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Identity and experience matter: Differences between secondary STEM teachers' self-efficacy and commitment in integrated STEM teaching activities

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Abstract

This study used a person-centered approach to examine secondary STEM teachers' beliefs and experiences in integrated STEM (Science, Technology, Engineering, and Mathematics) education. It aimed to identify distinct profiles of teachers based on their self-efficacy and commitment as designers, implementers, and disseminators of STEM activities and explore how these profiles relate to teaching subjects and experience. A survey of 629 Taiwanese teachers was analyzed using latent profile analysis and multinomial logistic regression. Three groups emerged, representing low, moderate, and high self-efficacy and commitment. For the three identities, different trends in self-efficacy and commitment of the low- and high-level groups were found. Additionally, mathematics teachers were more likely to fall into the low self-efficacy group, and teachers without integrated STEM experience tended to have lower self-efficacy and commitment. The results highlight variations in STEM teachers' identities and suggest the need for targeted professional development, particularly for mathematics educators.

Keywords: teacher identity, commitment, self-efficacy, STEM education, latent profile analysis

INTRODUCTION

The integration of science, technology, engineering, and mathematics (STEM) is increasingly viewed as promising education reform for more students to become effective STEM problem solvers. For example, in Taiwan, interdisciplinary STEM teaching approaches have been promoted, and since 2001, the national curriculum guidelines have combined individual subject areas (e.g., science and technology) into domains (e.g., life technology) (Lin, 2018). Teachers play an essential role in ensuring successful STEM education reform (Kewalramani et al., 2022; So et al., 2020). They need to combine content from two or more STEM disciplines (Sanders, 2009) to engage students in STEM activities with an integrated approach. Such interdisciplinary or cross-disciplinary combinations of the individual STEM disciplines for teaching and learning can be viewed as integrated STEM (iSTEM) education (Kelley & Knowles, 2016). In addition to implementing iSTEM modules and activities, teachers could design and distribute the learning modules and materials to promote iSTEM education. That is, STEM teachers could possess various identities (El Nagdi et al., 2018; Galanti & Holincheck, 2022), such as learners, implementers, disseminators, and designers of iSTEM teaching activities, and have different beliefs, perceptions, or attitudes toward these identities (Yang et al., 2023).

Like other education reforms, iSTEM education requires teachers to change their conventional practices and experiment with new methods. Previous research has shown that teachers' adoption of innovative practices and their changes in behaviors are heavily influenced by their self-efficacy (Chen et al., 2022; DeCoito & Myszkal, 2018; Sokha, 2024; Tschannen-Moran & Hoy, 2001) and commitment (McCaw, 2023; Yang et al., 2023). There have also been studies exploring teachers' self-efficacy, commitment, and related factors (e.g., Anning, 2024; Shahali & Halim, 2024). For example, Canrinus et al. (2011) conducted structural equation modeling to examine the relationships among job

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Contribution to the literature

- This study contributes to research on teachers' beliefs and perceptions of STEM education by taking a person-centered approach to examine heterogeneity in teachers' self-efficacy and commitment.
- This study deepens the understanding of differences in self-efficacy and commitment and the three identities (i.e., designers, implementers, and disseminators) between teacher subgroups.
- The results shed light on the development of STEM professional activities based on patterns of teachers' self-efficacy and commitment to the three identities.
- The results suggest a need to develop integrated STEM professional development activities with a focus on mathematics and mathematics teachers.

satisfaction, occupational commitment, self-efficacy, and change in the level of motivation, and found a significant direct effect of teachers' self-efficacy on their occupational commitment. Polizzi et al. (2021) investigated science and mathematics teachers' self-efficacy and discipline-based identity and revealed that mathematics teachers tended to have lower identity and self-efficacy.

Although the studies have highlighted the multiple identities of STEM teachers and the relationships between self-efficacy and commitment, the variable-centered approaches (e.g., structural equation modeling) they adopted have limitations. Studies on teachers' attitudes, perceptions, and beliefs have commonly adopted variable-centered approaches to examine the associations or correlations among factors or between predictors and outcomes for the overall sample. However, these approaches ignore the differences in the factors or relationships for various subgroups of the sample (Yoon & Kim, 2022). Specifically, these approaches may not capture the underlying combinations of teachers' attitudes, perceptions, and beliefs; nor do they identify different subgroups within the population that require various interventions. For example, the structural equation modeling method, majorly examining the whole sample variability, could disregard individual differences in the performance patterns among different factors. This could be problematic as teachers with different backgrounds and experiences may not follow similar patterns in their beliefs and practices. For example, Richter et al. (2014) used polynomial regression analyses to estimate curvilinear relationships between teachers' age and their participation in teacher professional development activities. Nonetheless, they confessed that the explanation of different developmental patterns of professional development activities was limited, and few insights into intraindividual change were provided. Thus, the results generated by the variable-centered approaches may not provide sufficient information for researchers and educators of teachers to customize professional development interventions for different teacher groups.

To shed light on teacher professional development in iSTEM education, this study took a person-centered approach and employed latent profile analysis to identify potential subgroup differences and examine the effects of predictors across these subgroups. This approach, with a focus on "the identification of groups of individuals who function in a similar way at the organism level and in a different way relative to other individuals at the same level" (Magnusson, 2003, p. 16), allowed us to move beyond the "average," and could offer insight into effective interventions for individuals or each subgroup. The purpose of this study was two-fold:

(1) to examine the heterogeneous profiles of secondary STEM teachers' self-efficacy and commitment as designers, implementers, and disseminators of integrated STEM teaching activities; and
(2) to investigate how the heterogeneous profiles are related to STEM teachers' teaching subjects and experience.

The research questions were as follows:

RQ1 What profiles can be identified from secondary STEM teachers' self-efficacy and commitment as designers, implementers, and disseminators of iSTEM teaching activities?

RQ2 What are the differences in self-efficacy, commitment, and identities between the teachers with different profiles?

RQ3 In what ways and to what extent do secondary STEM teachers' characteristics (i.e., teaching subject and STEM experience) predict the heterogeneous profiles of their self-efficacy and commitment?

THEORETICAL BACKGROUND

Teacher Self-Efficacy and Commitment

This study focused on STEM teachers' self-efficacy and commitment because review studies have indicated that they are crucial factors associated with teaching practices and student outcomes (Chesnut & Burley, 2015; Zee & Koomen, 2016). Zee and Koomen (2016) synthesized 40 years of research on teacher self-efficacy and concluded that it "shows positive links with students' academic adjustment, patterns of teacher behavior and practices related to classroom quality, and factors underlying teachers' psychological well-being, including personal accomplishment, job satisfaction, and commitment" (p. 981). The meta-analysis by Chesnut and Burley (2015) also found that teachers' self-efficacy significantly predicted their commitment to teaching with a moderate effect size.

From a social cognitive perspective, Bandura (1977) defined self-efficacy as "beliefs in one's capacities to organize and execute the courses of action required to produce given attainments" (p. 3). Additionally, influenced by the context and purpose of the desired action, self-efficacy beliefs are task-related and could further affect one's action (Bandura, 1997). For example, a mathematics teacher with high self-efficacy in mathematics teaching may have low self-efficacy in iSTEM teaching activities. Their low self-efficacy may result in low commitment to iSTEM teaching activities and reluctance to undertake iSTEM teaching practices (Yang et al., 2023). Thus, this study draws upon Bandura's perspective and addresses teacher self-efficacy in iSTEM teaching activities.

Two types of commitment, namely organizational and occupational commitments, are closely related to teachers. The first is the organizational commitment, which could be defined as "some form of psychological bonds between people and organizations" and an "affective attachment to the goals and values of an organization, to one's role in relation to goals and values, and to the organization for its own sake" (Buchanan, 1974, p. 533). The second type of commitment refers to people's affective attachment to their occupation or profession. For teachers, they may have both types of commitment. Their affective links to their schools and professional communities are their organizational commitment, while their affective attachment to their teaching and the subject areas could be viewed as occupational commitment. That is, teachers' organizational commitments can differ from their occupational commitments. The variety of organizational and occupational commitments could result in various patterns of teaching behaviors (Firestone & Rosenblum, 1988). Like self-efficacy, teacher commitment could be context specific. In this study, we focus on teachers' occupational commitment to iSTEM education and define teacher commitment as an affective attachment to and identification with iSTEM teaching activities (Allen & Meyer, 1990).

Moreover, self-efficacy and commitment could play a role in teachers' motivation process (Rosenholtz, 1989). Motivation can be broadly defined as the forces to arouse, direct, and maintain behaviors (Snowman et al., 2012). Two aspects of motivation can be distinguished as "can-do" and "will-do" motivation (Bennell, 2004). According to Bennell (2004), "'Will-do' motivation refers to the extent to which an individual has adopted the organizations goals and objectives. 'Can-do' motivation, on the other hand, focuses on the factors that influence the capacity of individuals to realize organizational goals" (p. 8). Teacher self-efficacy can be counted as one kind of "can-do" motivation, while teacher commitment can be counted as one kind of "will-do" motivation. Teachers who have higher self-efficacy in teaching would have higher commitment to teaching and feel more control of their work (Ware & Kitsantas, 2007). This implies that "can-do" motivation may drive "will-do" motivation. Nonetheless, a teacher who has high commitment to teaching may lack self-efficacy in teaching and then become less motivated or even demoralized. Thus, this study investigated the possible profiles of teacher self-efficacy and commitment at the person-centered level to illustrate the relationships between teacher self-efficacy and commitment across teacher subgroups.

Teacher Identities: Designer, Implementer, and Disseminator

Identities can be referred to as "the meanings that individuals hold for themselves- what it means to be who they are" (Burke, 2003, p. 196) in a community where individuals could play different social roles when they interact with others. For teachers, professional identity can be regarded as "the active pursuit of professional development and learning in accordance with a teacher's goals" (Beauchamp & Thomas, 2009, p. 177). In many countries, STEM teachers' major role is an instructor of one major STEM subject. In STEM education reform, however, they may be requested to take on more responsibilities. Science, mathematics, and technology teachers may be asked to enact new STEM curricula with the process of developing iSTEM teaching materials, transforming the materials into practice, and demonstrating iSTEM teaching practices. Designers, disseminators, as well as implementers of iSTEM education could be STEM teachers' multiple identities. Teachers' development of an identity could interact with their self-efficacy in tasks evolved from an identity and serve an important part in their commitment to the identity and related activities.

By using a validated instrument, Yang et al. (2023) measured secondary STEM teachers' self-efficacy and commitment as implementers, designers, and disseminators of iSTEM teaching activities, and explored the relationships between the two beliefs. In addition to the significant differences in teachers' self-efficacy and commitment to the three identities, they found that self-efficacy of being disseminators had the largest impact on teacher commitment to being disseminators, designers, and implementers. However, the variable-centered approach adopted by Yang et al. (2023) may not be suitable for explaining the heterogeneity in teachers' self-efficacy and commitment. The structural relationships for the whole sample may or may not exist in teacher subgroups who have different levels of self-efficacy and commitment.

It is much more reasonable to assume that there are qualitatively different groups in a population. Person-centered approaches focus on "the identification of groups of individuals who function in a similar way at the organism level and in a different way relative to other individuals at the same level" (Magnusson, 2003, p. 16). Model-based cluster analyses, such as latent profile analysis (LPA), provide rigorous criteria for determining the number of groups (Vermunt & Magidson, 2002). That is, LPA is a person-centered approach under the assumption that a categorical latent variable can explain the relationships among people (Ferguson et al., 2019). In this study, we employed LPA to identify and describe typologies of secondary STEM teachers based on their self-efficacy and their commitment.

Teachers' Background Characteristics

What are the factors associated with teachers' self-efficacy and commitment? Teaching experience is one of the critical factors. Yang et al. (2023) showed that secondary STEM teachers who had STEM teaching experience perceived higher self-efficacy and committed more to being implementers, designers, and disseminators of iSTEM teaching activities than those who had no STEM teaching experience. On the other hand, Thibaut et al. (2018) found that teachers' iSTEM teaching experience did not predict their attitudes toward teaching iSTEM, but there existed a negative correlation between having more than 20 years of teaching experience and teachers' iSTEM attitudes. Nonetheless, very little is known about the extent to which teachers' STEM teaching experience can predict the heterogeneous profiles of their self-efficacy and commitment. This study could bridge the gap by investigating the predictive power of STEM teaching experience among the profiles.

Additionally, the subjects taught by STEM teachers may play a role in predicting their STEM teaching self-efficacy and commitment. Wang et al. (2011) found that in-service teachers who taught different STEM subjects had different perceptions of iSTEM teaching, which in turn could shape their STEM teaching practice. This finding implies that teachers' teaching subjects could be a factor influencing how they perceive and enact iSTEM teaching. Moreover, Thibaut et al. (2018) revealed that experiences in teaching mathematics could be negatively correlated to teachers' attitudes toward iSTEM teaching. A similar result for mathematics teachers and their attitudes toward iSTEM was also found in Thibaut et al. (2019). To understand more about the differences in the self-efficacy and commitment of teachers teaching different STEM subjects, this study contrasted the predictive power of teaching mathematics with teaching other STEM subjects for the profiles of secondary STEM teachers' self-efficacy and commitment.

METHODS

STEM Education in Taiwan

STEM education has been highly promoted by the Ministry of Education in Taiwan to develop STEM talents, enhance citizens' science and technology proficiency, and increase the competitiveness of the country. According to international comparison studies on students' performance on STEM disciplines, Taiwan is one of the leading STEM players to have emerged in Asia, along with other East and Southeast Asian countries, including China, South Korea, Japan, and Singapore (Marginson et al., 2013). In Taiwan, some government-funded projects, such as High-Scope, Techshop+ and D. School, have established partnerships between science, mathematics, and technology teachers at the secondary school level and university researchers to design innovative STEM curricula (Lin, 2018). Additionally, interdisciplinary STEM approaches have been encouraged. According to the latest curriculum guidelines, an interdisciplinary science course of "Inquiry and Practice" is mandatory for all high school students who want to pursue STEM majors at university (Ministry of Education, 2018). However, some STEM teachers in Taiwan lack the proficiency to plan, design, and implement interdisciplinary science and technology courses (Lin, 2018) and so professional development programs and workshops are needed. The results of this study could suggest how to design professional development interventions for different STEM teacher groups.

Participants

To answer the two research questions, this study employed a stratified sampling method and recruited secondary school teachers of science, technology, or mathematics-related subjects (grades 7 to 12) in Taiwan. We divided the teacher population into northern, central, southern, and eastern/outer islands as the first stratum, and used the type of school (i.e. junior high school, grades 7 to 9; senior high school, grades 10-12; and secondary school, grades 7 to 12) as the second stratum. We then selected participants from the strata to ensure that the sample was representative. We collected 705 questionnaires from the teachers, of which 52 invalid questionnaires and 24 questionnaires with missing data in one of the observed items were excluded from the data analysis. In the end, a total of 629 questionnaires were analyzed.

This study followed the ethical considerations necessary for research involving human beings. All participating teachers were informed of the study purpose, and their participation was voluntary and anonymous. They understood that they could withdraw from the research at any stage, and that their data would only be used for research purposes.

Measures

The self-report questionnaire comprised two sections. In the first section, secondary STEM teachers were asked to provide their background information, including their demographics, highest degree received, total years of teaching, and iSTEM teaching experience. The second section consisted of 46 items to measure teacher self-efficacy and their commitment to being implementers, designers, and disseminators. Each item was rated on a 5-point scale, from strongly disagree (1) to strongly agree (5).

Teacher Background Characteristics

Information about teachers' teaching subjects and their STEM teaching experience was collected by the items in the first section. We created a dichotomous variable for teaching subjects by recording teachers who reported their teaching subject as including mathematics (1 = Math) and those teaching other STEM subjects (0 = non-Math). There are two reasons for treating teaching subjects as a dichotomous variable. Theoretically, mathematics is a common foundation of the other STEM disciplines, while empirically, experiences of teaching mathematics could be negatively correlated to teachers' attitudes toward iSTEM teaching (Thibaut et al., 2018). STEM teaching experience was also a dichotomous variable (0 = without STEM teaching experience, 1 = with STEM teaching experience) because this study adopted a person-centered approach to grouping teachers' self-efficacy and commitment, and aimed to explore whether teachers having experience of iSTEM teaching s one factor influencing which group they are in.

Teacher self-efficacy

Teacher self-efficacy was measured by 28 items adapted from Riggs and Enochs (1990) and Yang et al. (2023). Among them, 10, 8, and 10 items were designed to examine teachers' self-efficacy as an implementer, a designer, and a disseminator, respectively. The sample questions included

> I can design different iSTEM teaching activities based on students' diverse abilities (Designer),
>
> I can guide students to engage in iSTEM teaching activities (Implementer), and
>
> I can demonstrate iSTEM teaching activities for other teachers to observe (Disseminator).

Teacher commitment

Teacher commitment to iSTEM teaching was measured by 18 items (Meyer et al., 1993; Yang et al., 2023). For each identity, six items were used to measure teachers' commitment to the identity. For example:

> I would like to be a professional in the design of iSTEM teaching activities (Designer),
>
> I feel a responsibility to the profession in the implementation of iSTEM activities (Implementer), and
>
> I am proud to be in the profession of disseminating iSTEM teaching activities (Disseminator).

Data analysis

To address the first research question, we employed LPA to identify heterogeneous profiles as latent classes based on the three-factor scores of teachers' self-efficacy and three-factor scores of teacher commitment, as LPA is an exploration analytic method for identifying latent classes based on multiple continuous outcome variables (Oberski, 2016). First, we treated the items of teacher self-efficacy for being designers, implementers, and disseminators as three factors to calculate the factor scores using the regression method for every participant. The same process was conducted to calculate the factor scores of teacher commitment to being designers, implementers, and disseminators. Next, LPA was conducted using the six-factor scores to identify the best-fitting number of profiles, which we refer to as groups in the study. Within each group, participants had similar patterns of teachers' self-efficacy and commitment. The criteria for selecting the best-fitting number of groups included the Akaike Information Criterion (AIC) (Akaike, 1974), the Bayesian Information Criterion (BIC) (Schwarz, 1978), the adjusted BIC (ABIC), the Vuong-Lo-Mendell-Rubin likelihood ratio test (VLMR-LRT) and the Lo-Mendell-Rubin adjusted likelihood ratio test (LMR-adjusted LRT) (Nylund et al., 2007). Lower values of the AIC, BIC, and ABIC and higher entropy suggest a better-fitting model. The significant VLMR-LRTs and LMR-adjusted LRTs indicate that having one more group (k+1 groups) better fits data over the model without the additional group (k groups) (Lo et al., 2001). In this study, once the best-fitting model was identified, each teacher was assigned with the group membership estimated in the best fitting model.

The general assumption of LPA is that the outcome variables are locally independent and normally distributed within each class (Sterba, 2013). The factor scores, derived from correlated but independent factors, were analyzed as the outcome variables rather than as item-level data. The analytical results of the three-group model (see **Table 2**) showed that measures of skewness and kurtosis for each factor score within each group all fell between -1.0 and 1.0, suggesting that the data were approximately normal. One limitation of LPA is that the individual is classified into a certain class which has the highest probability. That is, LPA does not provide an absolute solution to the individual's class. In practical

Table 1. Results of a series of latent profile analyses

No. of group	2	3	4	5	6
AIC	6997.82	6255.12	5809.18	5369.28	5072.61
BIC	7082.26	6370.67	5955.83	5547.05	5281.49
ABIC	7021.94	6288.12	5851.06	5420.05	5132.27
Entropy	0.86	0.90	0.93	0.94	0.93
LRT	1665.13**	756.70*	459.95***	548.80***	310.67
ALRT	1629.02**	740.29*	449.97***	536.89***	303.93
Nth group					
1st	274 (43.56%)	160 (25.44%)	33 (5.25%)	31 (4.93%)	30 (4.77%)
2nd	355 (56.44%)	329 (52.31%)	191 (30.37%)	157 (24.96%)	121 (19.24%)
3rd		140 (22.26%)	117 (18.60%)	241 (38.31%)	153 (24.32%)
4th			288 (45.79%)	160 (25.44%)	182 (28.93%)
5th				40 (6.36%)	109 (17.33%)
6th					34 (5.41%)

Note. LRT = VLMR-LRT; ALRT = LMR-adjusted LRT
*p < .05. **p < .01. ***p < .001.

applications, when entropy, a measure of the separation reliability of the profiles, has a value above .80, it is considered easily separable (Tein et al., 2013).

After the best fitting solutions were identified, MANOVA was performed to address the second research question and examine the differences in the Likert scales of each factor between the groups. Within each group, repeated measure ANOVA tests with Bonferroni post hoc comparisons were also adopted to examine whether teachers' self-efficacy and commitment differed regarding each identity using the Likert scales.

To answer the third research question, we used multinomial logistic regression to estimate the effects of the predictors (i.e., teaching subject and STEM teaching experience) on the groups. All analyses were performed using Mplus 8.8 and SPSS 25. The significance level was set at 5%.

RESULTS

Profiles of Secondary STEM Teachers' Self-Efficacy and Commitment

Table 1 presents the results of a series of LPA with two- to six-group solutions. The five-group model initially turned out to best explain the data because this model showed the least AIC, BIC, and ABIC among the two- to six-group models (**Table 1**), and the increment in model fit of the six-group from the five-group model was not statistically significant, based on VLMR-LRTs and LMR-adjusted LRTs ($\chi2 = 310.67$, $p = .60$; $\chi2 = 303.93$, $p = .60$, respectively). Nonetheless, the three-group model was selected because in the four- and five-group models there was at least one profile representing less than 6% of the participants, which was not sufficient for further application.

For the three-group model, the means of the six subscales of teachers' self-efficacy and commitment are shown in **Table 2** and **Figure 1**. Groups 1, 2, and 3, respectively, consisted of 160 (25.4%), 329 (52.3%), and 140 (22.3%) secondary STEM teachers. Significant

Table 2. Statistical measurements of the six scales for each group (N = 629)

Group	Construct	Identity	M	SE	95% CI LL	95% CI UL
1 n = 160 (25.44%)	Self-efficacy	Designer	2.54	.05	2.44	2.64
		Implementer	2.47	.06	2.37	2.59
		Disseminator	1.85	.04	1.77	1.04
	Commitment	Designer	2.16	.04	2.07	2.24
		Implementer	2.10	.05	2.01	2.19
		Disseminator	1.94	.04	1.86	2.02
2 n = 329 (52.31%)	Self-efficacy	Designer	3.36	.03	3.30	3.42
		Implementer	3.41	.03	3.35	3.47
		Disseminator	2.73	.03	2.66	2.79
	Commitment	Designer	3.09	.02	3.04	3.13
		Implementer	3.07	.02	3.03	3.12
		Disseminator	2.87	.02	2.83	2.91

Note. CI = confidence interval; LL = lower limit; UL = upper limit
**p < .01.

Table 2 (Continued). Statistical measurements of the six scales for each group (N = 629)

Group	Construct	Identity	M	SE	95% CI	
					LL	UL
3 *n* = 140 (22.26%)	Self-efficacy	Designer	3.89	.04	3.81	3.98
		Implementer	3.94	.04	3.86	4.02
		Disseminator	3.47	.06	3.36	4.12
	Commitment	Designer	4.05	.04	3.97	4.12
		Implementer	4.07	.04	3.99	4.14
		Disseminator	3.85	.04	3.77	3.93

Note. CI = confidence interval; LL = lower limit; UL = upper limit
**p < .01.

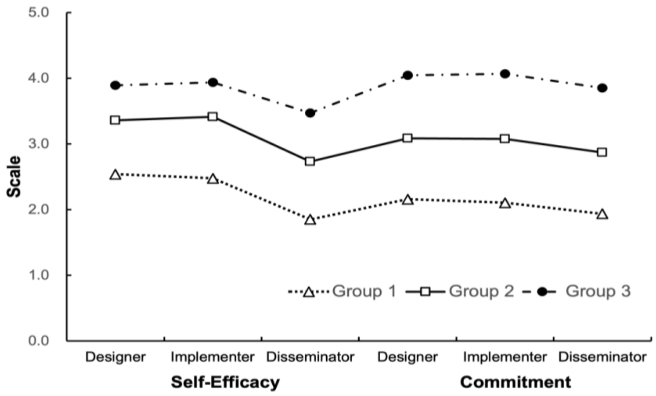

Figure 1. Teachers' self-efficacy and commitment of the three groups (Source: Authors' own elaboration)

differences in teachers' self-efficacy and commitment were found among the three groups (F (12, 1242) = 123.48 (Wilks' lambda), p < .001). **Table 3** shows the detailed results of MANOVA. For each subscale of teachers' self-efficacy and commitment, post hoc Bonferroni tests revealed that the difference between any two groups was statistically significant. The result supported that, comparatively, STEM teachers in Group 1 had the lowest mean scores for both self-efficacy and commitment to iSTEM teaching, teachers in Group 2 showed a moderate level of self-efficacy and commitment, and Group 3 had the highest mean scores for their self-efficacy and commitment. Based on the results of self-efficacy and commitment, the three profiles were labeled as low (Group 1), moderate (Group 2), and high (Group 3). Teachers' self-efficacy and commitment to being designers, implementers, and disseminators ranged between 1.9 and 2.5 in the low group, between 2.7 and 3.4 in the moderate group, and between 3.5 and 4.1 in the high group.

Differences in Self-Efficacy, Commitment, and Identities Between Teachers with Different Profiles

To answer the second research question, a mixed three-way repeated measures ANOVA was performed to examine the interactions among group (low, moderate, or high), construct (self-efficacy or commitment), and identity (designer, implementer, or disseminator). Greenhouse-Geisser adjusted degrees of freedom were used, and a significant three-way interaction was found (F (4, 1252) = 4.82, p = .002). Thus, a further examination of the interaction between construct and identity was conducted for each group. A two-way repeated measures ANOVA revealed significant interactions between construct and identity for all groups (Low: F (2, 318) = 48.36, p < .001, Moderate: F (2, 656) = 123.71, p < .001, High: F (2, 278) = 19.38, p < .001).

Table 3. MANOVA tests of between-group effects

Source	Dependent Variable	Type III SS	df	MS	F
Group	Self-Efficacy				
	Designer	142.72	2	71.36	227.46***
	Implementer	170.01	2	85.00	250.13***
	Disseminator	198.49	2	99.25	271.51***
	Commitment				
	Designer	266.80	2	133.40	620.26***
	Implementer	288.69	2	144.35	676.18***
	Disseminator	273.97	2	136.99	677.94***
Error	Self-Efficacy				
	Designer	196.39	626	0.31	
	Implementer	212.74	626	0.34	
	Disseminator	228.83	626	0.37	
	Commitment				
	Designer	134.64	626	0.22	
	Implementer	133.64	626	0.21	
	Disseminator	126.49	626	0.20	

***p < .001.

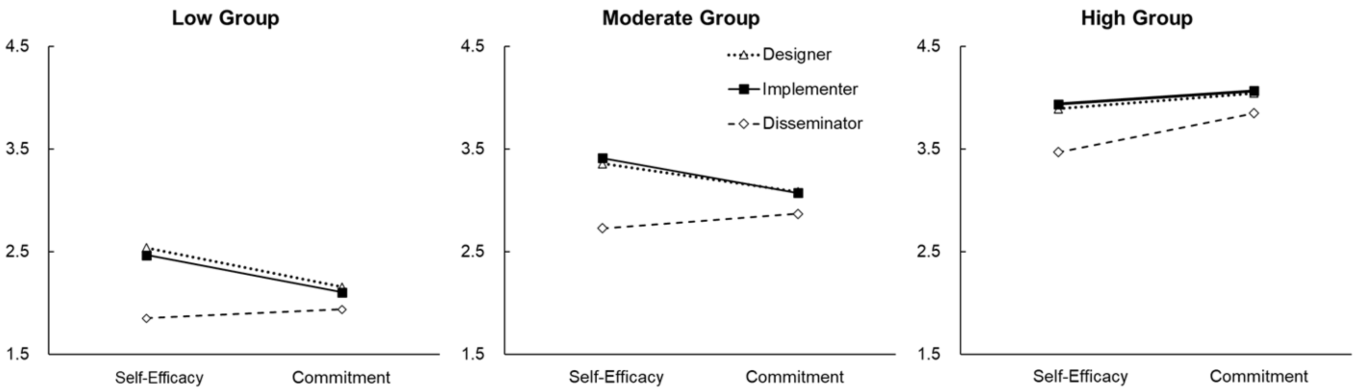

Figure 2. Differences between self-efficacy and commitment regarding the identities within the three groups *(Source: Authors' own elaboration)*

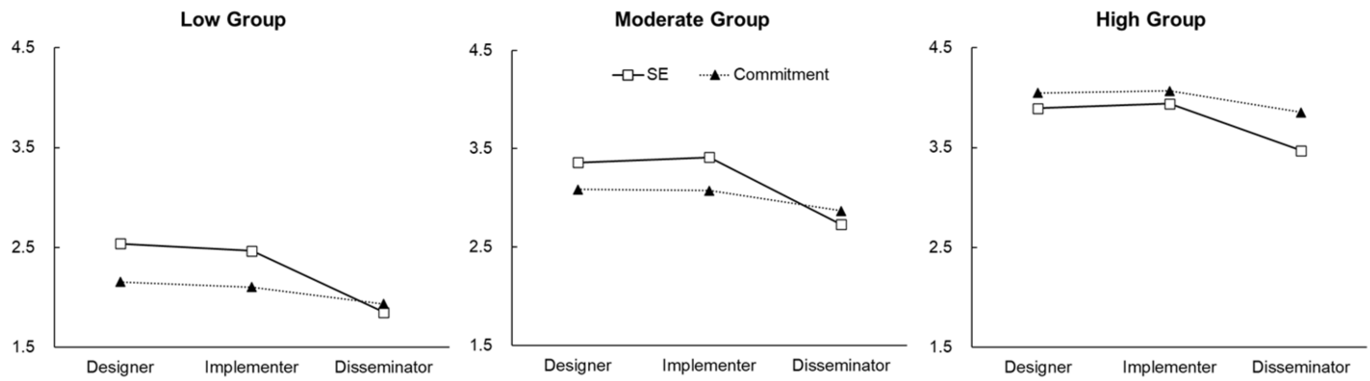

Figure 3. Differences in self-efficacy and commitment between the identities within the three groups (Source: Authors' own elaboration)

Figure 2 displays the differences between self-efficacy and commitment regarding the identities within the low, moderate, and high groups. In terms of teachers as designers, follow-up analyses of simple main effects for construction (self-efficacy vs. commitment) showed that secondary STEM teachers' self-efficacy was significantly higher than their commitment in the low and moderate groups (Low: $F(1, 159) = 30.28$, $p < .001$, Moderate: $F(1, 328) = 49.37$, $p < .001$). By contrast, teachers in the high group held significantly lower self-efficacy than their commitment to being designers ($F(1, 139) = 8.63$, $p = .004$). In terms of teachers as implementers, the follow-up analyses of simple main effects revealed a similar pattern. Teachers in the low and moderate groups had significantly higher self-efficacy than commitment (Low: $F(1, 159) = 24.09$, $p < .001$, Moderate: $F(1, 328) = 73.16$, $p < .001$), whereas in the high group, teachers' self-efficacy was significantly lower than their commitment ($F(1, 139) = 6.37$, $p = .013$). Regarding teachers as implementers, no difference was found between teachers' self-efficacy and commitment in the low group ($F(1, 159) = 3.01$, $p = .085$). However, teachers in the moderate and high groups showed significantly lower self-efficacy than their commitment to being implementers (Moderate: $F(1, 328) = 14.06$, $p < .001$, High: $F(1, 139) = 46.29$, $p < .001$).

Figure 3 displays the differences in self-efficacy and commitment between the identities within the low, moderate, and high groups. For the low and high groups, Bonferroni follow-up post-hoc comparisons indicated no significant difference in the self-efficacy of being designers and being implementers (Low: $p = .106$, High: $p = .155$). However, in the moderate group, teachers' self-efficacy of being implementers was significantly higher than their self-efficacy of being designers ($p = .018$). Additionally, the post-hoc comparisons demonstrated that in all three groups, teachers' self-efficacy of being designers and implementers was significantly higher than their self-efficacy of being disseminators ($p < .001$ for all groups).

In terms of secondary STEM teachers' commitment (**Figure 3**), Bonferroni follow-up post-hoc comparisons revealed no significant difference between their commitment to being designers and being implementers within the three groups (Low: $p = .051$, Moderate: $p = 1.000$, High: $p = .861$). By contrast, in the three groups, STEM teachers' commitment to being designers and implementers was significantly higher than their commitment to being disseminators ($p < .001$ for all groups).

Profiles, Teaching Subject, and STEM Experience

To address the third research question, secondary STEM teachers' teaching subject and STEM experience were assigned as predictors of the groups through a

Table 4. Numbers and percentages of teachers for teaching subject and STEM experience

Group	Low		Moderate		High		Total	
	n	%	n	%	n	%	n	%
Teaching Subject								
Math	84	52.5	137	41.6	50	35.7	271	43.1
Non-Math	76	47.5	192	58.4	90	64.3	358	56.9
STEM Experience								
With	28	17.5	98	29.8	75	53.6	201	32.0
Without	132	82.5	231	70.2	65	46.4	428	38.0

Table 5. Results of the multinomial logistics regression test

	Low vs. Moderate			Low vs. High			Moderate vs. High		
	β	*SE*	*OR*	β	*SE*	*OR*	β	*SE*	*OR*
Teaching subject	0.40*	0.20	1.48	0.59*	0.25	1.75	0.16	0.21	1.18
STEM experience	0.66**	0.24	1.93	1.64***	0.27	5.17	0.99***	0.21	2.88

Note. SE = Standard error; OR = odds ratio.
*p < .05, **p < .01, ***p < .001

multinomial logistic regression. The descriptive statistics for teaching subject and STEM experience of the three groups are presented in **Table 4**. It shows that the percentages of teachers teaching mathematics decreased from the low, moderate, to the high group, while the percentages of teachers having STEM experience increased from the low, moderate, to the high group.

The results of the multinomial logistics regression test are reported in **Table 5**. For teachers' teaching subject, we found that secondary STEM teachers who taught mathematics had a significantly higher likelihood of being categorized into the low group than the moderate (OR = 1.48) and the high groups (OR = 1.75), while there was no difference in the likelihood of being categorized into the moderate and high groups (OR = 1.18). For STEM experience, the results showed that teachers without STEM teaching experience had a significantly higher likelihood of being categorized into the low group than the moderate group (OR = 1.93) as well as the high group (OR = 5.17) and had a significantly higher likelihood of being categorized into the moderate group than the high group (OR = 2.88).

DISCUSSION

Frequencies of STEM teachers in low, moderate and high groups

Taking a person-centered approach, this study employed latent profile analysis and indicated that secondary STEM teachers could be classified by both the extent of their self-efficacy as well as commitment concerning the potential identities that they decide to adopt or not. The low, moderate, and high groups identified by LPA demonstrated marked differences in the levels of teachers' self-efficacy and commitment. Such differences may not be revealed by studies adopting variable-centered approaches (e.g., Canrinus et al., 2011; Shahali & Halim, 2024). Additionally, the distribution of teachers' self-efficacy and commitment to being designers, implementers, and disseminators (**Figure 1**) suggests that more than half of Taiwanese secondary STEM teachers (including the moderate and high groups) perceived neutral or higher self-efficacy and commitment to iSTEM education. The relatively high levels of self-efficacy and commitment could continue supporting the promotion of iSTEM education in Taiwan and may partially explain Taiwan's leading status in STEM performances (Marginson et al., 2013). Furthermore, the results also imply that STEM teachers in the high group were more willing to engage in iSTEM education than teachers in the moderate and low groups based on the significant differences in their self-efficacy and commitment to the three potential identities. The Ministry of Education in Taiwan may implement professional development programs or workshops, such as the program in O'Dwyer et al. (2023), to cultivate STEM teachers in the high group as seed designers and implementers of iSTEM education for further dissemination.

Three groups identified from the underlying difference in teachers' self-efficacy and commitment may suggest that the association between the two constructs may be more than a simple causal relationship. Although previous studies have indicated that self-efficacy is a predictor of commitment (e.g., Chesnut & Burley, 2015), research has also identified other types of associations between the two constructs, such as a moderating role of self-efficacy between commitment and other variables (Ballout, 2009). Future investigations of teacher education may explore different interplays between self-efficacy and commitment in terms of different profiles of self-efficacy and commitment for the three identities.

Differences Between and Within the Three Groups

Yang et al. (2023) found that Taiwanese STEM teachers' self-efficacy and commitment to being disseminators were significantly lower than their self-efficacy and commitment to being implementers and designers. By taking a person-centered approach and adopting LPA, this study further reveals the nuances among and within the groups. For the teachers in the low and moderate groups, their self-efficacy of being implementers and designers was significantly higher than their commitment to the two identities. On the contrary, for the high group, teachers' self-efficacy of being implementers and designers was significantly lower than their commitment to the two identities. These results suggest that in the high group, teachers' "will-do" was higher than their "can-do," whereas in the low and moderate groups, teachers' "can-do" was higher than their "will-do." This finding implies that, for the low and moderate groups, STEM teachers may be more likely impeded by their motivation for iSTEM teaching, while, for the high group, STEM teachers may need learning opportunities to enhance their self-efficacy.

Regarding the differences in self-efficacy between the identities within the three groups, in the moderate group, a significant difference in teachers' self-efficacy between being implementers and being designers was found, but such a difference was not shown in the low and high groups. These results provide more information about how professional developmental activities should be designed for teachers with different levels of self-efficacy and commitment. According to Wenger (1998), people would become committed to society if they could play a valid role in the policy-making process through a community of practices. To increase the self-efficacy of the high group as disseminators of iSTEM teaching, teacher educators may facilitate these teachers' reflective discussions of iSTEM teaching videos in dialogic-based training (e.g., Rodriguez et al., 2020). For the low and moderate groups, it is important to increase their STEM commitment to being designers and implementers of iSTEM teaching by involving them in a partnership between school and university (Berisha & Vula, 2023; Hamilton et al., 2021).

The Predictors of the Three Groups: Teaching Subject and Teaching Experience

This study examined how the heterogeneous profiles were related to STEM teachers' teaching subjects and found that secondary mathematics teachers were less likely to be categorized into the moderate or high group. This may be because mathematics plays a peripheral role in STEM education (English, 2016; Yang & Ball, 2024). According to English (2016), "it seems that mathematics learning benefits less than the other disciplines in programs claiming to focus on STEM integration" (p. 1). Although Taiwanese mathematics teachers performed very well in mathematical content knowledge and mathematical pedagogical content knowledge in an international comparative study on mathematics teachers' preparation (Schmidt et al., 2011), this study found that their self-efficacy for and commitment to iSTEM education were relatively low compared to STEM teachers of other subjects.

Moreover, the results suggest the importance of STEM teaching experience. Secondary STEM teachers who had no experience of STEM education were less likely to be categorized into the moderate and high groups. This result supports Bandura's theory that has identified mastery experience as a powerful source of self-efficacy (Bandura, 1997) and indicates that mastery experience could also be a powerful source of commitment. It implies that successful experience in iSTEM teaching may increase both teachers' self-efficacy and commitment. Professional development activities for Taiwanese STEM teachers should provide abundant opportunities for teachers to have successful experience in designing and implementing iSTEM curriculum materials.

Combined with the result that teachers with STEM teaching experience were more likely to be in the high group, this finding may imply that the high group had different teaching and professional development trajectories from the low and moderate groups that encouraged them to commit to the identities, even though they may not have had the same level of confidence in their capabilities to accomplish the related task. That is, teacher educators should provide different professional interventions for various groups. Guskey (2002) implied that teachers are more likely to commit to new practices when they can observe the positive impact on student outcomes. It has been suggested that Taiwanese government-funded projects scale up maker-centered learning environments to encourage the interactions between students and STEM teachers of the three groups as designers and implementers, as well as between the high group of STEM teachers as disseminators and the other two groups of STEM teachers as learners.

In the review study by Martín-Páez et al. (2019), engineering (58%) and science (21%) were the dominant disciplines among the STEM interventional studies reviewed, whereas none of the studies used mathematics (0%) as the dominant discipline in the STEM intervention. This study extends the current understanding by providing evidence for differences in mathematics and non-mathematics STEM teachers' self-efficacy for and commitment to iSTEM teaching. The result highlights the importance and urgency of developing iSTEM professional development activities and mathematics-based iSTEM teaching materials to support Taiwanese mathematics teachers. As key learning experiences shape academic paths (Smith, 2022), it is worth investigating how STEM teachers' learning and teaching experiences influence their self-efficacy and commitment in iSTEM teaching to understand why mathematics teachers may be different from other STEM teachers.

CONCLUSION AND LIMITATION

This study identified a three-profile model to characterize the patterns of secondary STEM teachers' self-efficacy and commitment to being implementers, designers, and disseminators of iSTEM teaching activities. This study contributes to research on teachers' beliefs and perceptions of STEM education in three ways.

First, a person-centered approach was adopted to identify heterogeneity in teachers' self-efficacy and commitment. This approach was less common in previous studies on teachers' self-efficacy and commitment.

Secondly, this study deepens the understanding of the differences in the two constructs and the three identities between teacher subgroups. The results shed light on the development of STEM professional activities based on the characteristics of patterns of teachers' self-efficacy and commitment to the three identities.

Thirdly, secondary mathematics teachers were found to have less self-efficacy and commitment to the three identities than those who taught other STEM subjects.

This result suggests a need to develop iSTEM professional development activities with a focus on mathematics and mathematics teachers by encouraging them and engaging them in collaboration with STEM teachers of the high group to become designers and implementers of iSTEM teaching activities. Overall, it is crucial to advance the role of mathematics for teacher professional development in iSTEM education.

This study has some limitations. First, the generalisability of the findings may be restricted because the results of this study were obtained based on data collected in Taiwan. Nonetheless, the questionnaire developed in this study could be used in other countries to determine and characterize STEM teachers' self-efficacy and commitment to the three identities.

Second, the data may suffer from self-reported bias. In addition, the potential identities in this study were assumed to be stable; however, Stronach et al. (2002) argued for occasional identities that could be mobilized in response to shifting contexts and tasks. How STEM teachers' identities could be mobilized, and how the occasional identities are associated with teachers' STEM beliefs deserves more research attention. Furthermore, the present study only considered teachers' teaching subject and STEM experience as dichotomous variables.

Further investigation could compare the teachers' profiles among a variety of teaching subjects of STEM using a larger sample size and investigate how the quantity and quality of teachers' experience in iSTEM teaching impacts their self-efficacy and commitment in the three identities. Only two predictors, teaching subject and STEM experience, were examined in this study. Future studies involving other influential sources of self-efficacy and commitment, such as vicarious experience and verbal persuasion, are needed.

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Declaration of interest: The authors declare that they have no competing interests.

Data sharing statement: The datasets generated and analyzed during the current study are not publicly available due to agreement between the participants and researchers.

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