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# Gender differences in preservice mathematics and science teachers' professional identities

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**Abstract:** The traditional marginalization of women in science, technology, engineering, and mathematics (STEM) may prevent female preservice teachers from seeing themselves as STEM teachers. However, gender differences in this issue remain underexplored. This study aims to examine whether and in what respects female preservice teachers differ in terms of their professional identities from their male counterparts. Participants include those majoring in mathematics (42), general science (44), and advanced science (47). The instruments include three versions of a Likert-type questionnaire measuring professional identities as general, disciplinary, and STEM teachers. Data were analyzed using Mann-Whitney U tests focusing on three components of professional identity (i.e., motivation, self-efficacy, and self-image). The results reveal that gender differences seldom occur in all respects, except when those majoring in advanced science self-identify as STEM teachers. Finally, this study provides implications regarding teacher education for STEM.

**Keywords:** gender difference, preservice teacher, professional identity, STEM education, teacher education

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## 1 Introduction

In the fields of science, technology, engineering, and mathematics (STEM), diversity is a key factor in promoting innovation and productivity (Daily & Eugene, 2013). Yet, despite their unique contributions, women have been underrepresented in these fields (Blackburn, 2017). Considerable effort has thus been devoted to increasing the female workforce in STEM (Greider et al., 2019), particularly through education (Yu et al., 2024). However, due to the masculine stereotypes of those who work in STEM (Ladachart et al., 2023), female students are more likely than male counterparts to struggle with developing their STEM identities (Kim et al., 2018). A STEM identity, which can be defined as an ability to see oneself as a STEM person, is said to increase the likelihood that a student will choose STEM as a prospective career avenue (Dou et al., 2019).

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Teachers play several roles in fostering students' STEM identities and influencing their decisions toward STEM-related professions (Marti-Hansen, 2018). For example, teachers can enact instructional activities in which students can exhibit their performance in STEM and then be recognized as STEM persons (Ladachart et al., 2024). Moreover, teachers can explicitly guide students to pursue careers in STEM (Anderson, 2023). Through making STEM interesting and listening to students' ideas in classrooms, teachers can also create an environment to raise students' interest and confidence to learn STEM (Sansone, 2017). In addition, teachers can serve as role models "who can positively shape a student's motivation by acting as a successful exemplar" (Gladstone & Cimpian, 2021, p. 2) in learning STEM and working within these fields.

Research has particularly shown the positive effect of female teachers on female students' STEM identities (Chen et al., 2020) and choices of STEM in higher education (Sevilla et al., 2023). For example, Dulce-Salcedo et al. (2022) observed that female students who were exposed to a higher proportion of female teachers in schools were more likely to choose STEM as majors in higher education. In alignment with this observation, Stearns et al. (2016) note that such exposure does not deter male students from choosing majors in STEM. The presence of female teachers in STEM classrooms reduces both female and male students' beliefs about the masculine stereotypes of STEM-related professionals (Riegle-Crumb et al., 2017) and the gender bias regarding their own STEM abilities (Sansone, 2019).

Consequently, raising the number of female teachers in schools to serve as role models in STEM is recommended as a strategic policy to increase female students' enrolment in STEM education (Stearns et al., 2016). However, Sansone (2017) argues that what really matters may not be the gender of teachers, but their characteristics instead. Specifically, how teachers perceive female and male students' abilities in STEM, as well as whether they equally treat female and male students, matters more than their gender itself (Sansone, 2019). These results warrant more studies to investigate gender differences in terms of teachers' characteristics. Although a teacher's professional identity is considered one key characteristic, research examining gender differences in STEM teachers' professional identities, to date, is scarce (Tang et al., 2021).

Preservice teachers (PTs) with majors in mathematics and science are those who will implement STEM education in the future (Tytler, 2020). Teacher education must thus prepare PTs' professional identities as STEM teachers (El Nagdi et al., 2018), in addition to their professional identities as general and disciplinary teachers (Beauchamp & Thomas, 2009; Giles et al., 2023). In this regard, a professional identity as a certain type of teacher (e.g., a general/mathematics/science/STEM teacher) can be defined as "an understanding of what it means to be (that type of) teacher, (not only) in one's own eye but also in the eyes of others" (Sachs, 2005, p. 8). Like female students of STEM (Kim et al., 2018), female PTs may experience gender bias in favor of men, which poses difficulties to the development of their STEM identities.

Given that a STEM identity is an integral part of a PT's professional identity as a STEM teacher (Galanti & Holincheck, 2022), female PTs may need particular support to develop their professional identities as STEM teachers. For example, female PTs may underrate their performance in STEM, which can inhibit them from developing their professional identities as STEM teachers (Tang et al., 2021). Thus, it is necessary to explore whether and in what aspects gender differences in PTs' professional identities as STEM teachers exist. Such an exploration could elicit useful information for the improvement of teacher education programs to better prepare female PTs to strengthen those professional identities. Special attention to female PTs is essential if they are expected to serve as role models in STEM for young students in schools.

## 2 Literature review

This section presents a review of the literature regarding the nature of individuals' identities and teachers' professional identities, particularly focusing on the case of PTs majoring in mathematics and science. As a theoretical construct, identity is based on a sociocultural perspective of learning (Lemke, 2001). In this perspective, learning is conceptualized as an increased ability to participate in a community of practice (Wenger, 1998), in which an individual engages to construct meanings and develops membership (Lave & Wenger, 1991). Within a certain community of practice, an identity can be defined as "being recognized as a certain 'kind of person'" (Gee, 2000, p. 99). Given that many communities of practice coexist in one's life (Wenger, 1998), an individual can at once have multiple identities based on traits, intuitions, discourse, and affinity (Gee, 2000).

Identity has become a theoretical lens to understand how an individual sees oneself as a certain type of person in a given context (Stryker & Burke, 2000). Once applied in a profession (e.g., teaching), this theoretical notion can be called a professional identity (Beijaard et al., 2004). Standing at the core of the teaching profession, a professional identity provides a framework for a teacher to construct one's own ideas of self with regard to how to be, act, and work (Sachs, 2005). As Enyedy et al. (2006) describe, a teacher's professional identity "lies at the intersection between one's personal history and individual psychology on the one hand, and one's cultural history and community of practice on the other hand" (p. 71). A teacher's professional identity thus has both psychological and sociological characteristics (Darragh, 2016).

Although a teacher's professional identity can be differently defined, Beijaard et al. (2004) highlight its four key aspects. First, it changes over time as the teacher gains and interprets experience. Second, it implies a relationship between the person and the context. Third, a professional identity involves the teacher's sub-identities that inevitably intersect. Finally, it requires a sense of agency in that the teacher must actively construct their designated identity. These aspects are relevant when PTs develop their professional identities during teacher education. Specifically, PTs use various experiences (e.g., coursework and practicum) to develop their professional identities (Avraamidou, 2014). Moreover, the development of PTs' professional identities is based on their existing identities, such as those related to gender and race (Dunleavy et al., 2021).

Considering PTs majoring in mathematics and science, their professional identities must involve the intertwining of STEM and teaching identities (Galanti & Holincheck, 2022). As Chung-Parsons and Bailey (2019) suggest, this process is hierarchical rather than fluid. In other words, PTs develop their STEM identities since childhood (Dou et al., 2019), before they construct their teaching identities through teacher education (van Putten et al., 2014). Consequently, PTs' STEM identities are central to their professional identities (Helms, 1998), although their teaching identities may be more pronounced in educational settings (Giles et al., 2023). Due to female marginalization in STEM education (Kim et al., 2018), female PTs with low levels of STEM identities may remarkably struggle to develop their professional identities as STEM teachers.

Teachers' professional identities have been qualitatively measured with a sociological emphasis (Lutovac & Kaasila, 2019). However, there have been recent calls for using quantitative methods with a psychological focus (Lutovac & Kaasila, 2018). In response to these calls, based on the intertwining of the STEM and teaching identities (Galanti & Holincheck, 2022), PTs' professional identities can be measured through two perspectives: (1) through the components of PTs' STEM identities (Dou et al., 2019), such as their interest in being STEM teachers, self-perception of performance in teaching STEM, and feeling recognized as STEM teachers (Cribbs & Utley, 2024); and (2) through the components of PTs' teaching identities (Hanna et al., 2020), such as motivation, self-efficacy, and self-image of being STEM teachers (Xie & Tse, 2024).

Regardless of how teachers' professional identities are measured, research has shown that female individuals tend to have difficulties in developing their professional identities as STEM teachers. Jiang et al. (2021), for example, have observed that female teachers struggle emotionally to successfully implement STEM education and construct their professional identities as STEM teachers. Likewise, Tang et al. (2021) report that female PTs are uncertain about their own abilities in STEM; they are thus prevented from seeing themselves as STEM teachers due to this uncertainty. These results suggest that female PTs may need special scaffolding to develop their professional identities as STEM teachers. This suggestion is important, given that scholarship on STEM teacher education is still at an early stage (Li & Anderson, 2020).

However, the suggestion that highlights female PTs' special need to develop their professional identities as STEM teachers may not be applied beyond the context of STEM education. When STEM education is not the focus (i.e., when ignoring STEM identity), research tends to show the opposite results. For example, Ehrich et al. (2020) observed that women are more disposed toward being effective teachers than men with regard to self-efficacy and interpersonal skills. Qin and Liu (2023) also found that female teachers show higher-level professional identities than their male counterparts and that gender moderates the effect of professional identity on professional learning. Pilen et al. (2013), nonetheless, report that female teachers are more vulnerable to tensions that arise while they develop their professional identities than male teachers.

Considering teachers' professional identities by component, research suggests mixed differences between the genders. Jugovic et al. (2022), for example, note that female PTs are more motivated to be teachers than male peers, who perceive the teaching profession as having a low status. This gender difference may result partly from the sources of motivation, which are intrinsic in female PTs, while they are extrinsic in male PTs (Yuce et al., 2013). In terms of self-efficacy, Brandon (2000) reports that male PTs are more self-efficacious in teaching science than female counterparts. Bursal (2010), however, did not observe gender differences in PTs' self-efficacy to teach mathematics and science. Further, upon comparing participants' drawings of themselves as science teachers, Akkus (2013) did not find differences in the images portrayed by female and male PTs.

Based on the studies reviewed above, female and male PTs majoring in mathematics and science may differ in their professional identities as STEM teachers. Although female PTs' teaching identities may be stronger than male PTs', their STEM identities are not vice versa. Little evidence, if any, indicates that female PTs' teaching identities can offset their STEM identities. If gender differences in PTs' professional identities as STEM teachers exist in favor of men, then female PTs may be reluctant to become STEM teachers and fail to serve as role models for female students. In this scenario, increasing the female workforce in STEM would be unlikely. Hence, it is crucial to explore gender differences in this regard so that teacher education can particularly support female PTs' professional identities as STEM teachers.

## 3 Research question

This study was conducted to contribute to a better understanding of gender differences in PTs' professional identities as STEM teachers. To this end, PTs' professional identities as STEM teachers were measured through three components: motivation, self-efficacy, and self-image of being STEM teachers. In the context of this study, STEM education entails the integration of STEM (Institute for the Promotion of Teaching Science and Technology, 2014). One's being a STEM teacher thus differs from one's being a general, mathematics, or science teacher. To estimate the influence of female marginalization in STEM education, PTs' professional identities as general and disciplinary teachers were measured for comparison with their professional identities as STEM teachers. The following research question was formulated to guide this study:

- In what specific ways do male and female PTs majoring in mathematics, general science, and advanced science differ in their motivation, self-efficacy, and self-image as general, disciplinary, and STEM teachers?

## 4 Research methods

To contribute to the literature, in which qualitative studies on teachers' professional identities are prevalent, a research project was initiated in Thailand with three aims: (1) disciplinary specificity; (2) an intertwining of STEM and teaching identities; and (3) gender differences in PTs' professional identities. This study focuses on the third aim. As a survey research (Berends, 2006), it investigates gender differences in the professional identities of PTs with various majors: mathematics, general science, and advanced science (i.e., physics, chemistry, and biology). Given the female marginalization in STEM education (Kim et al., 2018), the researchers are specially interested in determining whether gender differences manifest when PTs identify themselves as different types of teachers (i.e., general, disciplinary, and STEM teachers).

## 4.1 Context

In Thailand, STEM education has officially become part of the Basic Education Core Curriculum (Bureau of Academic Affairs and Educational Standards, 2017). In alignment with international literature (e.g., Kelley & Knowles, 2016), an engineering design process is proposed as an integrated approach to teaching and learning STEM (Institute for the Promotion of Teaching Science and Technology, 2014). Given this proposal, teachers (Srikoom et al., 2017) and PTs (Khwaengmek & Faikhamta, 2023) tend to perceive STEM education more as an integrated whole than as the siloed disciplines. However, few attempts have been made to change teacher education (Faikhamta & Lertdechapat, 2021) with an emphasis on PTs' understanding (Pimthong & Williams, 2021) or their pedagogical content knowledge (Lertdechapat & Faikhamta, 2021).

Similar to many countries in Asia, Thailand is traditionally dominated by patriarchal ideologies (Tantiwiramanond, 1997). Educational inequality in favor of boys has thus been evident (Knodel, 1997). However, the situation has substantially improved (Nawarat, 2018). As Coll et al. (2010) note, “gender differences in school science performance and participation in further science study or careers has not been a big issue for science education in the Thai context” (p. 18). This is also true in mathematics education, where there is no gender difference in students' performance (Darmawan, 2020). Nonetheless, gender inequity in education, as a cultural heritage, is still of concern (Levtov, 2014) when considering that STEM education has been introduced with an emphasis on engineering, socially perceived as a masculine discipline (Ladachart et al., 2020).

Regarding teacher education, Thailand has two types of programs (Siribanpitak, 2018), whose curricular structures are nationally framed by the Teachers Council of Thailand (2006). In the first type (four-year programs), students who have completed secondary education are recruited to pursue a bachelor's degree in education with a specific major. The second type are two-year programs, which are open for those completing a bachelor's degree in a specific discipline to pursue a master's degree in education for teaching that discipline. According to Rupavijetra and Rupavijetra (2022), the curriculum of teacher education programs tends to emphasize subject content and educational theory rather than practice. This study involves PTs enrolling in the first type of teacher education program, located in a university in the country's northern region.

In the university where this study was conducted, PTs enroll in teacher education programs requiring 136–138 credits, depending on their majors. The programs are organized in the form of two semesters per year. The first three years comprise disciplinary courses, educational courses, and teaching-methods courses. Per the Teachers Council of Thailand's (2006) attempts to make teacher education programs more practice-based, PTs are required to visit schools, observe classrooms, and work as teaching assistants for several weeks between the semesters of these three years (Rupavijetra & Rupavijetra, 2022). Afterward, PTs work as full-time teachers in schools for practicum and return to the university to complete an independent study in education in the first and second semesters of the final year, respectively.

As framed by the Teachers Council of Thailand (2006), the educational courses of teacher education programs are similar across PTs' majors. However, the number of disciplinary and teaching-methods courses vary, depending on the prospective tasks of PTs in each major. Specifically, PTs majoring in mathematics or general science may work across elementary, lower secondary, and higher secondary education. Thus, they are required to take disciplinary courses diversely. Moreover, they must attend two or three teaching-methods courses for different levels of education. In contrast, PTs majoring in advanced science (i.e., physics, chemistry, or biology) are expected to teach a discipline only in higher secondary education. They are required to take disciplinary courses in depth and complete only a teaching-methods course.

In response to the curricular demand in basic education (Bureau of Academic Affairs and Educational Standards, 2017), one course regarding STEM education is directed at PTs majoring in mathematics, general science, and chemistry. This course aims to introduce PTs to how STEM education can be enacted in an integrative manner through a five-stage cycle of the engineering design process (i.e., identifying a challenge, exploring ideas, developing solutions, testing prototypes, and presenting results), as promoted by the Institute for the Promotion of Teaching Science and Technology (2014). While PTs majoring in mathematics study this course in their third year, those majoring in general science and chemistry take this course in their second year. This course is not in the programs for PTs majoring in physics and biology, however.

## 4.2 Instrument

Hanna et al.'s (2020) questionnaire was adapted to measure PTs' professional identities, which are conceptualized as having four components (i.e., motivation, task perception, self-efficacy, and self-image). However, task perception was excluded due to its broad scope. In translating the questionnaire from English to Thai, the researchers attempted to find “a balance between a literal translation and a culturally specific translation” (van Widenfelt et al., 2005, p. 145). Three experts then checked the translation until a consensus was reached. In this regard, back translation was not conducted because of the experts' preference for cross-cultural adaptation. With the addition of adjectives (i.e., mathematics, science, and STEM) to specify certain types of teachers (i.e., general, disciplinary, and STEM), three versions of the questionnaire were created.

Each version of the questionnaire comprised 21 items divided equally among the three components (see Appendix). All three versions of the questionnaire featured a Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree) and were administered to 23 PTs majoring in technology in the same university. Despite the small number of respondents, the results at this stage indicated all three versions of the questionnaire to be reliably acceptable, with Cronbach's-alpha values greater than 0.90 (see Table 1). Given that a factor analysis requires "the ratio of respondents to variables…at least 10:1" (Yong & Pearce, 2013, p. 80), it was not done. Even the actual number of participants, as can be seen below, was not sufficient (N < 210). Thus, the researchers relied solely on the validity that was established for the original questionnaire.

**Table 1.** Reliability of the three versions of the questionnaire

| Three versions of professional identity | Cronbach's alphas | | | |
|---|---|---|---|---|
| | Components | | | Whole |
| | Motivation | Self-efficacy | Self-image | |
| General teachers | 0.90 | 0.95 | 0.94 | 0.96 |
| Disciplinary teachers | 0.98 | 0.97 | 0.98 | 0.99 |
| STEM teachers | 0.97 | 0.98 | 0.97 | 0.99 |

## 4.3 Data collection

Each version of the questionnaire was transformed into a digital format (i.e., Google Forms), with its front page presenting ethical statements for research on humans and asking for PTs' consent to participate in the study. The questionnaires' weblinks were then sent to first- to third-year PTs majoring in mathematics, general science, and advanced science by the instructors of the courses in which they were enrolled. These weblinks were also posted on a social media platform (i.e., Facebook) for fourth-year PTs in these majors, who were engaging in practicum at schools. PTs who consented to participate in the study were asked to complete all three versions of the questionnaire in an order based on their convenience. The weblinks were open for two weeks, with two reminders provided during that time for all potential participants to complete the questionnaire within the first semester of the 2023 academic calendar.

## 4.4 Participants

Because participation was voluntary, the total number of participants was 133 out of all 407 PTs in these majors (32.68%), including 42 of 183 (22.95%) majoring in mathematics, 44 of 137 (32.12%) majoring in general science, seven of 17 (41.18%) majoring in physics, 14 of 17 (82.35%) majoring in chemistry, and 26 of 53 (49.06%) majoring in biology. The participants varied in terms of years spent in the teacher education programs (see Table 2). Regardless of their majors, 29 participants (21.80%) were freshmen, 34 (25.56%) were sophomores, 16 (12.03%) were juniors, and 54 (40.60%) were seniors. Regarding gender, 29 (21.80%) were male, and 104 (78.20%) were female. As these participants might not fully represent all PTs in the university, this study rather sheds light on gender differences in PTs' professional identities than producing generalizable findings.

**Table 2.** Distribution of participants by major, gender, and year

| Major | | Number of participants | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Freshman | | Sophomore | | Junior | | Senior | |
| | | Male | Female | Male | Female | Male | Female | Male | Female |
| Mathematics | | 7 | 9 | 5 | 7 | 0 | 8 | 2 | 4 |
| General science | | 1 | 6 | 0 | 14 | 1 | 2 | 3 | 17 |
| Advanced science | Physics | 0 | 1 | 0 | 3 | 1 | 2 | 0 | 0 |
| | Chemistry | 0 | 2 | 1 | 0 | 1 | 1 | 2 | 7 |
| | Biology | 0 | 3 | 0 | 4 | 0 | 0 | 5 | 14 |

### 4.5 Data analysis

JASP was employed for data analysis (Goss-Sampson, 2020). After the questionnaires' reliability was rechecked in every respect with the actual data, which resulted in acceptable values of Cronbach's alpha ranging 0.87–0.96, the means and standard deviations for each component of the participants' professional identities, according to their majors and the three types of teachers, were calculated. Due to non-normal data distribution (Shapiro-Wilk test, $p < .05$), Mann–Whitney U tests were used for comparing professional identity components between genders (Morgan et al., 2011). If significant differences were detected ($p < .05$), Rank-Biserial correlations as effect sizes were computed, with values less than 0.10 considered trivial, those between 0.10 and 0.30 small, those between 0.30 and 0.50 medium, and those above 0.50 large (Goss-Sampson, 2020, p. 163).

## 5 Research results

The research survey was designed to examine gender differences in the professional identities of PTs with majors in mathematics, general science, and advanced science using three versions of a Likert-type questionnaire adapted from Hanna et al.'s (2020) instrument. Herein, their professional identities are operationally defined as having three components (i.e., motivation, self-efficacy, and self-image) regarding a certain type (i.e., general, disciplinary, and STEM) of teacher. Because gender gaps in individual fields of STEM may not be equal (Makarova et al., 2019), the results of this study are reported according to the PTs' majors. However, doing so was not possible in the case of those majoring in physics, chemistry, and biology, given the very small number of PTs in these majors. These participants were therefore pooled into a group of PTs majoring in advanced science.

## 5.1 PTs majoring in mathematics

As Figure 1 shows, female participants expressed their professional identities less strongly than their male counterparts for all components and all types of teachers. The gaps between female and male participants' professional identities were quite equal across the components when they identified as general and mathematics teachers. However, the gender gaps were considerably larger when the participants identified as STEM teachers. Despite this descriptive pattern, the Mann–Whitney tests indicated that these gender differences in favor of male participants were significant only regarding their motivation to become STEM teachers (p = .030), with an effect size of 0.362 (see Table 3). Specifically, female participants were less motivated to be STEM teachers when compared to the male participants.

**Figure 1.** Descriptive results in case of PTs majoring in mathematics

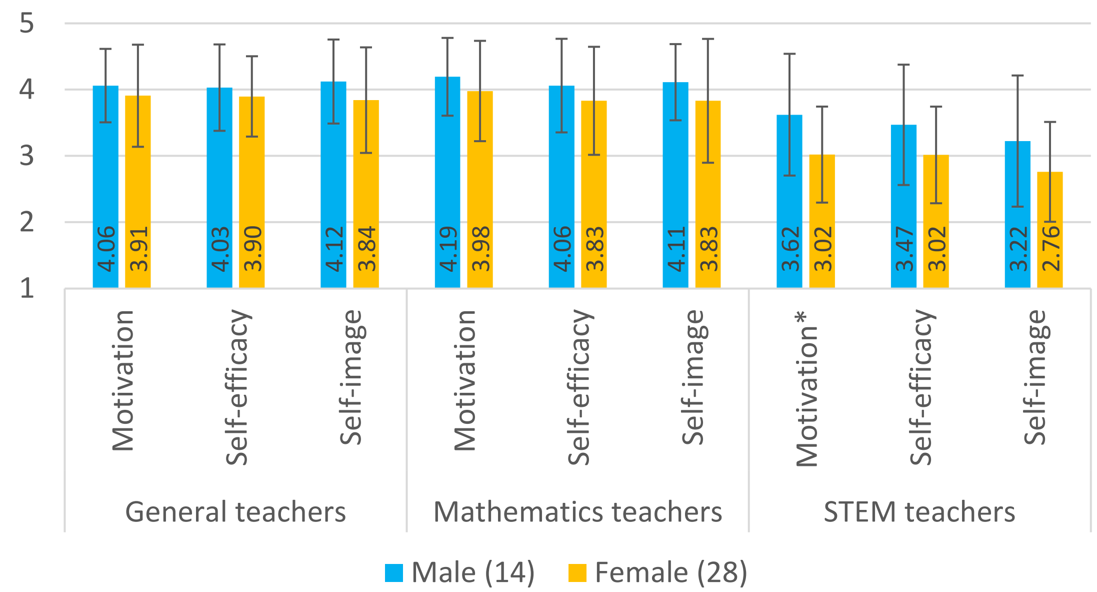

**Table 3.** Inferential results in case of PTs majoring in mathematics

| Type of teacher | Components | W | p (one tailed) | Effect size |
|---|---|---|---|---|
| General teachers | Motivation | 215.000 | .310 | - |
| | Self-efficacy | 216.500 | .295 | - |
| | Self-image | 236.000 | .145 | - |
| Mathematics teachers | Motivation | 229.500 | .189 | - |
| | Self-efficacy | 226.000 | .215 | - |
| | Self-image | 224.000 | .231 | - |
| STEM teachers | Motivation | 267.000 | .030 | 0.362 |
| | Self-efficacy | 250.500 | .074 | - |
| | Self-image | 241.000 | .117 | - |

## 5.2 PTs majoring in general science

In contrast with participants majoring in mathematics, participants majoring in general science did not exhibit a certain pattern regarding gender differences in their professional identities (see Figure 2). Specifically, in the cases of identifying as general and science teachers, female participants showed a stronger or at least an equal sense of professional identity with respect to male counterparts. However, mixed results appeared when they identified as STEM teachers. In comparison to male peers, female participants imagined themselves as STEM teachers a bit more clearly, yet they were a bit less motivated to be STEM teachers. Female participants were also less self-efficacious in teaching STEM than male counterparts. Yet, none of these gender differences were significant according to the Mann–Whitney tests, as summarized in Table 4.

**Figure 2.** Descriptive results in case of PTs majoring in general science

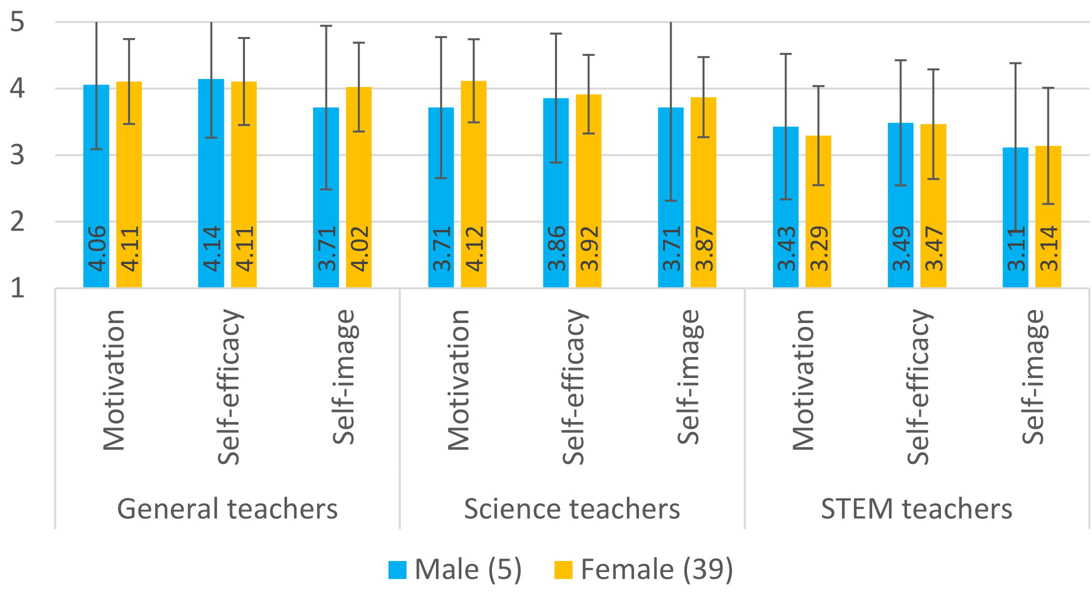

**Table 4.** Inferential results in case of PTs majoring in general science

| Type of teacher | Components | W | p (two tailed) | Effect size |
|---|---|---|---|---|
| General teachers | Motivation | 100.000 | .470 | - |
| | Self-efficacy | 105.000 | .397 | - |
| | Self-image | 86.000 | .672 | - |
| Science teachers | Motivation | 68.500 | .864 | - |
| | Self-efficacy | 97.500 | .507 | - |
| | Self-image | 95.500 | .537 | - |
| STEM teachers | Motivation | 115.000 | .264 | - |
| | Self-efficacy | 101.500 | .448 | - |
| | Self-image | 108.500 | .348 | - |

## 5.3 PTs majoring in advanced science

For participants majoring in advanced science, a pattern similar to that occurring in those majoring in mathematics emerged. Specifically, female participants showed their professional identities less strongly than their male counterparts for all components and all types of teachers (see Figure 3). As Table 5 shows, the Mann–Whitney tests confirmed that female participants were significantly less self-efficacious as science teachers than male colleagues ($p = .036$), with an effect size of 0.373. Moreover, female participants were less motivated ($p = .004$) and self-efficacious ($p = .017$) than male counterparts to become STEM teachers. Female participants were also less able than male peers to imagine themselves as STEM teachers ($p = .010$). The effect sizes of these differences are quite large (0.543, 0.441, and 0.484 respectively).

**Figure 3.** Descriptive results in case of PTs majoring in advanced science

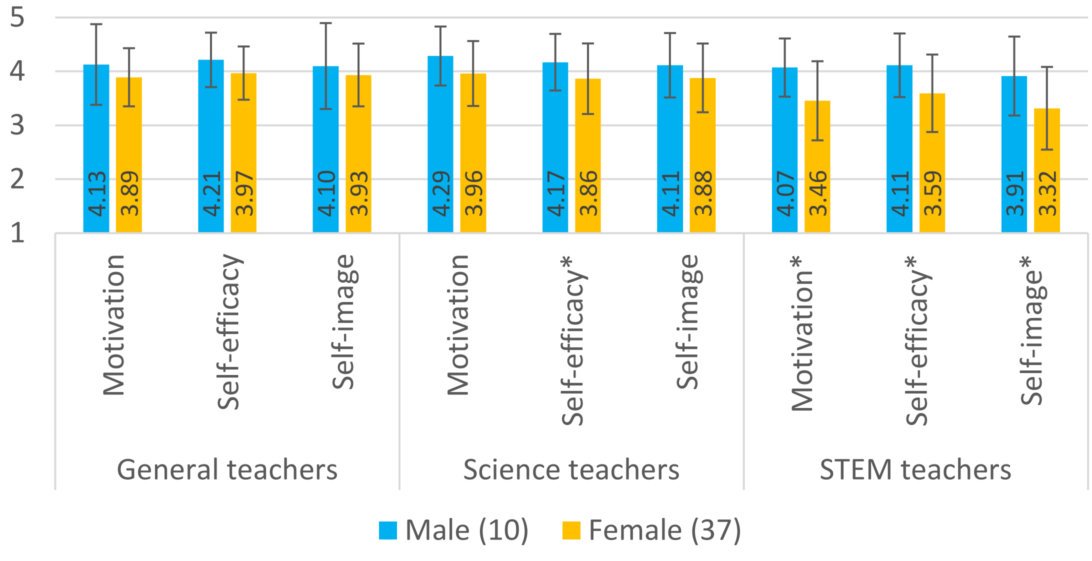

**Table 5.** Inferential results in case of PTs majoring in advanced science

| Type of teacher | Components | W | p (one tailed) | Effect size |
|---|---|---|---|---|
| General teachers | Motivation | 236.500 | .090 | - |
| | Self-efficacy | 229.000 | .127 | - |
| | Self-image | 234.000 | .102 | - |
| Science teachers | Motivation | 242.500 | .068 | - |
| | Self-efficacy | 254.000 | .036 | 0.373 |
| | Self-image | 233.500 | .105 | - |
| STEM teachers | Motivation | 285.500 | .004 | 0.543 |
| | Self-efficacy | 266.500 | .017 | 0.441 |
| | Self-image | 274.500 | .010 | 0.484 |

## 6 Discussion

As women can uniquely contribute to the fields of STEM (Blackburn, 2017), increasing the female workforce in STEM is important (Greider et al., 2019). However, the masculine stereotypes around STEM can prevent female students from choosing STEM fields as prospective career avenues (Makarova et al., 2019). In this regard, female students may specially need female individuals who have succeeded in learning STEM to serve as role models (Gonzalez et al., 2020). Female teachers can indeed be such role models (Sevilla et al., 2023). Nonetheless, akin to female students, female teachers must work against gender bias in STEM (Navarro et al., 2022). They may not even identify themselves as STEM teachers (Tang et al., 2021). Exploring the gender differences in PTs' professional identities as STEM teachers is therefore vital to provide relevant support to female PTs.

Using a Likert-type questionnaire adapted from Hanna et al.'s (2020) instrument, this study explored how female and male PTs majoring in mathematics, general science, and advanced science differed in terms of their professional identities as STEM teachers. Their professional identities are compartmentalized under their motivation, self-efficacy, and self-image of being STEM teachers. This study's results reveal that differences in favor of male PTs exist in all three components in the case of PTs majoring in advanced science. Such differences in favor of male PTs appeared only in terms of motivation to be STEM teachers in the case of PTs majoring in mathematics. Further, gender differences did not manifest at all in the case of PTs majoring in general science. Thus, gender differences in PTs' professional identities as STEM teachers vary across majors.

Gender differences in PTs' professional identities as STEM teachers may cumulatively result from female marginalization in STEM education (Kim et al., 2018), the intensity of which can vary across the disciplines (Makarova et al., 2019). To be certain about this issue, PTs' professional identities as general and disciplinary teachers are used as baselines. The results indicate that gender differences in PTs' professional identities as general teachers do not exist in any respect. For PTs' professional identities as disciplinary teachers, gender differences manifest only in the case of those majoring in advanced science regarding their self-efficacy to teach science. Based on these comparisons, it is highly likely that gender bias in STEM education creates more difficulties for female PTs than for male PTs to develop their professional identities as STEM teachers.

Explanations are required as to why gender differences in PTs' professional identities as STEM teachers are more pronounced than gender differences in their professional identities as general and disciplinary teachers. One sensible explanation is that STEM education in Thailand is nationally presented as an integrated pedagogy through an engineering design process (Institute for the Promotion of Teaching Science and Technology, 2014), thus highlighting engineering as a new domain for teachers (Srikoom et al., 2017). Given the social perception of engineering as being very masculine (Ladachart et al., 2020), female PTs may thus be less likely than male PTs to endorse this engineering-oriented approach. This perception may enlarge gender differences in PTs' professional identities when they focus on STEM education.

The curricular structure of teacher education in each major may further be a factor influencing PTs' professional identities as STEM teachers. Among this study's participants, PTs majoring in mathematics and general science had a course about STEM education in their programs, while most of the PTs majoring in advanced science did not. Moreover, PTs majoring in mathematics and general science take disciplinary courses more broadly than PTs majoring in advanced science. Within these courses, female PTs majoring in mathematics and general science may be more positive toward STEM education and teaching out of their majors than those majoring in advanced science. Thus, gender gaps in PTs' professional identities as STEM teachers can be smaller among PTs majoring in mathematics and general science when compared to PTs majoring in advanced science.

In this study, PTs' professional identities as general and disciplinary teachers were used as baselines to estimate the influence of female marginalization in STEM education on their professional identities as STEM teachers. The results regarding these characteristics are worth discussing in light of the extant literature. Regardless of their majors, female and male PTs included in this study did not differ in terms of their professional identities as general teachers. More specifically, they did not differ in terms of motivation to be teachers in general. These results are inconsistent with prior studies (Ehrich et al., 2020; Jugovic et al., 2022; Qin & Liu, 2023; Yuce et al., 2013) that note gender differences in favor of women. These inconsistencies can be discussed in terms of contextual differences between this study and other studies.

Elsewhere, the teaching profession may be perceived as having a low status (Jugovic et al., 2022), particularly by male individuals whose motivation to be teachers are mainly extrinsic (Yuce et al., 2013). In contrast, teaching in Thailand "has been regarded as a highly respected career" (Rupavijetra & Rupavijetra, 2022, p. 614). Moreover, policies (e.g., provision of financial incentives for teachers and recruitment of high-achieving students to become teachers) have been enacted to sustain the status of the teaching profession (Parkay et al., 1999). Thus, even though teaching may have been perceived as a feminine profession (Basten, 1997), which is still dominated by female teachers (UNESCO Institute for Statistics, 2023), the high status of the teaching profession can motivate male individuals to choose it as a prospective career.

Regarding PTs' professional identities as disciplinary teachers, gender differences did not manifest in the case of those majoring in mathematics or general science in this study. These results align with findings (Coll et al., 2010; Darmawan, 2020) indicating that gender differences among Thai students of mathematics and science are insignificant. These results are also consistent with a prior study (Bursal, 2010) that notes no gender differences in PTs' self-efficacy in teaching mathematics and science. Moreover, these results support prior research (Akkus, 2013) reporting no gender differences in PTs' self-images as science teachers. An exception, however, must be noted in the case of PTs majoring in advanced science. Echoing Brandon's (2000) results, female PTs were found less self-efficacious in teaching science than male peers.

A closer look is thus required to explain the exception in the case of PTs majoring in advanced science, who exhibit gender differences in self-efficacy to teach science. As shown in Table 2, of all PTs in this group (47), 26 majored in biology (55.32%), 14 majored in chemistry (29.79%), and seven majored in physics (14.89%). According to Chen et al.'s (2020) “hard-soft spectrum within science subjects” (p. 77), physics with its masculine traits is usually placed on the hard end, followed by chemistry and then biology with increasingly feminine traits. Given this spectrum's characteristics, female PTs majoring in biology, as the majority in this group (22 of 47), made a large contribution to the perceived gender differences in self-efficacy to teach science. These participants may not be self-efficacious to teach other science subjects beyond biology.

## 7 Implications

This study provides insights into gender differences in PTs' professional identities as STEM teachers. It reveals that female PTs are less likely than male PTs to develop their professional identities as STEM teachers. The masculine stereotyping of professionals in STEM and the female marginalization in STEM education may create additional barriers for female PTs in this regard. Such differences in favor of male PTs may be especially obvious when female PTs identify themselves with a discipline that has feminine traits (e.g., biology). As PTs' professional identities can predict their likelihood of entering and continuing in the teaching profession after graduation (Horvath et al., 2018), these results imply that female PTs are less likely than male peers to be STEM teachers. Female PTs thus need special support.

Prior research has suggested that teacher education programs must not only develop PTs' pedagogical content knowledge to implement STEM education (Lertdechapat & Faikhamta 2021), but also support PTs' professional identities as STEM teachers (El Nagdi & Roehrig, 2020). In agreement with these suggestions, the researchers add that female PTs require special attention and scaffolding. In addition to having a course or courses on

STEM education for all PTs (Pimthong & Williams, 2021), teacher education programs may need an additional course aiming explicitly to reduce gender gaps in PTs' professional identities as STEM teachers. In such a course, which should not be limited to female PTs, feminine characteristics can be highlighted through pedagogical approaches, classroom environments, and teacher educators.

For example, a women-oriented course on STEM education may introduce PTs to biomimicry as a pedagogical approach to STEM education (Vasinayanuwatana & Plianram, 2023). Because biomimicry involves using an engineering design process inspired by nature to spark innovation and technology (Eagle-Malone, 2021), this pedagogical approach can highlight both feminine and masculine traits in biology and engineering, respectively. Moreover, the instructor of such a course should create female-friendly environments, listening to female PTs' ideas and believing in their abilities in STEM (Sansone, 2017). Like female students in schools (Gonzalez et al., 2020), female PTs may need role models who succeed in learning and teaching STEM. If possible, the instructor should thus be female in order for the course to be effective.

Once teacher education programs succeed in strengthening female PTs' professional identities as STEM teachers, an increase in the number of female teachers who are motivated and self-efficacious to teach STEM can be expected. To follow up, schools can assign female teachers across classrooms. These female teachers can particularly serve as role models for female students (Sevilla et al., 2023), in addition to implementing STEM education and developing all students' STEM identities. This assignment can be done without a concern about reducing the likelihood that male students will choose STEM-related professions (Stearns et al., 2016). In doing so, female students will be more likely than ever to pursue STEM-related careers (Dulce-Salcedo et al., 2022). Gender diversity in the STEM-related workforce can then be imagined.

## 8 Limitations

This study has several limitations that must be acknowledged. For example, as the researchers used convenience sampling, the study participants are not representative of all PTs in the university. Moreover, this study measured only how strongly the participants identified themselves as three types of teachers. It thus does not include a discussion on the quality of being such kinds of teachers. In addition, the very small proportion of male participants in this study, though reflecting national patterns, may have influenced the results. Furthermore, without the use of qualitative methods, the complex nature of participants' professional identities was not captured in this study. Gender differences in the participants' professional identities as STEM teachers might also be more pronounced if measured through the components of STEM identity. Despite the above limitations, among others, this study shows that differences between female and male PTs' professional identities do exist. Future research should thus explore these gender differences in more depth.

## Research ethics

This research was conducted in accordance with the ethical principles approved by the Human Research Ethics Committee of Chiang Rai Rajabhat University's Research and Development Institute (Code Number: COE.P3-001/2566).

### Author contributions

Ladapa Ladachart: formal analysis, visualization, writing—original draft preparation, writing—review and editing
Wittaya Pulsawad: submission for ethical approval, data curation
Anusorn Tong-on: supervision, project administration
Luecha Ladachart: conceptualization, validation, writing—original draft preparation, writing—review and editing.

All authors have read and agreed to the published version of the manuscript.

### Artificial intelligence

Artificial intelligence was not used in the research, but it was used to proofread some sentences in the article after human editing.

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### Informed consent statement

Informed consent was obtained from all research participants.

### Data availability statement

Data is available upon a request to the corresponding author.

### Conflicts of Interest

The authors declare no conflicts of interest.

# Appendix

| Component | Item |
|---|---|
| Motivation | 1. I want to become a (math/science/STEM) teacher because I am interested in (math/science/STEM) education. |
| | 2. I want to become a (math/science/STEM) teacher because I like being a (math/science/STEM) teacher. |
| | 3. I want to become a (math/science/STEM) teacher because like teaching (math/science/STEM). |
| | 4. I want to become a (math/science/STEM) teacher because I want to have my own (math/science/STEM) class. |
| | 5. I want to become a (math/science/STEM) teacher because I want a job that involves working with children (who are interested in math/science/STEM). |
| | 6. I want to become a (math/science/STEM) teacher because I like working (about math/science/STEM) in a school. |
| | 7. I want to become a (math/science/STEM) because I like to work with children (who are interested in math/science/STEM). |
| Self-image | 8. I see myself as a (math/science/STEM) teacher. |
| | 9. I would miss teaching (math/science/STEM) if I stopped the teacher training program. |
| | 10. I truly enjoy teaching (math/science/STEM). |
| | 11. I actively have looked for opportunities to work in (math/science/STEM) education. |
| | 12. I frequently talk to peers about teaching (math/science/STEM). |
| | 13. I feel part of a community of (math/science/STEM) teachers. |
| | 14. I think it is valuable to be able to talk about (math/science/STEM) education. |
| Self-efficacy | 15. I can implement new strategies to teach (math/science/STEM). |
| | 16. I can gauge students' learning of (math/science/STEM that) I have taught. |
| | 17. I can adjust my (math/science/STEM) lessons appropriately. |
| | 18. I can provide appropriate challenges for students who are very capable of (math/science/STEM). |
| | 19. I can help my students value learning of (math/science/STEM). |
| | 20. I can establish routines to keep (math/science/STEM) learning activities smoothly. |
| | 21. I can get students to believe that can do well in learning (math/science/STEM). |

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