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Relation between Teacher Autonomy Support, Student Self-Efficacy, and Behavioral Engagement: A Moderated Mediation Model in Project-Based Team Learning*

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Team learning is a widely used teaching approach within the realm of engineering pedagogy. However, there hasn't been much discussion of the teacher's function as a designer of the learning environment, particularly in terms of promoting student engagement in team-based learning. To fill this gap, this study creates a self-determination theory-based model of how teaching strategies and task types affect students' behavior engagement in team learning conditions. An empirical study of 255 questionnaires from Chinese students majoring in Engineering Management and Engineering Cost was conducted. The findings showed a beneficial association between teacher autonomy support and student behavioral engagement, with self-efficacy serving as a partial mediating factor. Additionally, the study demonstrated that exploratory learning significantly moderated the link among teacher autonomy support and student self-efficacy. This investigation broadens the study context to team-based learning, combining teachers and students to build an effective bridge between teaching and learning. Furthermore, the study underscores the significance of matching teaching styles with task characteristics in project-based team learning, providing valuable insights for addressing undesirable behaviors like free-riding.

Keywords: teacher autonomy support; self-efficacy; behavioral engagement; exploratory learning; self-determination theory

1. Introduction

Engineering education plays a vital role in higher education [1]. With the ever-changing requirements of future engineers, engineering education is undergoing a paradigm shift from traditional lecture-based instruction to more student-centered approaches [2]. In this regard, teamwork is strongly encouraged as a teaching strategy in higher engineering education and is widely applied in various engineering practice [3]. Prior research has demonstrated the effectiveness of project-based team learning as a teaching model [4]. Teamwork provides students with valuable practical experiences in simulated projects, fostering essential skills such as communication and collaboration [5]. However, challenges in teamwork, such as dysfunctional inefficiencies and process loss, can hinder its effectiveness [6]. One significant indicator of process loss is the generally poor engagement of team members. Free-riding may occur when some members in a team want to rely on others to complete tasks [7]. The presence of free-riding behavior can have a detrimental impact on project outcomes, as it not only diminishes students' interest in learning but also hampers their ability to grasp relevant information [8]. The benefits of team learning can be overshadowed by negative learning experiences among students [9]. Therefore, it is crucial to explore ways to enhance team members' engagement. In light of the project-based team learning context, examining the elements that influence student behavioral engagement is the aim of this study.

Teachers' behavior, as an important environmental factor [10], plays an important role in increasing or decreasing student engagement [11]. Students' perception and understanding of the information in the environment aids them in molding their emotions, self-image, and behavior [12]. Among teachers' behavior, teacher autonomy support is essential for fostering effective connections between students and teachers [13]. The self-determination theory defines teacher autonomy support as students feeling that their opinions are acknowledged and encouraged, and that the teacher gives them the opportunity to gather knowledge and make decisions [14]. SDT argues that teacher autonomy support helps to meet students' needs for autonomy and competence, which in turn fosters a sense of ownership and thus tends to show greater engagement, persistence, and effort in the pursuit of goals [15]. Conversely, conflicts

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between teachers and students can lead to a decline in behavioral engagement [16]. Further investigation is needed to understand the underlying mechanisms that connect teacher autonomy support with student behavioral engagement [17].

Self-determination theory (SDT) is a widely recognized theoretical framework used to understand the intricate connections between the environment, individual motivation, and behavioral performance across various settings [18]. According to SDT, individuals' level of autonomy in their environment can foster the cultivation of intrinsic motivation, which in turn supports intrinsically driven behavior and adaptive learning outcomes [15]. Self-efficacy, one of the numerous personal motivating variables, can modify behavior and be influenced by surroundings [19]. Specifically, self-efficacy is developed in a supportive learning environment where students' fundamental psychological needs are met [20]. When students have a strong belief in their capacity to successfully accomplish a task, they are more inclined to invest effort and enthusiasm, which consequently enhances their level of engagement [21]. Undoubtedly, self-efficacy acts as a significant mediator in elucidating how teacher autonomy support influences student behavioral engagement.

It is crucial to recognize that diverse contextual factors can lead to varying results. In addition to the learner, the task's complexity is a crucial contextual element in the learning process. Students may excel in simpler task steps, but may require additional guidance and support when faced with more complex ones [22]. In this study, we define more complex tasks as exploratory learning tasks, which involve experimenting with new options. Exploratory learning is characterized by organizational learning practices that emphasize flexibility, experimentation, and exploration [23]. Challenging and innovative task questions can empower students to take initiative and act independently [24]. As the complexity of tasks increases, students' need for autonomy also increases [25]. When confronted with complex and innovative tasks, team members may require both technical and emotional support while also desiring autonomy to explore different task solutions. Teachers with autonomy support can empower students by granting them agency and offering problem-solving guidance [26]. This process further develops students' cognitive abilities, enabling them to think more deeply about assignments and enhancing their sense of competence [22]. To examine the impact of varying levels of exploratory learning on a connection among teacher autonomy support and student self-efficacy, the present research incorporates exploratory learning as a significant moderating variable.

To summarize, this study used structural equation modeling (SEM) to investigate the relationship between teacher autonomy support and student behavioral engagement in project-based team learning. Additionally, self-efficacy was introduced as a mediating variable to delve deeper into the underlying psychological mechanisms of this connection. Moreover, the study's objective was to examine the connection among teacher autonomy support and student self-efficacy while taking into account the moderating role of exploratory learning.

2. Theoretical Background and Literature Review

2.1 Teacher Autonomy Support

According to SDT, teacher autonomy support involves fostering students' pursuit of personal goals and endorsing their self-directed behaviors. In this process, students will feel that the teacher supports their autonomy [27]. Autonomy-supportive teachers exhibit characteristics such as considering the perspectives of students, allowing students to express themselves, and providing opportunities for decision-making [28]. Furthermore, they support students in cultivating their motivation and enhancing their self-regulation abilities. Teacher autonomy support in this study refers to respecting students' ideas, providing ample practice opportunities, and offering necessary assistance and support to ensure successful task completion.

An autonomy-supportive teaching style helps students experience an autonomous learning environment [29]. Autonomy is characterized by three key factors: (a) perceiving that one's actions stem from internal sources rather than external control, (b) having the ability to choose and engage in behaviors freely instead of feeling compelled, and (c) selecting and carrying out actions based on personal interest and relevance [30]. Thus, autonomy-supportive teaching strategies are a unique but interrelated experience-supportive teaching practice [29]. Drawing on the specific behavioral strategies of autonomy support proposed by Nunez et al. [31], the teachers' autonomy support in this paper is embodied in the following aspects: (a) providing students with interesting and moderately challenging material, (b) emphasizing the significance of tasks or behaviors, (c) acknowledging and accepting students' negative emotions, (d) demonstrating flexibility rather than exerting control, and (e) offering students the opportunity to make voluntary choices or providing meaningful assistance when choices are limited. By nurturing students' intrinsic motivation and fostering their willingness to engage in academic assignments, these strategies support the growth of students' autonomy and self-awareness.

2.2 Self-efficacy

Bandura [32], an American psychologist, first introduced the concept of self-efficacy. Bandura defines self-efficacy as a person's capacity to assess and have faith in their own activities when attempting to accomplish goals in a task or organization [33]. It reflects an individual's confidence in successfully accomplishing a specific task. Therefore, self-efficacy is not synonymous with competence itself, but rather represents confidence in one's own effectiveness. Ahola et al. [34] emphasized the contextual nature of self-efficacy, particularly in relation to individuals' perceptions of their task-specific capabilities within collaborative group learning environment. Hence, within this research, self-efficacy is explicitly defined as the perceived capability of team members to accomplish specific tasks within the context of project-based team learning.

Researchers have different perspectives on how to categorize the components of self-efficacy. In general, scholars classify self-efficacy into three main categories: task-specific self-efficacy, general self-efficacy, and domain-specific self-efficacy [35]. An individual's confidence in their capacity to carry out a particular assignment successfully is referred to as task-specific self-efficacy. Domain-specific self-efficacy relates to an individual's confidence in their capacity to achieve a goal within a specific functional domain or context [36]. On the other hand, general self-efficacy refers to a person's overall belief in their capacity to negotiate a variety of contexts and meet novel challenges. It remains stable across different time periods and situations, encompassing a comprehensive and meaningful sense of self-belief [37]. This study aims to evaluate and assess the team members' self-perceived abilities when confronted with new challenges or adapting to diverse environments within the context of team learning. It does not specifically examine self-efficacy within a particular field or task. The concept of general self-efficacy will be employed in this study to measure individuals' self-efficacy.

2.3 Behavioral Engagement

Numerous studies have highlighted the significance of student engagement as a fundamental concept both theoretically and practically [38]. Engagement can be defined as the active engagement and commitment that students demonstrate towards learning activities [39]. According to Astin's student engagement theory [40], learning is maximized when the learning environment is created to promote active participation. Students dedicate more time and effort to monitoring and fostering their intrinsic motivation and the effort they put into the learning process.

Existing research suggests that student engagement is a multidimensional and scalable concept [41]. There is no consensus on the components and measurement methods of engagement across different research backgrounds [42]. Skinner and Belmont [43] argued that student engagement in learning activities encompasses both emotional and behavioral aspects. Fredricks et al. [42] classified student engagement into cognitive, emotional, and behavioral forms. Among this, behavioral engagement is important and necessary to attain good marks and decrease disengagement [44]. Research has consistently demonstrated that behavioral engagement exhibits stronger correlations with academic success compared to other forms of student engagement, indicating its significant predictive power [38]. Yang et al. [45] conducted their research using only the dimension of behavioral engagement. Consequently, following a similar approach, the purpose of this study is to look into how teachers' teaching methods affect the behavior of their students in project-based team learning.

Behavioral engagement can be generally characterized as the degree of students' interactions and responses in academic, extracurricular, and other situations [38]. It primarily pertains to aspects such as persistence, effort, questioning, practice, and adherence to rules. In this study's framework of project-based team learning, we define behavioral engagement as the level of active involvement and dedicated effort demonstrated by team members throughout multiple projects.

3. Hypotheses and Theoretical Model

3.1 Teacher Autonomy Support and Behavioral Engagement

The teacher-student framework in SDT theory emphasizes the influential role teachers play in fostering or impeding student engagement and motivation to learn [46]. Lately, scholars have directed their attention to studying teacher autonomy support, emphasizing the importance of positive teacher-student relationships in fostering student engagement [28, 47]. Teacher autonomy support serves as a motivational stimulus, with educators employing diverse strategies to ensure students' active involvement and sustained engagement in their learning activities [48]. When students receive autonomy support from their teachers, they feel supported and cared for, which enhances their confidence and relaxation [49]. Additionally, they are encouraged to approach their work in their own way, thereby fostering appropriate learning behaviors [30]. Based on SDT, when teachers fulfill students' basic psychological needs for autonomy (holding a sense of volition and self-identity),

competence (feeling capable of interacting with the external world), and relatedness (experiencing emotional connections with others), opportunities for student self-motivation are created and maintained [50]. Consequently, individuals are more likely to exhibit proactive behaviors [51]. Numerous empirical studies have supported these findings [45, 52]. For instance, Ruzek et al. [52] analyzed data and discovered a positive association between teacher autonomy support and adolescents' behavioral engagement and motivation for mastery at the start of the academic year. According to a study by Yang et al. [45] involving a sample of Chinese elementary and secondary school students, emotional support from teachers is essential for meeting students' psychological needs and promoting behavioral engagement and self-efficacy. Therefore, building on the aforementioned findings, this study puts forward the following hypotheses.

Hypothesis 1: Teacher autonomy support is positively related to student behavioral engagement.

3.2 The Mediating Effect of Self-Efficacy

According to earlier studies, motivation and students' willingness to study are tightly related. This is due to the fact that motivation refers to intangible internal impulses and aspirations, whereas engagement refers to externally observable acts that emerge from these motivations and aspirations. Among various motivational variables, self-efficacy has received significant attention from scholars. Numerous studies have shown that self-efficacy has a favorable effect on students' learning engagement [53, 54]. Self-efficacy supports and reinforces adaptable learning behaviors, claims social cognitive theory [55]. Self-belief in one's ability to accomplish a task significantly influences their drive and conduct, including the level of effort they invest, their responses to challenges, and their cognitive processes. Individuals who possess high self-efficacy are generally inclined and actively involved when presented with novel challenges. They persistently strive to overcome challenges, strengthening and boosting their self-efficacy along the way. Conversely, individuals with poor self-efficacy frequently experience self-doubt, withdraw when confronted with challenges, and gradually reduce their engagement [56]. According to Ardura et al.'s research [57], students who had stronger academic self-efficacy showed more drive and enthusiasm for their studies. According to Granado et al. [58], self-efficacy is a predictor of higher levels of engagement. Wilson et al. [59] found a favorable correlation between self-efficacy and engagement in the context of engineering education.

While self-efficacy can enhance engagement, it does not necessarily translate into greater autonomous motivation and engagement [60]. According to SDT, teachers who actively engage with students and support their learning process, can easily meet students' psychological needs. This, in turn, promotes intrinsic motivation and further enhances self-efficacy [61]. Many research have demonstrated the beneficial connection between teacher autonomy support and self-efficacy [47, 52, 62, 63]. In fact, in the study conducted by Ruzek et al. [52], it was observed that teachers' provision of emotional support impacts students' perceptions of their own competence, subsequently influencing their levels of behavioral engagement. Duchatelet et al. [62] demonstrated that when teachers adopt autonomy-supportive behaviors, they contribute to the enhancement of self-efficacy among students who are motivated by autonomy. In an engineering student study, Hsu et al. [63] found a significant impact of teachers' support on students' self-efficacy perceptions.

Additionally, based on the triadic interaction determinism, environmental circumstances, behavior, and personal subjective aspects are considered autonomous theoretical entities that interact and influence each other simultaneously. Self-efficacy, as an individual factor, has been found to mediate these interactions [64]. Wang et al. [17] has also confirmed this. In conclusion, this study proposes the following hypothesis.

Hypothesis 2: Self-efficacy plays a mediating role in connecting autonomy support with behavioral engagement.

3.3 The Moderating Effect of Exploratory Learning

Exploratory learning is a process that involves creating new knowledge, exploring new technologies and strategies, discovering new opportunities and rules. It can manifest in various forms such as exploratory, innovative, developmental, and flexible [65]. This study will offer a team-level definition of exploratory learning, focusing on activities that promote the team's ability to explore and develop new ideas and task-related skills.

Storme et al. [66] found that tasks related to creativity are idiosyncratic, unconventional, and multifaceted. When faced with challenging and creative tasks, team members tend to invest more time and effort, leading to increased persistence and a higher likelihood of considering diverse options [67]. In addition, tasks requiring creativity and flexibility offer the possibility of using higher cognitive processes specific to creativity [68]. Being flexible helps individuals acquire new knowledge and develop new skills. This prevents them from

becoming stuck in a "competence trap" and enables them to actively learn from experiences, increasing their self-efficacy. Therefore, while routine tasks primarily require information about existing knowledge, mastering challenging tasks involves transferring new information to enhance individuals' effectiveness assessment. As for this, job complexity was found to be a strong predictor of efficacy beliefs by Tierney and Farmer [69]. In light of this, we propose that the implementation of exploratory learning, contributes to enhanced self-efficacy among team members. When members perceive recognition for their work and receive adequate support, they are more inclined to take risks, explore new approaches, and develop various competencies, leading to an improvement in self-efficacy.

In addition, Coces et al. [70] proposed that in the context of exploratory learning, learners should be granted increased autonomy while still receiving assistance and guidance when needed. When presented with more difficult job steps, students might appreciate more support and direction. On the other hand, providing students with complete autonomy can enhance their motivation and confidence when engaging in task completion. In summary, this study puts forth the following hypotheses.

Hypothesis 3: Exploratory learning positively moderates the association between autonomy support and self-efficacy.

Hypothesis 4: Exploratory learning positively moderates the indirect effects of self-efficacy on the association between autonomy support and behavioral engagement, that is, the greater the degree of exploratory learning, the more pronounced the indirect effects.

4. Method

4.1 Sampling and Data Collection

To collect data, we employed the cluster sampling method to include students majoring in Engineering Management and Engineering Cost at Tianjin University of Technology. These majors emphasize workshop teaching methods aimed at enhancing students' practical skills and fostering their professional abilities. The university and instructors actively promote students' engagement in project activities, such as science and technology projects or entrepreneurship and innovation programs. Our study targeted junior and senior students from both majors, and with the assistance of professors, we distributed paper questionnaires during class. Before the survey, the researchers informed the students about the purpose and nature of the study, which helped to achieve a high response rate. Additionally, we conducted further research by delivering questionnaires online to students who have recently graduated of the two majors. To maximize the response rate, the authors individually communicated with participants via phone or WeChat in advance.

First, students were told that engagement was entirely voluntary. Secondly, to mitigate potential common method biases, we implemented program control measures during the questionnaire stage. We made substantial changes to the instructions, response sentences, and scoring methods to ensure a balanced distribution of positive and negative questions. Additionally, participants were asked to recall a remarkable project activity they had been involved in or were currently participating in, serving as a reference for their responses. It's important to note that all questions were designed without any right or wrong answers, and the answers provided were strictly for academic research purposes, ensuring complete anonymity. A total of 255 questionnaires were returned, with 151 out of 160 questionnaires distributed on site and 104 out of 200 questionnaires distributed online. The response rate was 70.8%. After removing questionnaires with missing, anomalous, and disqualified data, we received 236 valid surveys in total, yielding a real response rate of 92.5%. The demographic details of the study's participants are shown in Table 1.

According to Harman's single-factor test, the first component accounted for 38.30% of the total variation, falling short of the 40% criterion that is considered critical. Moreover, the goodness-of-fit indices of the one-way model containing common method factors (χ^2/df = 9.628, NFI = 0.456, CFI = 0.481, TLI = 0.429, RMSEA = 0.192) were found to be very poor, indicating no significant common method deviations in the present study.

4.2 Measures

The measurement items in this study are mainly based on mature items published in previous studies, combined with the modification and adjustment of the semantic expressions to suit the research context. This paper uses standard translation steps [71], including forward translation, assessment, backward translation and assessment. Rigorous questionnaire translation ensures conceptual equivalence. There were a total of 29 measuring items in the questionnaire that was used in this investigation. All measures utilized a five-point Likert scale ranging from 1 to 5 (1 = strongly disagree, 5 = strongly agree) for item evaluation. An overview of the measures and sample items were provided as follows:

Table 1. Background Information of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	102	43.2%
	Female	123	56.8%
Major	Engineering Cost	181	76.7%
	Engineering Management	55	23.3%
Grade	Junior	63	26.7%
	Senior	79	33.5%
	Graduate	94	39.8%
Scale	2–4	23	9.7%
	4–6	81	34.3%
	6–8	60	25.4%
	>8	72	30.5%
Team Formation Style	Free	181	76.7%
	Teacher	38	16.1%
	Random	17	7.2%
Team Role	Leader	34	14.4%
	Member	202	85.6%

Self-efficacy. Self-efficacy of the individuals was assessed using the General Self-Efficacy Scale [72]. The scale comprises 10 items, involving individuals' perceptions or beliefs about whether they can adapt their behavior to the challenges in the environment. One example: I can always solve a problem if I try my best.

Teacher Autonomy support. Assessing teacher autonomy support will be done using the Learning Climate Questionnaire (LCQ) [73]. We selected four measurement items from the scale (e.g., ''I think my instructor has provided me with many choices'').

Behavioral engagement. To measure behavioral engagement, we adopted a scale developed by Lam et al. [74], which is suitable for international use. We selected five items from the Behavior Scale that align with the specific research variables chosen for investigation. We made necessary modifications and adaptations to suit the unique context of this study (e.g., ''In the project team, I tried my best'').

Exploratory learning. In order to measure exploratory learning, we adopted the measurement method developed by Kostopoulos et al. [75], and selected four out of the five measurement items related to exploratory learning for this study (e.g., ''team members tried a new creative way to complete the work'').

Control Variables. First, gender was used as a control variable in this study since gender has been linked to engagement with earlier research [76]. Additionally, because team diversity is associated with active engagement [77], we included major, grade, and team formation method diversity as control variables. Similarly, Koh et al. [78] found that team size affects initial participation, so we included scale as a control variable. Lastly, Tang et al. [79] showed that team role is meaningful and affects performance by influencing the cooperation of team members. Therefore, team role is controlled in this paper.

4.3 Pilot Study

Before collecting data for the full study, a pilot study with a sample size of 50 was conducted to assess the scale's validity. Participants in the pilot study were college students at Tianjin University of Technology who were enrolled in the Engineering Management and Engineering Costing program. The participants of the pilot study represent the population selected for the study. The gathered data was put to the test using factor analysis. The Kaiser-Meyer-Olkin (KMO) test and Bartlett's sphericity test were conducted as initial analyses. Hair et al. [80]proposed that a KMO value greater than 0.60 and a significant Bartlett's Test of Sphericity ($P < 0.001$) are indicators of suitability for factor analysis. The KMO test yielded a measure of 0.883, and Bartlett's test of sphericity had a significance level of 0.000 ($P < 0.001$), suggesting suitability for factor analysis. Next, principal component factor analysis resulted in the identification of four factors, explaining 61.902% of the total variance. All variables had factor loadings above 0.4, meeting the minimum acceptable threshold suggested by Hair et al [80]. Consequently, the factor analysis included all of the test items.

5. Results and Hypotheses Testing

5.1 Descriptive Statistics

The mean, standard deviation, and correlation coefficients for all the variables are displayed in

Table 2. Descriptive Statistics and Intercorrelations

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10
1. Gender	1.57	0.50	1									
2. Major	1.23	0.42	–0.22**	1								
3. Grade	3.90	0.85	0.04	0.05	1							
4. Scale	2.77	0.99	0.04	–0.09	0.30**	1						
5. Team Formation Style	1.31	0.60	–0.16*	0.07	0.29**	0.31**	1					
6. Team Role	1.86	0.35	0.11	–0.12	–0.04	0.05	0.05	1				
7. AS	4.00	0.84	0.13	–0.13*	0.08	0.02	–0.07	–0.02	1			
8. SE	3.43	0.69	–0.10	0.13	0.01	–0.14*	–0.04	–0.20**	0.38**	1		
9. BE	3.75	0.69	0.03	0.19**	0.47**	0.10	–0.01	–0.12	0.32**	0.38**	1	
10. EL	3.87	0.79	–0.02	0.07	–0.06	–0.13*	–0.17**	–0.07	0.41**	0.42**	0.29**	1

Note: n = 236, AS = autonomy support, SE = self-efficacy, BE = behavioral engagement, EL = exploratory learning, **p < 0.01, *p < 0.05, two-tailed.

Table 1. As shown in Table 2, each variable was correlated within and between structures, and the magnitude and direction of the correlation coefficient were as expected. In this study, significant positive correlations were found between teacher autonomy support and both self-efficacy ($r = 0.38$, $p < 0.01$) and behavioral engagement ($r = 0.32$, $p < 0.01$). Moreover, self-efficacy was positively correlated with behavioral engagement ($r = 0.38$, $p < 0.01$). Additionally, exploratory learning showed positive associations with behavioral engagement ($r = 0.29$, $p < 0.01$), self-efficacy ($r = 0.42$, $p < 0.01$), and autonomy support ($r = 0.41$, $p < 0.01$).

5.2 Measurement Model

AMOS 27.0 was used to confirm the construction validity of our measurement scale with four latent variables (autonomy support, self-efficacy, behavioral engagement, and exploratory learning).We calculated five fitting indices, namely normed chi-square (χ^2/df), Tucker-Lewis index (TLI), comparative fit index (CFI), incremental fit index (IFI), and root mean square error of approximation (RMSEA). An χ^2/df value below 5 and a TLI, IFI, or CFI greater than 0.9 indicate good model fit, while a RMSEA value below 0.08 suggests suitability [81]. The findings demonstrated that the measurement model exhibited a favorable fit (χ^2/df = 2.479, TLI = 0.902, CFI = 0.914, IFI = 0.914, RMSEA = 0.079).

Furthermore, the construction validity was analyzed from the aspects of convergent validity and discrimination validity. In this paper, we use the convergent validity evaluation criteria proposed by Hair [82]. All measurement items had normalized factor loadings that were higher than the threshold of 0.5, as shown in Table 3. All latent variables exhibited CR (combined reliability) values above the cut-off value of 0.7, and all of the values of AVE (average variance extracted) were more than the cut-off value of 0.5. Therefore, this study's measurement scale has good convergent validity.

A model's discriminant validity is determined by comparing the correlation coefficients and the square root of the AVE. When the square root of the AVE is equal to or larger than the correlation coefficient with other variables, good discriminant validity is attained [83]. The results in Table 4 indicate good discriminant validity among all latent variables.

Cronbach's alpha was used to assess the internal consistency of the measurement model, ensuring its reliability. The findings (Table 5) demonstrate that all four variables exhibit high internal consistency, surpassing the recommended threshold of 0.70 [84].

5.3 Test of Hypotheses

To investigate the relationship between autonomy support, self-efficacy, and behavioral engagement, this study conducted multiple regression analysis, controlling for six demographic variables: gender, major, grade, scale, team formation style, and team role. The results are presented in Table 6. H1 predicted a link among teacher autonomy support and behavioral engagement. From M6, autonomy support positively predicts behavioral engagement ($\beta = 0.30$, $p < 0.001$), indicating that higher degrees of teacher autonomy support are linked to higher degrees of behavioral engagement among team members. Therefore, H1 was supported.

The study used the three-step mediated regression method proposed by Z. L. Wen et al. [85] to examine the role of self-efficacy as a mediator between autonomy support and behavioral engagement. The procedure involved evaluating the independent variable's significant influence on the mediator variable, the independent variable's significant impact on the outcome variable, and noticing that the influence of the independent variable on the outcome variable decreased or disappeared when both variables were concurrently added to the

Table 3. Confirmatory Factor Analysis Results

Dimensions	Items	Standardized Factor Load	AVE	CR
Autonomy Support	AS1	0.848	0.710	0.907
	AS2	0.892		
	AS3	0.810		
	AS4	0.818		
Self-Efficacy	SE1	0.703	0.532	0.918
	SE2	0.550		
	SE3	0.769		
	SE4	0.781		
	SE5	0.775		
	SE6	0.711		
	SE7	0.762		
	SE8	0.690		
	SE9	0.739		
	SE10	0.780		
Behavioral Engagement	BE1	0.725	0.545	0.857
	BE2	0.759		
	BE3	0.737		
	BE4	0.762		
	BE5	0.708		
Exploratory Learning	EL1	0.898	0.813	0.946
	EL2	0.885		
	EL3	0.926		
	EL4	0.898		

Table 4. Discriminant Validity

Variable	Autonomy Support	Self-Efficacy	Behavioral Engagement	Exploratory Learning
Autonomy Support	0.710			
Self-Efficacy	0.313	0.532		
Behavioral Engagement	–0.973	–0.198	0.545	
Exploratory Learning	0.341	–0.256	–0.351	0.813
AVE square root	0.843	0.729	0.843	0.902

Table 5. Reliability Analysis

Dimensions	Items	Cronbach's α
Autonomy Support	4	0.91
Self-Efficacy	10	0.92
Behavioral Engagement	5	0.83
Exploratory Learning	4	0.93

regression equation. If these three conditions were satisfied, it could be inferred that the independent variable's influence was mediated by the mediator variable.

M2 satisfies the first requirement by supporting the relationship between teacher autonomy support and self-efficacy. The second requirement is met by M6 since it exhibits a substantial link between behavioral engagement and self-efficacy. The findings in the M7 demonstrated that self-efficacy strongly correlated positively with behavioral engagement ($\beta = 0.28$, $p < 0.001$) but the effect of autonomy support on engagement dramatically decreased ($\beta = 0.19$, $p < 0.001$). This meets the third requirement of the test for the mediation effect. Therefore, H2 was supported and self-efficacy partially mediated the impact of autonomy support on behavioral engagement.

In order to further verify H2, PROCESS macro was used to verify the hypothesis. The assumption that the indirect effect fits the normal distribution was not necessary when using the bootstrap method to confirm the indirect effect [86]. Meanwhile, the confidence intervals for the subsequent deviation correction were obtained using 5000 bootstrap samples. The Bootstrap test revealed that in the path of autonomy support-self-efficacy-behavioral engagement, the mediating effect was 0.0959, 95%CI = [0.0458, 0.1584], and there was no zero in the confidence interval. This suggests that self-efficacy was a key mediator in linking teacher autonomy support with behavioral engagement. 63.34% of the overall effect was due to the indirect effect.

Table 6. Hierarchical Regressions for Main Study Variables

	Self-Efficacy				Behavioral Engagement		
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**
Control variables							
Gender	–0.08	–0.12	–0.10	–0.10	0.04	0.01	0.04
Major	0.07	0.14	0.08	0.08	0.18**	0.21***	0.18***
Grade	0.05	0.01	0.01	0.01	0.49***	0.46***	0.46***
Scale	–0.13	–0.14*	–0.11	–0.12	0.03	0.02	0.06
Team Formation Style	–0.01	0.02	0.05	0.06	–0.16**	–0.14*	–0.14*
Team Role	–0.19**	–0.18**	–0.17**	–0.15	–0.09	–0.08	–0.03
Independent variable							
AS		0.41***	0.29***	0.31***		0.30***	0.19***
Moderating variable							
EL			0.28***	0.28***			
Interaction							
AS×EL				0.13*			
Mediator variable							
SE							0.28***
Adj.R^2	0.05	0.21	0.27	0.29	0.26	0.35	0.41
ΔR^2	0.08	0.16	0.06	0.02	0.28	0.09	0.06
F	3.10**	10.16***	12.04***	11.47***	14.63***	18.67***	21.05***
ΔF	3.10**	48.68***	19.42***	5.13*	14..63***	31.33***	24.34***

Note: n = 236, AS=autonomy support, SE = self-efficacy, EL = exploratory learning, ***p < 0.001, **p < 0.01, *p < 0.05.

To validate the moderated mediation model, this study utilized the Baron and Kenny program [87]. To address collinearity concerns, the independent variable and moderator variable underwent central processing prior to their inclusion in the regression equation. M3 in Table 6 found that, with regression coefficients of 0.29 and 0.28, respectively, autonomy support and exploratory learning had substantial positive effects on self-efficacy. M4 indicated a positive correlation between the interaction terms of autonomy support and exploratory learning with self-efficacy (β = 0.13, p < 0.05). Exploratory learning was found to be a moderator of the connection between teacher autonomy support and self-efficacy, supporting H3.

In addition, to evaluate the conceptual model, we utilized model 7 from the PROCESS macro. Results are presented in Table 7, where it can be seen that the variables for the interaction between autonomy support and exploratory learning strongly predicted self-efficacy (β = 0.1227, p < 0.05). A further simple slope analysis showed that for project teams with high exploratory learning level (M+1SD), autonomy support was significantly positively predicted with self-efficacy (β = 0.3521, 95%CI = [0.213, 0.4912], p < 0.001). For project teams with low exploratory learning level (M-1SD), autonomy support still positively predicted self-efficacy, albeit with a smaller effect size (β = 0.1594, 95%CI = [0.0351, 0.2836], p < 0.05). According to the research above, there was a significant moderating effect of exploratory learning on the connection between autonomy support and self-efficacy. The impact of autonomy support on self-efficacy grew as exploratory learning levels rose. Thus H3 was verified again. According to H4, exploratory learning was suggested to have a positive moderating effect on the indirect relationship, and the corresponding test results can be found in Table 8. In the low grouping of exploratory learning (M-1SD), the indirect effect between autonomy support and behavioral engagement is significant (β = 0.048, 95%CI = [0, 0.1204], p < 0.001). Indirect effects in the high grouping of exploratory learning (M+1SD) were also significant (β = 0.0806, 95%CI = [0.0232, 0.156], p < 0.001). Significant differences in indirect effects were observed between the two levels

Table 7. Testing the Moderated Mediation Effects of Teacher Autonomy Support on Self-Efficacy

	Self-Efficacy		
	Coeff	**SE**	**t**
Constant	0.7020	0.3325	2.1116
AS	0.2557	0.0517	4.9499***
EL	0.2429	0.0551	4.4118***
AS×EL	0.1227	0.0541	2.2663*
R-sq	0.3135		
F	11.4669		

Note: n = 236, AS=autonomy support, EL = exploratory learning, ***p < 0.001, **p < 0.01, *p < 0.05.

Table 8. Mediating Effects at Different Levels of Exploratory Learning

	Index	Effect	BootSE	BootLLCI	BootULCI
The mediating role of self-efficacy	Eff1(M-1SD)	0.0480	0.0311	0	0.1204
	Eff2(M)	0.0678	0.0224	0.0298	0.1180
	Eff3(M+1SD)	0.0806	0.0349	0.0232	0.1560

(95%CI = [0.0605, 0.1213]). Therefore, H4 was supported.

6. Discussion

6.1 The Mediating Effect of Self-Efficacy

The results showed that the association between teacher autonomy support and student behavioral engagement was mediated by student self-efficacy. According to this finding, teacher autonomy support is better for improving student self-efficacy, which is essential for encouraging student engagement in a project-based team learning environment. These findings provide empirical confirmation for preceding claims that stress the critical role of teacher autonomy support in encouraging student behavioral engagement and the critical mediation role of self-efficacy [15, 88]. This finding aligns with SDT [89], indicating that when students are given more autonomy and receive support from teachers, it satisfies their need for competence. As a result, their self-efficacy beliefs are enhanced, leading to increased engagement within task teams. Conversely, insufficient autonomy support from teachers may lead students to perceive their learning challenges as threatening. The reason behind this conduct is a lack of self-efficacy. Due to this, behavioral engagement will also decline [90], which will result in a number of detrimental problems such free-riding. Thus, by establishing a link among teacher autonomy support and student behavioral engagement through self-efficacy, this paper proposes that teachers adopting autonomy support to enhance team members' self-efficacy may serve as a valuable strategy to mitigate undesirable behaviors, such as free-riding, within teams.

6.2 The Moderating Effect of Exploratory Learning

Most previous studies have used factors such as perceived peer support and social support as moderating variables between autonomy support and self-efficacy [91, 92]. This study shifts the research perspective to the task level. Unlike general classrooms, project types in team learning are more heterogeneous. By introducing exploratory learning as a moderator, this study investigated how teacher autonomy support influences student self-efficacy. The results showed that exploratory learning significantly moderated the connection among teacher autonomy support and student self-efficacy. Teacher autonomy support had a favorable predicative impact on student self-efficacy in highly exploratory learning teams. This finding highlights the crucial role of teacher autonomy support in fostering exploratory learning. For instance, Coces [70] proposed that exploratory learning supports creative thinking and empowers learners to take control of their learning process, with teachers providing guidance and support as necessary. Moreover, exploratory learning activities can strengthen students' conceptual understanding, problem-solving abilities, and self-efficacy [69]. This high level of exploratory learning is often observed in practical assignments such as science and technology projects for college students and innovation and entrepreneurship training programs. On the other hand, in teams with relatively low levels of exploratory learning, teacher autonomy support still predicts student self-efficacy, but the effect is relatively smaller. To further combine this conclusion with practice, we conducted in-depth interviews with some teachers and students. Based on the results of the interviews, in tasks with limited exploratory learning, such as studio practice or workshop activities, where students adhere to standardized procedures and approaches, the influence of teacher autonomy support is diminished. If the teacher used a more controlled teaching method at this time, a more significant beneficial impact might be made. These insights provide unexpected considerations regarding the potential benefits of a controlling teaching style.

6.3 Theoretical Implications

From a theoretical perspective, this study significantly adds to the body of research on the teacher autonomy support. Previous studies have focused extensively on classroom, in-school and out-of-school activities [93, 94]. For instance, in the context of a classroom-based study, Hospel et al. [47] investigated the specific impacts of teacher autonomy support on student engagement. Additionally, Jang et al. [94] revealed a favorable correlation between students' timely engagement and satisfaction with campus life and the autonomy support provided by teaching assistants. However, there is limited research available that specifically investigates the interaction between teaching and learning in team-based learning settings. This study extends

the research to team learning, offering a new perspective and understanding of the teaching-learning interaction. By exploring the link among teachers' teaching styles and students' learning behaviors, it provides valuable theoretical support for teaching practices in team learning. Secondly, this study integrated SDT into team learning and investigated mechanisms that mediated student self-efficacy, enhancing our understanding of teachers' impact on student learning. Furthermore, in prior research, moderating variables mainly focused on subjective psychological dimensions, such as perceived peer support and social support. In this study, we chose task types that lean towards the objective aspect as moderating variables, which holds significant theoretical implications. By introducing task type as a moderator, we investigate the interplay between teachers and students in terms of instructional design and task arrangement, revealing the underlying mechanism through which task type influences the learning process and outcomes.

6.4 Practical Implications

This study provides practical insights for teacher teaching methods in project-based team learning, specifically in the field of engineering education. It highlights the significance of improving the practical outcomes of team learning and provides guidance for educators in this domain. The findings highlight the significance of teacher teaching style and offer practical recommendations for guiding teaching practices. Teachers should adapt their teaching style to different task types to boost students' self-efficacy and increase behavioral engagement. Furthermore, this study offers insights for preventing negative behaviors like free-riding in team learning and provides constructive suggestions to enhance engagement and performance.

6.5 Limitations and Further Research Directions

Our study has a few limitations. Firstly, the narrow scope and limited sample size may introduce sampling bias. Future research should consider expanding the sample size for better representativeness. Secondly, we focused on behavioral engagement, but it would be valuable for future researchers to explore the impact of teachers' teaching styles on different dimensions of student engagement. Lastly, this study focuses on individual-level mechanisms. However, Shin et al. [95] suggested that multilevel analysis is superior to other traditional statistical methods in modeling academic growth. Future research could attempt to analyze at multiple (e.g., individual, organizational , and group) levels.

7. Conclusions

In the context of project-based team learning, this study sought to examine the relationship between teacher autonomy support, student self-efficacy, and student behavioral engagement. In the meanwhile, we looked into how exploratory learning affected the relationship between autonomy support and self-efficacy. The results revealed a strong correlation between teacher autonomy support and student behavioral engagement, with student self-efficacy serving as a mediating factor. Exploratory learning moderated the impact of teacher autonomy support on student self-efficacy. This study investigated the match between teacher teaching style and task type using exploratory learning as a moderator. Adapting teaching strategies based on the varying types of tasks is an effective mechanism to harmonize the learning experience and preclude the emergence of counterproductive behaviors, such as the phenomenon of student free-riding.

Data Availability Statement – The data that support the findings of this study are available from the corresponding author upon reasonable request.

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