as well as academic cultures lead to the formation of ***disciplinary tribes*** with: "… their own traditions and categories of thought which provide the members of the field with shared concepts of theories, methods, techniques and problems" [20]. The physical boundaries, such as independent space, and symbolic boundaries, such as distinct knowledge bases, emanating from the disciplinary boundedness, create an "us/them" sorting mechanism among disciplinary tribes. It plays a critical role in the development of

disciplinary identities, which means a recognition of the value of discipline, an expectation to engage in relevant work, and a desire to be accepted into the tribe. Universities function with disciplinary identities as their faculty employment, departmental organization, and fiscal allocations around disciplinary boundaries, and students construct a collective "we" through disciplinary associations [21]. The professionalism and stability of identity accentuate the similarities (in mindset, norms, and values) within the group. And students tend to favor members of their disciplinary group, a phenomenon known as in-group bias. However, out-group stereotyping is raised simultaneously, resulting in the emergence of disciplinary centralism and inhibiting communication across disciplines.

With the advent of interdisciplinary research trends, the boundaries of disciplines continue to blur. The overlaps of fields lead to the conflict of differentiated cognitive modes and challenge how individuals view their disciplinary affiliations. How students responded to the cross-disciplinary encounter, both positive and negative, marked the reformation of academic identities around disciplines [22]. Researchers have defined four possible outcomes, including ***Dominance,*** where one of the two identities dominates over the other. ***Compartmentalization*****,** where one of the identities can be activated and expressed, depends on the context or situation where the subject finds herself. ***Intersection***, where the subject identifies with the fairly small intersection of both. For example, students might identify primarily with other biochemists more so than with biologists at large or chemists at large, though other ingroup members are restricted to the relatively small group of biochemists. ***Merger*****,** where ingroup identification is extended to other members of either group and often manifests itself in a problem-oriented identity that resists disciplinary boundaries [23][24]. The merger is perceived as the most desirable state where we form an interdisciplinary identity.

In this study, we define *interdisciplinary identity* as how students describe themselves and are positioned by others in the role of being an interdisciplinary learner. As a framework for understanding interdisciplinary identity, we turn to Godwin's identity research[25], which regards interest, recognition, and performance as three dimensions of identity. Among them, ***interest*** refers to a desire or curiosity to think about and do well in an interdisciplinary field. ***Recognition*** refers to the perception of being recognized by others as an interdisciplinary learner. ***Performance*** means belief in one's ability to perform required interdisciplinary tasks successfully. This structure encompasses self-perception of one's values, beliefs, and

experiences. Also, it entails a deep psychological perception of belonging to the interdisciplinary group, in line with the features of identity.

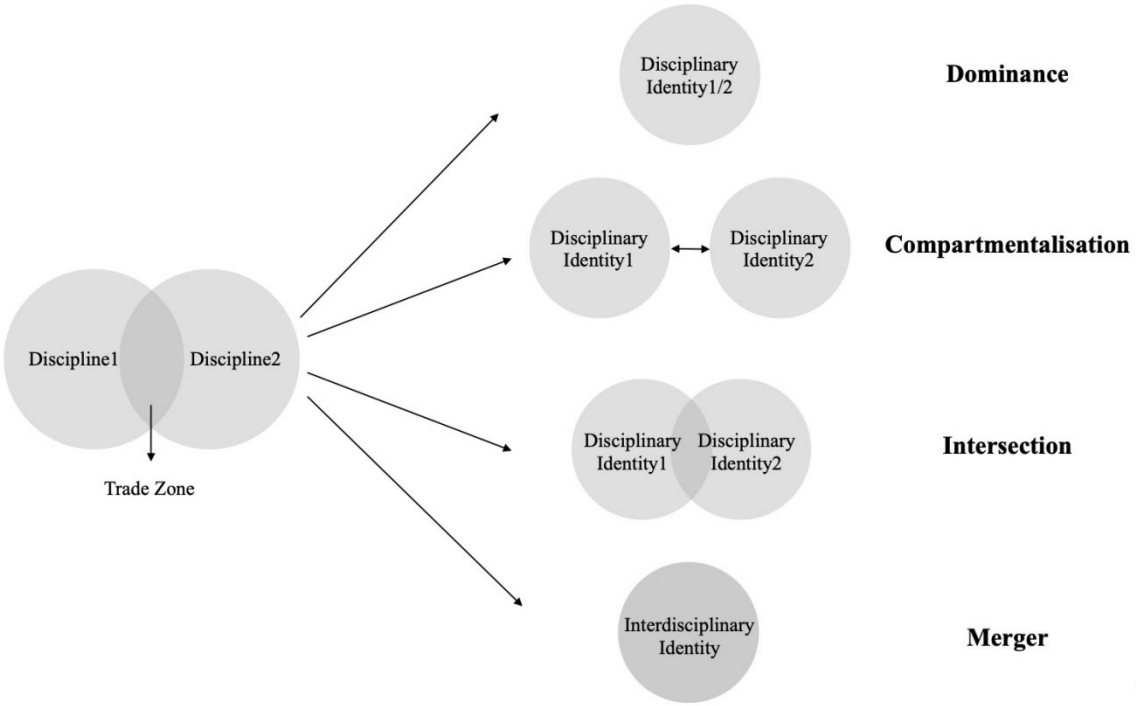

Figure1. The Forming Process of Identity

Identity-based motivation theory

Identity-based motivation theory highlights the role of identities in shaping individuals' motivations and behaviors [26]. It includes two main points: (1) Identity is not fixed but dynamically shaped by the environment. Identity-based motivation theory emphasizes the importance of creating an inclusive environment that supports individuals' identities. Such an environment can help individuals feel a sense of belonging and motivate them to engage in behaviors consistent with their identities. Furthermore, studies have revealed that identity construction is mainly related to four types of elements: ***Individual attributes***. According to the essentialist and individualist theories of identity, identities derive from personal attributes such as race and gender. ***Social relationships***. Social identity theory proposes that identities grow out of social relationships by categorizing ourselves as different from some groups and similar to others. ***Authority distribution***. The endorsement of laws, rules, and traditions defines one's position in a larger institutional structure where people internalize power as norms and expectations attached to their identity traits. ***Culture***. Differentiate oneself from others by course system, model of thinking, theory of value, etc. [27]. (2) People are more

likely to be motivated to achieve goals and engage in behaviors consistent with their identities. Relevant studies have shown that identity, an essential dimension of self-concept, can effectively predict one's behaviors, including social relationship construction, performance, etc. For example, researchers have examined connections between identity and persistence, and intentions to pursue careers [28]. This theory provides a theoretical foundation for further understanding the relationship between interdisciplinary teaching system, interdisciplinary identity, and interdisciplinary competence.

Conceptual framework

How the interdisciplinary teaching system and interdisciplinary competence have been connected

Interdisciplinary competence refers to the capability to integrate and apply knowledge from multiple disciplines to solve complex problems. Our study adopts Lattuca's (2012) [29] definition of interdisciplinary competence, which encompasses abilities to work across disciplines both within (awareness of disciplinarity, appreciation of disciplinary perspectives, etc.) and outside the field (reading outside the field, thinking in different ways, etc.) [30]. The interdisciplinary teaching system is composed of interdisciplinary design both in content and practices. Overall, it can be summarized in two aspects: (1) **Comprehensive curriculum emphasis.** It provides different perspectives on a particular problem both within and outside the field and emphasizes comprehensive qualities, such as professional values and critical thinking. It promotes a holistic understanding of the relationships among perspectives derived from different disciplines and the integration of interdisciplinary knowledge structures. With repeated exposure to interdisciplinary thoughts, learners develop more advanced epistemological beliefs, enhance critical thinking ability and metacognitive skills, and help individuals to overcome narrow disciplinary bias and achieve interdisciplinarity [31][32]. (2) **Student-centered teaching methods.** Recent years have seen an increase in the number of studies linking interdisciplinary learning with the development of active methodologies such as problem-based learning [33]. The "student-centered teaching methods," compared to "teacher-centered teaching methods," is a relatively new teaching paradigm that emphasizes the dominant position of students in the teaching process, aims to cultivate students' transferability and raise students' interdisciplinary learning purpose [34]. This kind of teaching approach is quite reasonably close to constructivist instructional learning theory and

its teaching principle, which takes over the logic of discipline standard by the logic of talent cultivation and human development and breaks the situation of disciplinary demarcation.

Thus, it is proved that students who are immersed in the interdisciplinary teaching system can develop adaptive thinking, communication skills, and collaborative competence both within and outside the disciplinary field. Therefore, we propose the following hypothesis:

H1: Interdisciplinary teaching system has a significant positive impact on the interdisciplinary competence of engineering graduate students.

How interdisciplinary identity and interdisciplinary teaching system have been connected

The identity-based motivation theory holds that identity is not fixed but often fluid, negotiable, and strategically defined [35]. Moreover, it emphasizes the importance of creating an inclusive environment that can help individuals feel a sense of belonging and motivate them to engage in behaviors consistent with their identities. Reviews of research on interdisciplinary identity not only involve self-definitions associated with individual expertise such as a solid disciplinary foundation, an understanding of the integrative process, and the ability to participate in collaborative research[36], but also rely on organizational efforts, such as university cultures, organizational structures, infrastructural support, and power structures, to create affiliation [19].

However, the discussions above have overlooked an important viewpoint that identity usually arises in the learning process within the interdisciplinary teaching system and performs the bridging function in boundary crossing. In this study, we consider the interdisciplinary teaching system as a tool for developing interdisciplinary identity. More than simply the sum of knowledge reflected through a curriculum design or class syllabi, the interdisciplinary teaching system represents a comprehensive curriculum of study or training that structures students'awareness of learning. By providing multiple interpretive perspectives across disciplines and creating an experiential teaching environment for real and complex issues, situational interests in interdisciplinary learning can be stimulated and promote the formation of interdisciplinary identity [37]. Also, the interdisciplinary teaching system contains a social process shaped by engagement in interdisciplinary teaching, as the students and instructors collectively construct knowledge related to particular topics. And

self-categorization often arises from social interactions and performs in the form of communities, including informal networks and peer mentorship. The community situation helps students experience a growing openness toward concepts and approaches from other disciplines and develop relations of reciprocal recognition [7][36]. Furthermore, a desire to protect in-group relationships requires openness and willingness to accept different fields and leads to the development of an identity congruent with their perception of the interdisciplinary community [28]. Thus, this interdisciplinary teaching system can help students to expand their academic vision and integrate disciplinary knowledge while prompting them to think from different perspectives and enhancing their innovation [38]. This sense of accomplishment and acquisition can orient them positively towards an exploration that, at times, felt beyond their comfort zone, further enhancing their interdisciplinary identity. In brief, the interdisciplinary teaching system contributes to the formation of interdisciplinary identity.

How identity and interdisciplinary competence have been connected

It shows that one's identities have much influence on their chosen actions[39][40]. How students see themselves or identify as a particular kind of person in a specific context is believed to influence their motivational goal-setting and subsequent actions and performance[26]. Individuals with consistent behavior and identity often perform better. For example, Farmer et al. found that creativity identity significantly affects employee creativity. If they cannot get due protection and commitment from their identities, they will feel threatened, think their behaviors are meaningless, and refuse to complete the corresponding tasks [41]. Based on the identity-based motivation theory, we believe that interdisciplinary identity has an important impact on the interdisciplinary competence of engineering graduate students. Their commitment to interdisciplinary identity will push them to cross the boundaries of respective disciplines towards a creative endeavor, such as adopting unconventional learning methods [42], and exhibit higher inclusiveness towards interdisciplinary knowledge and methods. Thus, we assume that interdisciplinary identity has a significant positive impact on interdisciplinary competence. Therefore, we propose the following hypothesis:

H2: Interdisciplinary identity plays an intermediary role between the interdisciplinary teaching system and interdisciplinary competence.

Data and methods

Data collection

To explore the research questions, questionnaire data are gathered from engineering graduate students studying at three renowned research universities in China, namely Zhejiang University, Harbin Institute of Technology, and Southeast University. Data are collected using paper and web-based questionnaires during 2021 and 2022. A total of 462 responses are obtained, out of which 310 are considered eligible for analysis based on the fulfillment of response eligibility criteria.

Measures

This research aims to assess the correlation between interdisciplinary teaching systems, interdisciplinary identity, and interdisciplinary competence, as presented in Table 1. To achieve this objective, three scales are employed alongside demographic data.

Interdisciplinary Teaching System. The interdisciplinaryteaching system（IDTS）is composed of interdisciplinary design both in content and practices. To measure students' perceptions of the emphasis on the interdisciplinary teaching system, the instructional strategy scale adapted from the *curricular experiences scales* developed by Lattuca et al.[43] is used. Combined with the context of engineering education in China, it is modified and simplified and finally retains 18 questions. It includes two core dimensions: *Comprehensive Curriculum Emphasis,* which reflects engineering students' perceptions on the interdisciplinarity extent to which the course content emphasizes, including engineering thinking, professional values, professional skills, broad and systems perspectives, etc. And *student-centered instructional practices* reflect students' self-evaluation of the interdisciplinarity from different instructional techniques, including problem-based teaching, team-based learning, etc. Each item is rated on a Likert scale from (1) Strongly disagree to (5) Strongly agree (five-item scale, alpha=0.865).

Interdisciplinary Identity. We define interdisciplinary identity as how students describe themselves and are positioned by others in the role of being an interdisciplinary researcher. Interdisciplinary Identity levels are measured by an interdisciplinary identity scale adapted from the *Identity scale* [25]. Interdisciplinary identity is measured from three

dimensions, including **recognition, interest, and performance**, and t items are retained. Each item is rated on a Likert scale from (1) Strongly disagree to (5) Strongly agree (RMSEA=0.055, GFI=0.834, AGFI=0.809, five-item scale, alpha=0.889).

Interdisciplinary Competence. We define interdisciplinary competence as the ability to creatively solve complex and uncertain real-world problems by integrating interdisciplinary knowledge, skills, and values, including reading outside the field, thinking in different ways, etc. This dependent variable is measured by the scale developed by Lattuca et al. (2017)[43] which contains 8 items. Each item is rated on a Likert scale from (1) Strongly disagree to (5) Strongly agree. And the reliability coefficient (Cronbach's alpha) of 0.847 is well above the conventional 0.70 threshold.

Table 1. Variables

Variable groupings	Specific variables	Type
Interdisciplinary Teaching System (IDTS)	Comprehensive Curriculum Emphasis (*cce*)	Independent variables
	Student-centered Instructional Practices (*sip*)	
Interdisciplinary Identity (IDI)	Interest (*it)*	Mediators
	Recognition (*rn*)	
	Performance (*pe*)	
Interdisciplinary competence (IDC)	-	Dependent variable

Analytical approach

The present study utilizes SPSS Version 26.0 and PROCESS Version 4.0 to analyze the collected data. Descriptive statistics, including the mean and standard deviation (SD), are employed to evaluate participant characteristics and scores on self-report questionnaires. Furthermore, we employ the Bootstrap method to test the overall effect of multiple mediators and the single effect from each mediator, following Preacher and Hayes's (2008)[44] recommendations.

Figure 2 depicts the conceptual framework, which serves as a foundation for our data analysis. Initially, we set the bootstrap samples to 5000 and select a 95% confidence level for

confidence intervals. Subsequently, we conduct data analysis to examine the overall mediation and the single mediation of each mediator. This analytical method aims to explore whether and how interdisciplinary identity moderates engineering students' interdisciplinary competence by enhancing or inhibiting the impact of the interdisciplinary teaching system.

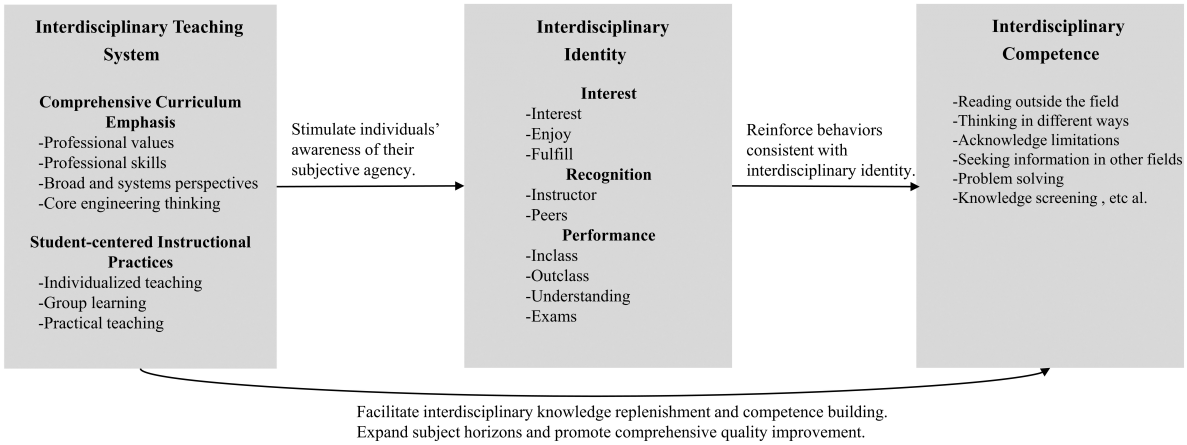

Figure 2. Conceptual Framework

Results

Statistical analysis

Table 2 describes students' gender, graduate program, age, discipline, and discipline status. The demographic information disclosed in this survey corresponds to the engineering students' population represented in the studied institutions. Table 3 shows the descriptive statistics and correlation analysis of graduate students' interdisciplinary teaching system (IDTS), interdisciplinary identity (IDI), and interdisciplinary competence (IDC). Moreover, Spearman's correlation coefficient is computed alongside descriptive statistics for the survey subscales in Table 3.

Table 2. Descriptive Statistics for Control Variables

Variable	Group	N	N(%)	Group	N	N(%)
Gender	Male	181	58.4%	Female	129	41.6%
	Master of Science in Engineering	125	40.3%	Master of Engineering	105	33.9%

Engineering graduate program	Doctor of Engineering	80	25.8%			
Age	Under 20	13	4.2%	Between 20-25	253	81.6%
	Above 25	44	14.2%			
Engineering Discipline	Chemical	33	10.6%	Environmental	23	7.4%
	Mechanical	42	13.5%	Biomedical	23	7.4%
	Optical	11	3.5%	Civil	45	14.5%
	Hydraulic	21	6.8%	Dynamic Mechanical	24	7.7%
	Electronic and Communication	22	7.1%	Electrical	19	6.1%
	Control Science	18	5.8%	Computer Science	29	9.4%
Discipline Status	Key discipline	260	83.9%	Key cultivating discipline	38	9.0%
	Other disciplines	22	7.1%			

Table 3. Correlation of Major Variables

Variable	**Mean**	**Std**	**IDTS**	***cce***	***sip***	***it***	***rn***	***pe***	**IDC**
IDTS	3.427	1.008	-						
cce	3.653	1.034	0.961***	-					
sip	3.522	0.947	0.802***	0.606***	-				
it	3.810	0.799	0.400***	0.339***	0.419***	-			
rn	3.495	0.842	0.438***	0.445***	0.429***	0.583***	-		
pe	3.610	0.820	0.444***	0.393***	0.430***	0.629***	0.679***	-	
IDC	3.558	0.868	0.539***	0.481***	0.513***	0.606***	0.634***	0.688***	-

Note.*p<0.1;***p<0.05;***p<0.001.

According to the data presented in Table 3, the overall assessment of the quality of the interdisciplinary teaching system among engineering graduate students is quite positive (M=3.427, SD=1.008). Furthermore, the evaluation of comprehensive curriculum emphasis

(M=3.653, SD=1.034) surpasses that of student-centered instructional practices (M=3.522, SD=0.947), indicating that students are more likely to perceive the interdisciplinary nature of comprehensive curriculum emphasis. In contrast, the implementation of student-centered instructional practices needs to be strengthened. Besides, engineering graduate students demonstrate a generally high level of interdisciplinary identity. Specifically, the interest dimension scores (M=3.810, SD=0.799) are higher than those of the performance dimension (M=3.610, SD=0.820) and the recognition dimension (M=3.495, SD=0.842). This indicates that the interdisciplinary identity of engineering students is primarily reflected in their attitudes and emotions rather than their abilities and actions. Moreover, this investigation finds that engineering graduate students exhibit a favorable evaluation of their interdisciplinary competence (M=3.558, SD=0.868).

In this study, Spearman correlations are also computed to supplement the descriptive statistics on the survey subscales, as presented in Table 3. The findings of the correlation analysis indicate a significant association between the variables under consideration in the preliminary stage. Additionally, the scale utilized in this study is found to possess good reliability, as evidenced by Cronbach's alpha coefficient exceeding 0.6. The subsequent phase of this investigation entails the development of a theoretical model to investigate the precise relationships between the variables.

Relationships between interdisciplinary teaching system and interdisciplinary competence

The effect of the interdisciplinary teaching system on the interdisciplinary competence of engineering graduate students is examined, and the results are shown in Table 4.

Table 4. Regression of Interdisciplinary Teaching System and Interdisciplinary Competence

Variable	Model 1			Model 2			Model 3		
	B	S.E.	β	B	S.E.	β	B	S.E.	β
IDTS	0.579	0.052	0.539***	0.589	0.052	0.548***	-	-	-
cce	-	-	-	-	-	-	0.263	0.057	0.276***
sip	-	-	-	-	-	-	0.369	0.063	0.358***
Controls	N			Y			Y		
N	310			310			310		
R^2	0.291			0.306			0.324		

F	126.212***	22.258***	20.710***

Note.*p<0.1;***p<0.05;***p<0.001.

Compared to Model 1, Model 2 incorporates control variables, specifically gender, age, marriage, graduate program, and discipline type. As a result, the R^2 value increases from 0.291 to 0.306 after including control variables. The findings indicate that Model 2 demonstrates overall statistical significance at the 0.001 level (F=22.258; p<0.001) and manifest that the interdisciplinary teaching system has a significant positive effect on interdisciplinary competence (β=0.548, p<0.001), thereby supporting H1.

Model 3 further reveals the relationships between two distinct dimensions and interdisciplinary competence: Comprehensive Curriculum Emphasis (β=0.276, p<0.001) and Student-centered Instructional Practices (β=0.358, p<0.001). Notably, student-centered instructional practices are shown to be particularly effective in enhancing students' interdisciplinary competence compared to comprehensive curriculum emphasis that emphasizes design thinking and systematic thinking.

Relationships among interdisciplinary teaching system, interdisciplinary identity, and interdisciplinary competence

Tables 5, 6, and 7 present the findings of the study on the mediating effect of various dimensions of interdisciplinary identity on the relationship between interdisciplinary teaching system and interdisciplinary competence. The results offer insights into the role of interdisciplinary identity in promoting interdisciplinary competence within the context of the interdisciplinary teaching system.

Table 5. Mediating Effect of Identity Interest

Effect type	**Coeff**	**Bootstrap se**	**Z**	**Bias-corrected95% CI**	
				LLCI	ULCI
Direct effect	0.3797***	0.0486	7.8099	0.2840	0.4754
Indirect effect	0.1996***	0.0400	4.9900	0.1247	0.2832
Total effect	0.5793***				
Specific path's effect					
IDTS - *it*	0.4309***	0.0563	7.6564	0.3201	0.5416
***it* - IDC**	0.4633***	0.0451	10.2670	0.3745	0.5521

Note.*p<0.1;***p<0.05;***p<0.001.

Table6. Mediating Effect of Identity Recognition

Effect type	Coeff	Bootstrap se	Z	Bias-corrected95% CI	
				LLCI	ULCI
Direct effect	0.3262***	0.0509	6.4126	0.2261	0.4263
Indirect effect	0.2531***	0.0437	4.9725	0.1693	0.3402
Total effect	0.5793***				
Specific path's effect					
IDTS - *rn*	0.5845***	0.0603	9.6889	0.4658	0.7033
***rn* - IDC**	0.4331***	0.0421	10.2966	0.3503	0.5158

Note.*p<0.1;***p<0.05;***p<0.001.

Table 7. Mediating Effect of Identity Performance

Effect type	Coeff	Bootstrap se	Z	Bias-corrected95% CI	
				LLCI	ULCI
Direct effect	0.3129***	0.0464	6.7491	0.2217	0.4041
Indirect effect	0.2664***	0.0479	5.5616	0.1763	0.3644
Total effect	0.5793***				
Specific path's effect					
IDTS - *pe*	0.4685***	0.0539	8.6944	0.3625	0.5745
***pe* - IDC**	0.5687***	0.0439	12.9471	0.4823	0.6551

Note.*p<0.1;***p<0.05;***p<0.001.

The results show that interdisciplinary identity has a significant mediating effect between interdisciplinary teaching system and interdisciplinary competence. According to the results of each mediating effect, the interdisciplinary teaching system still has a significant direct effect on interdisciplinary competence after adding multiple mediators, which means that interdisciplinary identity exerts a partial mediating effect.

And this study furtherly tests three dimensions of interdisciplinary identity. As the above statistics show, the asymptotic critical ratio for each dimension's indirect effect of IDTS on IDC is 4.99, 4.9725, and 5.5616 separately, which leads to a rejection of the null hypothesis that the total indirect effect is zero. Among them, the confidence interval of the interest dimension (LLCI, ULCI) at the 95% level is (0.1247, 0.2832), excluding 0, with a mediating

effect of 0.1996. The confidence interval of the endorsement dimension (LLCI, ULCI) at the 95% level is (0.1691, 0.3402), excluding 0, with a mediating effect of 0.2531. The confidence interval of the performance dimension (LLCI, ULCI) at the 95% level is (0.1763, 0.3644), excluding 0, with a mediating effect of 0.2664. The results above supported hypothesis H2 and reflected that interdisciplinary identity performance and recognition are more important mediators than interdisciplinary identity interest.

Relationships between course experiences and interdisciplinary identity

To investigate the underlying factors that contribute to interdisciplinary competence in an interdisciplinary teaching system, a linear regression analysis is conducted, and the findings are presented in Table 8.

Table 8. Regression of Course Experiences and Interdisciplinary Identity

Independent Variable	**Dependent Variable**		
	it	*rn*	*pe*
cce	0.1280**	0.3140***	0.1960***
sip	0.3500***	0.2930***	0.3070***
N		310	
R2	0.1870	0.2380	0.2120
F	11.8070***	48.0740***	41.3670***

Note.*p<0.1;***p<0.05;***p<0.001.

The results show that the comprehensive curriculum emphasis and student-centered instructional practices both have a very significant positive impact on interdisciplinary identity. Overall, the regression coefficients of the two models are significantly positive, among which student-centered instructional practices have a stronger effect on shaping interdisciplinary identity than the comprehensive curriculum emphasis, reflecting that student-centered teaching methods and group learning methods are more able to stimulate engineering graduate students to form interdisciplinary identity. Specifically, comprehensive curriculum emphasis has the strongest positive effect on recognition (β=0.3140, p<0.001), followed by performance (β=0.1960, p<0.001) and interest (β=0.1280, p<0.001), while student-centered instructional practices have the strongest positive effect on interest (β=0.3500, p<;0.001), followed by the performance (β=0.3070, p<0.001) and recognition (β=0.2930, p<0.001). The results indicate that comprehensive curriculum emphasis has a

more significant and positive effect on helping students recognize their interdisciplinary identity, and students can gain more interest in interdisciplinary identity and believe in their abilities to conduct interdisciplinary tasks when they are taught by student-centered instructional practices.

Discussion

This study aims to track how engineering students' attitudes toward disciplinary affiliation, which we call interdisciplinary identity, can be fostered by an elaborate teaching system and its influence on interdisciplinary competence. Using the data from 310 engineering graduate students, we test the relationship among interdisciplinary teaching systems, interdisciplinary identity, and interdisciplinary competence. Our results provide empirical support for identity-based motivation theory and add to the current understanding of how the interdisciplinary teaching system can serve to further our understanding of students' interdisciplinary competence. Through data analysis, this study primarily draws the following conclusions.

First, this work examines an often-understudied connection between identity and motivation. It is imperative to understand how students are developing a sense of identity and utilizing their identities to guide goal-setting processes and actions in postsecondary environments. In this study, we introduce the concept of interdisciplinary identity and find it playing a partial mediating role between the interdisciplinary teaching system and the interdisciplinary competence of engineering graduate students. Specifically, the dimension of performance exhibits the most significant mediating effect. This result is consistent with Bandura's social cognitive theory, which holds that individuals who possess a strong belief and confidence in their ability to complete tasks tend to set higher levels of goals and strive to activate relevant resources, employ effective strategies, and persistently exert efforts to acquire the necessary competence. Therefore, the perceived interdisciplinary learning support should be strengthened to improve the performance dimension of interdisciplinary identity, such as continuous dynamic teaching feedback, diversified examination methods, comprehensive examination content, and scientific assessment criteria.

Second, our study investigates the effective teaching pattern for fostering interdisciplinary identity. It proves that both comprehensive curriculum emphasis and student-centered instructional practices have a significantly positive impact on interdisciplinary identity, while the latter yields a more substantial influence. Student-

centered instructional practices such as group learning and problem-based learning lead to communities of interdisciplinary practice. The interdisciplinary exchange between different voices in the interdisciplinary community enables students to engage in dialogues about interdisciplinary behaviors and meaning, affirming the importance of a supportive interdisciplinary learning environment. Students identify behaviors congruent to a member of the interdisciplinary community while losing their sense of superiority over what was initially identified as disciplinary turfs. It allowed them to break disciplinary boundaries and negotiate an academic identity across these boundaries [22]. This signaled the internalization of a group identity, with consequences for how they oriented themselves toward other interdisciplinary learners. These findings align with the concepts of socialization, which demonstrate how engagement with peers, faculty, and curriculum shapes a novice's perception of the field.

Third, our study provides suggestions on interdisciplinary teaching system design for building interdisciplinary identity and enhancing interdisciplinary competence. It finds that comprehensive curriculum emphasis has the strongest positive influence on identity recognition, followed by identity performance and identity interest. And student-centered instructional practices have the strongest positive influence on interest, followed by recognition and performance. It indicates that the specific dimension can be improved by targeted curricular design. For example, the teaching system should treat students as its focus, experience as its method, teams as its form, and autonomy as its mechanism to raise students' enthusiasm and interest in interdisciplinary learning. In addition, encouraging students to carry out interdisciplinary community learning activities, such as special seminars and mutual aid groups, and maintain equal contributions of participants, can help members develop interpersonal relationships and social ability.

Conclusion

In recent years, many scholars have conducted various studies on interdisciplinary education and have reached a consensus on some issues, such as recognizing the necessity of cultivating interdisciplinary graduate students and establishing interdisciplinary learning groups. However, more attention needs to be paid to the subjective experiences of graduate students in this interdependent world where knowledge needs to be navigated instead of required. Because students can increase their awareness of other possible perspectives, control complex problems, and address intellectual fixedness or rigidity in their own thinking and way of knowing, which can be regarded as subjective experiences [45]. This study

emphasizes the crucial role of interdisciplinary identity in linking external teaching with internal competence and seeks to identify effective and practical approaches for cultivating interdisciplinary identity. One area for future research includes developing domain-specific identity-based motivation measures for students. These measures should involve connections between students' current identities and envisioned identities, as well as how these connections motivate current actions in and out of the classroom. Especially the informal curriculum occurs outside the classroom, for example, in research assistantships, conference participation, and co-authoring papers with faculty. Such activities socialize students into the norms and values of different academic disciplines.

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