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# Shaping self-efficacy in online mathematics: A comparative study by gender and semester level

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## Abstract

Self-efficacy plays an important role in online mathematics learning, especially because the process demands a high level of independence and self-regulation. However, few studies have explored how sources of self-efficacy may differ based on gender and academic stage in the context of distance education. This study aimed to examine whether there are significant differences across five sources of self-efficacy–mastery experience, vicarious experience, social persuasion, physiological state, and belief–based on students' gender and academic semester. A total of 104 students from the Mathematics Education program at Universitas Terbuka participated in this study. As the data did not meet the normality assumptions, the Mann–Whitney U and Kruskal–Wallis tests were used. The results showed no significant differences between male and female students across any of the self-efficacy dimensions. However, the academic semester revealed significant differences in two dimensions: social persuasion and belief, with middle-semester students scoring the highest. This implies that self-efficacy support strategies should be tailored to students' academic stages. Those in early semesters may benefit more from peer modelling and encouragement, while those nearing graduation may need more support to manage academic stress. Future studies should involve more diverse samples to validate these results.

**Keywords:** academic semester; distance education; gender; mathematics education; online learning; self-efficacy

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## Introduction

Online learning refers to the delivery of structured learning activities through digital platforms, where students and instructors interact asynchronously or synchronously across distance and time. In this study, online learning is situated within the context of distance education, where students engage in mathematics courses via learning management systems (LMS) supplemented by online tutorials and independent learning modules. This mode of learning requires a high degree of autonomy and digital literacy (Dhawan, 2020; Rasheed et al., 2020) and poses unique challenges to student engagement and persistence.

Self-efficacy has been increasingly recognised as a pivotal factor in supporting students' success in online learning environments. The limited nature of social interaction, often accompanied by feelings of isolation, creates a unique set of challenges for learners in virtual spaces (Cho et al., 2010; Cho & Jonassen, 2009; Zhu, 2019). Several studies have consistently reported that dropout rates in online learning tend to be higher than those in traditional face-to-face settings, with low self-efficacy frequently cited as a significant contributor to this trend (Ali & Leeds, 2009; Lee & Choi, 2011). Given the highly self-directed nature of online education, it is almost inevitable that self-efficacy serves as a core determinant of academic success in distance learning contexts (Florjančič, 2022; Hodges, 2008).

A growing body of literature further underscores the substantial role that self-efficacy plays in online learning achievement. Yokoyama (2019), for instance, concluded that academic self-efficacy is positively correlated with learning outcomes. This notion was echoed by Sang (2023), who discovered that self-efficacy not only influences academic performance but also significantly enhances students' satisfaction with their learning experience. Going beyond individual confidence, Fuzi et al. (2024) highlighted that the combination of self-efficacy and self-regulated learning skills has a meaningful impact on learners' overall success in digital classrooms. Yokoyama (2024) emphasized a similar finding in the context of blended learning, where self-efficacy shows notable benefits. Warren et al. (2021) argued that blended learning environments can enrich students' experiences while simultaneously strengthening their academic confidence.

The relevance of self-efficacy becomes even more pressing when it comes to mathematics learning online. Self-efficacy refers to an individual's confidence in their ability to perform specific tasks (Bandura, 1997; Li & Wang, 2024; Mubarrak et al., 2022; Vatou et al., 2024). In the context of mathematics, this belief becomes more focused on mathematical self-efficacy, which refers to how capable learners perceive themselves to be in understanding and applying mathematical concepts (Bandura, 1997; Nahlati et al., 2023; Nurhayati et al., 2025). Mathematics itself demands not only logical thinking and persistence in solving problems, but also the ability to grasp abstract and symbolic ideas, which are often more challenging to develop in online settings, where direct interaction and real-time feedback are limited. Students with high self-efficacy are generally more resilient in the face of academic challenges, showing greater ability to adapt, recover, and maintain motivation under pressure (Usher & Pajares, 2009; Zimmerman, 2002). They are more likely to approach learning tasks with confidence, actively participate in discussions, and persist when encountering complex or unfamiliar material (Bandura, 1997; Komarraju & Nadler, 2013). They engage more confidently in learning activities, participate actively in discussions, and persist in completing tasks, even when the material is complex. For these reasons, strengthening students' self-efficacy is not just beneficial; it is essential for their success in online mathematics learning environments.

Therefore, it is important to recognise that self-efficacy is not a singular, uniform trait. According to Bandura (1997), self-efficacy is shaped by four main sources: mastery experiences (personal success or failure), physiological states (emotional and physical reactions to challenges), social persuasion (encouragement and feedback from others), and vicarious experiences (learning through observation of others). Understanding these dimensions allows for a more nuanced examination of how self-efficacy is developed and activated in digital learning environments. Therefore, rather than merely measuring general levels of self-efficacy, this study focused on assessing its underlying sources using a specifically designed instrument.

Moreover, variations in self-efficacy, or more precisely, its sources, may also be influenced by individual characteristics such as gender and academic stage. In a meta-analysis, Huang (2013) noted that male students tend to report higher levels of mathematics self-efficacy by the time they reach upper-secondary education. Similarly, the Organization for Economic Co-operation and Development (OECD, 2013, 2015) reported that females consistently demonstrate lower self-efficacy in mathematics, which has implications for their participation in STEM fields, including engineering. In contrast, Julaihi et al. (2022) found no significant gender-based differences in mathematics self-efficacy within online learning environments. Regarding academic progression, Shell et al. (1989) and Pitsia et al. (2017) suggested that self-efficacy can evolve over time, implying that the semester level may also be a relevant factor in understanding these variations.

While previous research has investigated the general role of self-efficacy in online learning, few have examined how its underlying sources differ according to individual characteristics such as gender and academic semester, particularly in distance education settings. Moreover, studies exploring self-efficacy in online mathematics learning often focus on general perceptions rather than disaggregated sources. This study addresses this gap by using a validated instrument to measure five specific sources of self-efficacy, including a fifth dimension, belief, which captures students' internal confidence in their ability to succeed. By comparing these sources across gender and academic semesters, this study offers new insights into how different groups experience and develop self-efficacy in online mathematics learning. Therefore, the present study aimed to determine whether students' self-efficacy sources differed significantly by gender and academic semester level.

## Methods

### Research design

This study employed a quantitative comparative design with a non-experimental approach. A comparative quantitative non-experimental method was chosen because the aim of the study was to examine differences in self-efficacy source scores between pre-defined groups (i.e. by gender and semester level), rather than establishing causal relationships. This design is suitable for exploratory analysis in educational settings, where manipulation of variables is neither practical nor ethical (Creswell & Creswell, 2017). No interventions or manipulations were applied to the variables; instead, existing group differences were statistically analysed. The procedures involved four main steps: (1) identifying and selecting participants enrolled in the Mathematics Education programme; (2) distributing the SMOLSES questionnaire through Google Forms; (3) collecting responses during a one-month period; and (4) analysing the data using non-parametric statistics.

In this context, mathematics learning was conducted fully online through the Universitas Terbuka (UT) Learning Management System (LMS), supplemented by asynchronous tutorials, digital modules, and online discussions. The mathematical content covered educational mathematics subjects, such as learning theories in mathematics, problem-solving strategies, and teaching mathematics at the secondary level. Therefore, the focus of the learning was not on pure mathematics but rather on mathematics education within an applied educational context.

## Participant

Participants were selected based on the following criteria: (1) they were actively enrolled in the Mathematics Education program; (2) they had completed at least one semester; and (3) they had participated in online mathematics learning through the UT LMS. A total of 104 students were recruited using convenience sampling, as they were accessible during the study period and were willing to participate voluntarily. Although no strict formula was used to determine the minimum sample size, the current number exceeded the minimum threshold ($n > 30$ per group) for non-parametric comparison tests (Hollander et al., 2013).

For the analysis, students were categorised into three academic groups based on their semester level: early (semesters 1–3), middle (semesters 4–7), and advanced (semester ≥8). This classification reflects learning stages commonly observed in open and distance education contexts, where academic progression does not always follow a strict four-year structure due to flexible enrolment, part-time study, and external commitments such as employment or family responsibilities (Lee & Choi, 2011; Muljana & Luo, 2019; Xu & Jaggars, 2013). In such settings, semester grouping serves more as an indicator of accumulated learning experience than as a measure of academic age.

Each group represented different levels of exposure to the online learning environment: early semester students were likely adjusting to the platform and independent study routines, middle-semester students had developed greater familiarity and engagement, and advanced students were typically focused on completing final assignments or preparing for graduation-related tasks.

## Instrument

The Sources of Mathematics Online Learning Self-Efficacy Scale (SMOLSES) used in this study was developed by researchers based on Bandura's (1997) theoretical framework and adapted for the online mathematics learning context. The instrument consists of 28 items divided equally into five dimensions: mastery experience (five items), vicarious experience (five items), social persuasion (five items), physiological state (four items), and belief (nine items).

The content validity was reviewed by three experts in educational psychology and mathematics education. A Gregory validity coefficient of 0.94 was achieved, indicating a high agreement among raters. Internal consistency reliability was assessed using Cronbach's alpha, resulting in coefficients above 0.7 for each dimension, suggesting acceptable to good reliability (George & Mallery, 2003). The scale consists of five dimensions:

- Mastery Experience – refers to students' direct experiences of success or failure in learning mathematics.
- Vicarious Experience – assesses the influence of observing peers' success or failure.
- Social Persuasions – includes encouragement, support, and feedback from others.
- Physiological State – captures emotional and physical responses related to stress, anxiety, or confidence during learning.
- Belief – reflects students' confidence in their ability to succeed in mathematics.

Each dimension is measured using several items on a Likert scale. In this study, the SMOLSES instrument was used specifically to compare the mean scores across gender groups and academic semester levels.

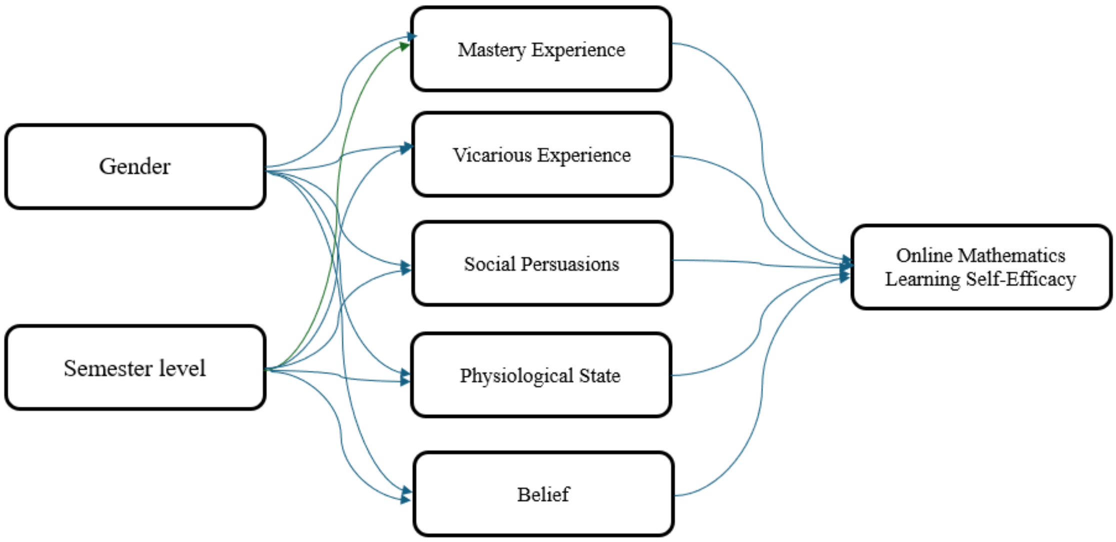


**Figure 1.** Theoretical framework of SMOLSES

## Data analysis

As the data did not meet normality assumptions (as tested by the Shapiro–Wilk test), non-parametric methods were applied. The Mann–Whitney U test was used to compare two independent groups (male vs. female), while the Kruskal–Wallis H test was used to assess differences among the three semester groups. These tests are widely recommended for ordinal or non-normally distributed data in educational research (Field, 2018; Pallant, 2020). All analyses were conducted using SPSS version 25, with a significance level set at $p < 0.05$.

## Results

This section focuses on exploring patterns in the self-efficacy source scores among students grouped by specific demographic characteristics. We wanted to see if perceptions varied across gender and academic progression, and whether students in early, middle, or advanced semesters held different levels of confidence in their online mathematics learning experience.

The results are presented in two tables, summarising the mean scores and standard deviations for each dimension of the sources of self-efficacy. Statistical significance levels are also included to indicate whether any observed differences are meaningful or not.

**Table 1.** Mean scores of self-efficacy sources by gender

| Self-Efficacy Source Dimension | Male (n=33) M (SD) | Female (n=71) M (SD) | U-value | p-value |
|---|---|---|---|---|
| Mastery Experience | 3.394 (0.872) | 3.291 (0.732) | 1069 | 0.470 |
| Vicarious Experience | 3.861 (0.794) | 3.836 (0.823) | 1165.5 | 0.966 |
| Social Persuasions | 3.143 (0.681) | 3.062 (0.899) | 1105 | 0.641 |
| Physiological State | 4.132 (0.716) | 4.043 (0.770) | 1111.5 | 0.671 |
| Belief | 3.899 (0.768) | 3.912 (0.839) | 1137.5 | 0.812 |

Note: Mann–Whitney U Test results indicate no statistically significant differences between male and female students across all dimensions ($p > 0.05$).

Table 1 presents a comparison of the self-efficacy source scores between male and female students. Overall, the results indicated no statistically significant differences across any of the five dimensions ($p > 0.05$). Although male students scored slightly higher than female students in most areas, such as mastery experience, vicarious experience, social persuasion, and physiological state, the differences were minor. Interestingly, in the belief dimension, female students had a slightly higher average score than their male counterparts, although the difference was not significant. These findings suggest that male and female students experience self-efficacy in relatively similar ways. This may be because both groups had equal access to learning resources and were exposed to the same structure and support systems in UT's online learning environment.

**Table 2.** Mean scores of self-efficacy sources by semester group

| Self-Efficacy Source Dimension | Early (Semesters 1–3) M (SD) | Middle (Semesters 4-7) M (SD) | Advanced (Semesters ≥8) M (SD) | $\chi^2$ (Kruskal–Wallis) | p-value |
|---|---|---|---|---|---|
| Mastery Experience | 3.284 (0.728) | 3.564 (0.847) | 3.182 (0.764) | 2.461 | 0.292 |
| Vicarious Experience | 3.685 (0.848) | 4.107 (0.684) | 3.838 (0.855) | 4.304 | 0.116 |
| Social Persuasions | 2.914 (0.605) | 3.485 (0.965) | 3.019 (0.928) | 10.504 | 0.005* |
| Physiological State | 4.056 (0.682) | 4.308 (0.633) | 3.893 (0.900) | 3.249 | 0.197 |
| Belief | 3.952 (0.743) | 4.214 (0.710) | 3.599 (0.908) | 7.847 | 0.020* |

Note: Asterisks (*) indicate statistically significant differences between groups ($p < 0.05$).

Table 2 presents a comparison of the self-efficacy source scores based on students' academic semesters. Of the five dimensions, two showed statistically significant differences across groups: social persuasion ($p = 0.005$) and belief ($p = 0.020$). In both cases, students in the middle semesters (4–7) scored the highest, followed by those in the advanced group (≥8), with early semester students (1–3) scoring the lowest. For example, in the belief dimension, students in the middle group had an average score of 4.214, compared with 3.952 in the early group and 3.599 in the advanced group. These patterns suggest that students in the middle phase of their academic journey may feel more confident and supported, possibly because they have already adjusted to the learning system and developed stronger academic routines than first-year students. In contrast, early semester students may still be adapting to online learning, while those in later semesters may be dealing with increased pressure related to final projects or graduation. Meanwhile, the other three dimensions–mastery experience, vicarious experience, and physiological state–did not show any significant differences across semester groups, which may indicate that these aspects of self-efficacy remain relatively stable over time.

Taken together, these results suggest that gender does not play a significant role in shaping students' self-efficacy across any of the measured dimensions in this study. Male and female students appear to share similar experiences and confidence levels when learning mathematics online, which may reflect the standardised and equitable structure of the UT learning system.

In contrast, students' academic progress appears to be more influential. The significant differences found in the social persuasion and belief dimensions highlight how students' confidence and perception of support evolve throughout their academic journeys. Middle-semester students seem to benefit most from these sources, possibly due to their accumulated experience and growing familiarity with the learning process. These patterns point to the importance of academic stage in understanding self-efficacy development, which will be explored further in the following discussion.

## Discussion

The absence of statistically significant differences between male and female students across all dimensions of self-efficacy aligns with several recent studies conducted in online learning environments. For example, Julaihi et al. (2022) found that gender differences in mathematics self-efficacy tend to diminish when students are exposed to similar learning conditions and technology. Similarly, Wu and Shein (2025) reported that male and female students in fully online mathematics courses demonstrated comparable levels of confidence, suggesting that digital learning may provide a more level playing field in terms of access and participation.

Although not statistically significant, the slightly higher mean scores observed among male students in several dimensions are worth noting. Prior studies have shown that such patterns may reflect internalised social expectations rather than actual differences in abilities (Whitcomb et al., 2020). This implies that interventions to boost self-efficacy should consider psychological and cultural influences, especially in STEM-related fields.

In contrast, the differences observed across the academic semesters were more substantial. Students in the middle semesters consistently scored higher in both the belief and social persuasion dimensions. This supports the findings of Luo et al. (2022), who observed that academic self-efficacy tends to increase during the middle phase of undergraduate study, possibly due to growing academic familiarity and peer interaction. A similar trend was reported by Liu et al. (2024), who noted that confidence levels often rise during the second and third years, then plateau or decline due to increased workload and pressure in the final stages of study.

The lower scores in the advanced group may be linked to academic stress and the demands of completing final projects or preparing for graduation. Zheng et al. (2023) emphasised that high stress levels in the final year can negatively impact students' academic confidence. These findings suggest that students’ sense of self-efficacy is dynamic and influenced not only by their academic standing but also by the specific challenges they face at different stages of their learning journeys.

It is important to clarify that the semester groupings used in this study (early = semesters 1–3; middle = 4–7; advanced = ≥8) are grounded in the structure of distance education, where students often follow non-linear academic paths. Unlike conventional four-year programs, open university learners typically balance their studies with work, family, and other responsibilities, which can extend their study duration. As Xu and Jaggars (2013), and Muljana and Luo (2019) point out, in distance education contexts, the semester level is better interpreted as an indicator of cumulative learning experience rather than chronological time. Therefore, the use of the term “fourth year” does not necessarily apply, and our classification reflects a more authentic academic progression in distance learning.

These findings have several practical implications, particularly for educators and instructional designers in distance learning environments. First, given that no significant gender differences were found, self-efficacy interventions do not necessarily need to be gender-specific. Instead, equal access to online resources, inclusive content, and responsive support systems should be maintained for all students.

More importantly, the variation in self-efficacy sources across semesters highlights the need for stage-sensitive support. Early semester students may benefit from structured onboarding programs, exposure to peer role models, and scaffolding strategies that build confidence in learning mathematics online. These efforts can help students adjust to the demands of independent learning while reducing early disengagement.

Students in the middle phase of their studies appeared to experience the highest levels of belief and perceived social support. This suggests that reinforcing collaborative learning opportunities, peer feedback, and instructor encouragement during this stage can further strengthen students’ confidence and engagement.

Meanwhile, students in advanced semesters may face increased academic pressure, which could erode their self-efficacy despite their experience. Institutions should consider offering academic counselling, time management workshops, or mental health resources to help these students maintain their sense of competence and persistence as they approach graduation.

Designing self-efficacy support strategies tailored to students' academic stages, rather than treating all learners the same, could contribute to more equitable and effective online mathematics learning experiences.

## Conclusion

This study explored whether students' sources of self-efficacy in online mathematics learning differ based on gender and academic semester. The findings revealed no statistically significant differences between male and female students across all five self-efficacy dimensions, suggesting that gender does not play a major role in shaping students' perceptions of their ability and support in this learning context. In contrast, the academic semester showed significant differences in two key dimensions: social persuasion and belief. Students in the middle semester consistently reported higher confidence and perceived support than those in the early or advanced stages. These results suggest that students' academic stage, rather than gender, may influence how they build and experience self-efficacy in distance mathematics education.

Although this study offers valuable insights, it has several limitations. The sample was limited to students from a single open university program, and the categorisation of semester levels may not align perfectly with all educational systems in the country. Additionally, self-reported measures are subject to bias and may not fully capture students lived experiences. Future research could address these limitations by involving a larger and more diverse sample across multiple institutions and exploring other influencing factors, such as employment status, geographic location, or prior experience with online learning. Practically, the findings highlight the importance of designing stage-sensitive support strategies to enhance students' confidence and engagement throughout their academic journey in online mathematics-learning environments.

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### Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript.

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## Author Contributions

**Suci Nurhayati:** Conceptualization, writing - original draft, editing, methodology and visualization; **Mery Noviyanti:** Validation and supervision; **Liana Mohamad:** Writing - review, and methodology

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