Pre-service science and technology teachers' self-efficacy

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ABSTRACT: The aim of this research was to investigate pre-service science and technology teachers' self-efficacy. Self-efficacy is a crucial factor in teachers' performance when coping with the challenges of the social, economic and natural environment of the 21st Century. For this study, a survey by questionnaire was carried out on a sample of 140 pre-service science and technology teachers. The results indicate that the level of self-efficacy overall was above average, although differences were found between study areas and between the sexes, with moderate effect sizes. Differences between the study areas can be attributed to different teaching methods, with more goal orientation in problem-based learning. Female students exhibited higher persistence in tasks. Teaching practice can contribute to self-efficacy and improve the motivation for performing tasks. The findings of this study could be helpful for the designers and practitioners of teacher training programmes.

INTRODUCTION

Given the rapid changes in society and the economy, teaching has a crucial role in developing the knowledge, skills and attitudes to ensure sustainability and national prosperity [1]. More than ever, the education system has a crucial role in educating and training students to become key stakeholders, ensuring sustainability and, later, responsible citizens [2]. Many higher education institutions that train pre-service teachers have taken steps to redesign study programmes to reflect the knowledge and skills required for the 21st Century [2-5].

Education in science, technology, engineering and mathematics (STEM) is needed to reduce the gap between the skills of graduates and the demands of the labour market [2]. A gap has been identified in science and technology (S&T) teaching in lower and upper secondary education, where there is a shortage of S&T teachers; and a difference has been noted between new and experienced teachers, as revealed by the Organisation for Economic Co-operation and Development (OECD) [1].

Teacher knowledge generally has four domains; namely, subject matter knowledge, pedagogical knowledge, context knowledge and pedagogical content knowledge [6]. Teacher knowledge and self-efficacy condition the behaviour of S&T teachers in the classroom [2]. The rapid expansion of digital technology, with its impact on the social, natural and economic environment needs to be reflected in S&T learning outcomes [2][7]. This should guide integrated curriculum development, including for pre-service programmes [2].

Pre-service teachers must be able to acquire knowledge, skills and attitudes in a learning context, and then transfer them to new classroom contexts. They need a wide range of cognitive and metacognitive skills, such as critical thinking, creative thinking, learning skills and self-regulation. They need social and emotional skills, such as empathy, self-efficacy and co-operation, as well as practical skills, such as handling new information and communication technologies, machines and devices. Although knowledge and skills are most important, self-efficacy is a skill that greatly helps students in achievement, motivation and learning [4].

It is of great importance that higher education institutions support the development of students' self-efficacy, especially in teacher training programmes [4]. Avsec and Jamšek argue that self-efficacy can help develop students' technological and scientific literacy, which is the main outcome of S&T education, as well as their attitude towards S&T [2].

In general, experienced teachers have a high level of self-efficacy developed during their teaching experience. However, novice teachers, even with up to five years of experience, often do not feel confident in their pedagogical skills, in the use of different practices and in their ability to manage the classroom and, in general, are dissatisfied with their performance in the classroom and in school [8]. Many countries face the question of how to attract highly qualified

and motivated individuals to the teaching profession. A study showed that the main motivations for choosing the teaching profession are:

- Teaching influences the development of children and young people, and contributes to society.
- Teaching means a secure job and a reliable income [8].

If individuals are selected to become teachers, they must be well trained in how to teach their students. For quality teaching, the teacher must have basic teacher knowledge, as defined by Grossman [6], as well as cross-curricular skills, such as creativity, critical thinking and problem-solving. It has been shown that teachers with these skills likely have higher levels of self-efficacy [8].

SELF-EFFICACY

Bandura was the first to define self-efficacy belief as a psychological construct. He observed that students are motivated when they believe in their own effectiveness in completing tasks. According to Bandura an individual's level of motivation, affective states and actions are based on previous experiences and on their beliefs. This leads to the development of general expectations and specific beliefs about the individual's coping skills. Self-efficacy influences the fulfilment of tasks and the development of cognitive skills. High self-efficacy promotes intrinsic goals and encourages analytical thinking. Teachers' self-efficacy is a belief in the ability to teach and to promote students' learning [9].

Self-efficacy can be represented as multidimensional with three aspects of teacher self-efficacy, i.e. classroom management, instruction and student engagement [8]. Teacher self-efficacy in classroom management refers to the teacher's belief in their ability to create an orderly learning environment, and thus to effectively manage disruptive student behaviour. Teacher self-efficacy in instruction refers to the teacher's belief about their ability to feel confident in applying a wide range of teaching methods and assessment strategies. Teacher self-efficacy in student engagement refers to the teacher's conviction in the emotional and cognitive support they can give their students and their ability to motivate students to learn. The study showed that teachers feel least confident in motivating students to learn, i.e. in student engagement.

According to Bandura [9] in his social cognitive theory, there are four sources of student self-efficacy:

- *mastery experiences* - creating self-efficacy through success in dealing with a situation;
- *vicarious experiences* - creating self-efficacy through observational vicarious experiences provided by social models. Students observe peers and obtain information about their abilities;
- *social persuasions* - the beliefs of teachers can influence the academic self-efficacy of students;
- *psychological, physiological and mood state* - negative feelings (e.g. stress, anxiety, etc) can be interpreted as signals of failure or weakness [9].

Self-efficacy is important in educational research. Meta-analyses of studies showed that students' self-efficacy can be influenced by higher education programmes [4]. Intervention programmes based on social cognitive theory effectively contribute to higher self-efficacy.

Self-efficacy is positively related to a mastery of goal orientation [10]. Students with high levels of self-efficacy tend to strive to develop new skills and acquire knowledge. A positive correlation between self-efficacy and intrinsic values has been found [10]; also students' self-efficacy can improve academic achievement [11]. Students with higher self-efficacy have higher levels of achievement and persistence in technology and engineering majors [10-12]. Moreover, the way students behave and perform is a reflection of themselves to their peers and can be a source of developing self-efficacy [12][13].

Pre-service teachers' self-efficacy can be developed through various active forms of learning, e.g. inquiry-based learning, problem-based learning and project-based learning, where students perform tasks following strategic approaches with limitations and constraints taken into account [3][5][14]. Teamwork and other collaborative work can promote the development of self-efficacy by reflecting on the performance of others and receiving feedback from teachers [3][15].

A student-centred approach, with opportunities for discussion and answering critical thinking questions, in addition to providing content knowledge, also teaches problem-solving, deductive thinking, communication, self-evaluation and teamwork. This way of teaching has had a positive impact on the level of self-efficacy by understanding content and applying knowledge. Teacher subject matter knowledge can be a source of teachers' credibility and affects students' self-efficacy in knowledge conceptualisation [3].

On the other hand, perceived task difficulty, dissatisfaction with the learning environment and material may provoke stress and frustration, and does not improve self-efficacy [15]. Students' self-efficacy might affect their emotional characteristics, e.g. satisfaction with learning, motivation and goal orientation, as well as higher order-thinking

skills, e.g. design thinking, critical thinking, problem-solving and creativity [4][12][15][16], as well as academic achievements [4].

The pre-service S&T teachers' self-efficacy can be an effective estimate of their readiness for teaching practice. Therefore, this study aims to gain more insight into the nature of pre-service S&T teachers' self-efficacy.

Research questions examined in this study are:

- What is the level of self-efficacy of pre-service S&T teachers?
- What is the level of self-efficacy by gender and grade level of S&T pre-service teachers?
- What is the difference in self-efficacy between part-time and full-time pre-service S&T teachers?

METHOD

The Faculty of Education at the University of Ljubljana offers study programmes for various pre-service teachers. An important study programme is a pre-service teacher programme for two STEM subjects. During the study programme students acquire subject matter, pedagogical and pedagogical content knowledge. The selected STEM subjects are part of the study programme for preschool and primary school teaching.

Pre-service S&T teachers' self-efficacy was explored in the following areas:

- The field of *biology* is concerned with the understanding of organisms in the environment and the human body. Students acquire theoretical and practical knowledge through laboratory and fieldwork.
- *Chemistry* requires visualisation skills to represent and understand the structure of matter. Great importance is attached to the ability to handle substances and experiment safely.
- *Physics* enables students to understand basic physical concepts and their application in natural phenomena. Students learn to organise and manage laboratory work.
- The *home economics* section covers a variety of contents, such as environmental ecology, nutrition, organising and managing school meals.
- In *technology* the emphasis is on basic knowledge of mechanical engineering, electrical engineering, material processing as a technical practicum, and pedagogical content knowledge.
- *Mathematics* is about teaching to understand and apply basic mathematical knowledge and theorems. In addition, students acquire knowledge about understanding the contents and didactic features of mathematics instruction in primary and secondary schools.
- The field of *computer science* provides students with practical and theoretical knowledge for the effective use and integration of information and communication technologies in various educational fields.

Sample

The sample in this study included 140 undergraduate pre-service S&T teachers aged 19-46 enrolled in a two-subject teacher study programme from the Faculty of Education, Ljubljana, Slovenia. These students consist of both full-time ($n = 70$) and part-time ($n = 70$) S&T students. There were 123 (or 87.9%) females and 17 (or 12.1%) males. The sample consisted of 72 (or 51.4%) pre-service technology teachers and 68 (or 48.6%) pre-service science teachers. There were 27 (or 19.3%) pre-service S&T teachers in the first grade; 29 (or 20.7%) in the second grade; 49 (or 35.0%) in the third grade; and 35 (or 25%) in the fourth grade.

Instrument

For surveying pre-service S&T teachers' self-efficacy, a 21-item questionnaire was applied, with three subscales:

- feeling efficient (8 items) - belief in personal ability to meet specific goals and/or expectations;
- making an effort (5 items) - belief that ability can grow with effort [17];
- showing stability, being flexible (8 items) [18].

The self-efficacy questionnaire reflects the complex nature of self-efficacy. A 5-point Likert scale (1 - not very like me to 5 - very like me) was used for the evaluation. Cronbach's alpha values (α) showed that the questionnaire was moderately reliable on all subscales: *feeling efficient* (0.76); *making an effort* (0.74); and *showing stability, being flexible* (0.81).

Data Collection and Analysis

The survey was conducted in the academic years 2018/19 and 2019/20. The students were surveyed once, with a paper and pencil method. Testing took 10-15 minutes. The data were analysed with IBM SPSS (v. 22). To test reliability, a Cronbach's alpha coefficient was used. Descriptive statistics with a one-way ANOVA test and nonparametric tests were performed. Eta-squared (η^2) was used to measure the effect size of relationships between groups.

RESULTS AND DISCUSSION

Pre-service S&T teachers' self-efficacy was revealed on all subscales as being above the mid-point: *feeling efficient*; *making an effort*; and *showing stability, being flexible*, with mean (M) and standard deviation (SD) are: M = 3.97, SD = 0.56; M = 4.44, SD = 0.52; M = 3.83, SD = 0.65, respectively.

Shown in Figure 1 are the differences between the pre-service S&T teachers' self-efficacy levels. A one-way ANOVA revealed statistically significant differences in the subscale of *feeling efficient* (F = 6.127; *df* = 1; *p* = 0.015). Pre-service technology teachers report higher feeling (M = 4.08; SD = 0.46) than pre-service science teachers (M = 3.85; SD = 0.63), with a small size effect $\eta^2 = 0.04$. The Welch test for equality of means, where equal variances are not assumed showed statistically significant differences in the subscale of *making an effort* (F = 9.586; df_1 = 1; df_2 = 121.125; *p* = 0.003). Pre-service technology teachers (M = 4.57; SD = 0.42) are more convinced that ability grows with effort than pre-service science teachers (M = 4.31; SD = 0.58), with a medium effect size $\eta^2 = 0.07$.

There were no statistically significant differences in the subscale of *showing stability, being flexible* (F = 1.211; *df* = 1; *p* = 0.139). However, pre-service technology teachers showing stability are more flexible (M = 3.91; SD = 0.55) than are pre-service science teachers (M = 3.75; SD = 0.74). It seems that self-efficacy is most important to gain S&T literacy [2]. Students are confident in solving problems and are convinced by their hard work and effort. The results demonstrate that active teaching methods and student-centred approaches are successful in developing self-efficacy [3], [14][15].
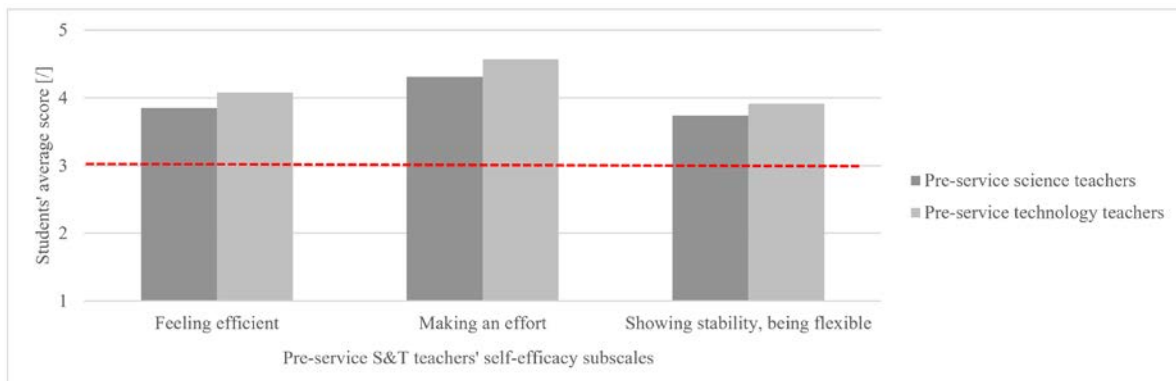

Figure 1: Average score on each subscale for pre-service S&T teachers' self-efficacy; with a mid-point 3.

Displayed in Figure 2 are the differences between female and male students on the three subscales of self-efficacy. A one-way ANOVA, where a different sample size was considered, revealed statistically significant differences between male students and female students in the subscale of *feeling efficient* (F = 5.482; *df* = 1; *p* = 0.025). Females (M = 4.05; SD = 0.46) believe in their abilities more than do males (M = 3.67; SD = 0.53), with a strong effect size $\eta^2 = 0.14$.
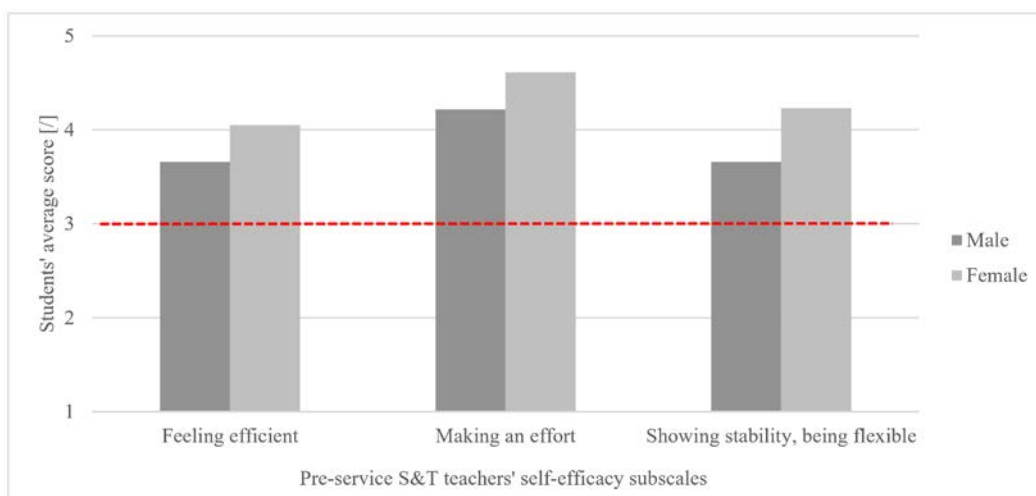

Figure 2: Average score on each subscale on pre-service S&T teachers' self-efficacy; mid-point 3.

A one-way ANOVA also showed statistically significant differences between males and females in the subscale of *making an effort* (*F* = 2.842; *df* = 1; *p* = 0.007). Females (M = 4.61; SD = 0.35) are more convinced that ability grows with effort than are males (M = 4.22; SD = 0.47), with a strong effect size, $\eta^2 = 0.19$. A one-way ANOVA also revealed statistically significant differences in the subscale of *showing stability, being flexible* (F =8.946; *df* = 1; *p* = 0.005). Females show a higher ability to take action (M = 4.22; SD = 0.47) than do males (M = 3.63; SD = 0.73), with an effect

size $\eta^2 = 0.20$, a strong effect, and they do not avoid solving complex problems. On average, females reported higher self-efficacy levels than males [8].

Female students are more confident in achieving goals they have set themselves and they believe in hard work. They are also more convinced that they can change their ability to achieve specific goals. Some studies reported that female students have lower self-efficacy than male students, because gender plays a crucial role for choices in education and employment [19]; this reveals stereotyping and negative attitudes towards S&T [13]. It also has been found that female students can be motivated by female role models, which increases their self-efficacy [19].

Pre-service S&T teachers' self-efficacy might differ between study grades (see Figure 3). A one-way ANOVA showed statistically significant differences between the first, second, third and fourth grade in the subscale of *feeling efficient* (F = 9.072; *df* = 3; *p* = 0.000), with a strong effect size $\eta^2 = 0.17$. The Scheffe *post-hoc* test revealed statistically significant differences between the first and the third grades (*p* = 0.023), and between the first and the fourth grades (*p* = 0.000). Pre-service S&T teachers in the fourth grade report the highest level of *feeling efficient* (M = 4.28; SD = 0.56), followed by the third grade (M = 4.02; SD = 0.54), second grade (M = 3.83; SD = 0.43) and the first grade (M = 3.63; SD = 0.64). The Welch test for equality of means showed statistically significant differences between the first, second, third and fourth grades in the subscale *making an effort* (F = 4.022; $df_1 = 3$; $df_2 = 64.458$; *p* = 0.047), with a medium effect size $\eta^2 = 0.08$.
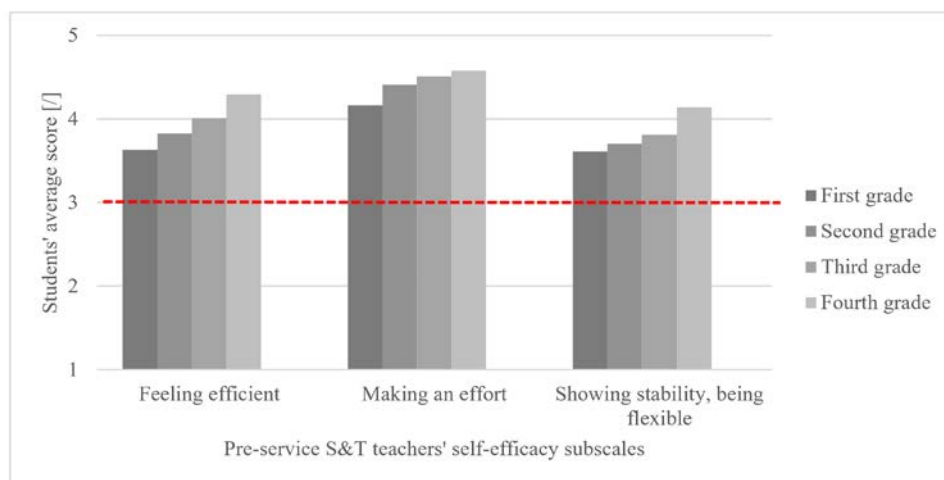

Figure 3: Average score on subscale on pre-service S&T teachers' self-efficacy by grade level; mid-point 3.

The Games-Howell *post-hoc* test revealed statistically significant differences between the first and the fourth grade (*p* = 0.037). Fourth grade students achieved a higher score (M = 4.58; SD = 0.45) than did the first grade (M = 4.16; SD = 0.67). The second grade received a 4.41 score (SD = 0.52); the third grade a 4.51 score (SD = 0.41). A one-way ANOVA showed a statistically significant difference between the first, second, third and the fourth grades at the subscale *showing stability, being flexible* (F = 4.380; *df* = 3; *α* = 0.006), with a medium effect size $\eta^2 = 0.09$.

The Scheffe *post-hoc* test revealed statistically significant differences between the first and the fourth grade (*p* = 0.015). Mean values showed that fourth grade achieved the highest score 4.14 (SD = 0.45) and the first grade the lowest 3.61 (SD = 0.73). In the middle were the second grade with M = 3.70 (SD = 0.66) and the third grade with M = 3.81 (SD = 0.66). In the first grade, students have general pedagogical and subject knowledge related to their selected area, while in the higher grades, students also gain knowledge from didactic subjects and have practice in gaining teaching experience. Gained content knowledge and skills are most important for self-efficacy [4]. In the higher grades there is greater emphasis on learning creativity, critical thinking and problem-solving, which are skills that promote self-efficacy [8].

A one-way ANOVA also showed statistically significant differences between part-time and full-time S&T students in the subscale *feeling efficient* (F = 18.294; *df* = 1; *p* = 0.000). Part-time S&T students reported higher belief about their efficiency (M = 4.16; SD = 0.47) than did full-time S&T students (M = 3.78; SD = 0.58), with an effect size $\eta^2 = 0.12$, a medium effect. The Welch test for equality of means showed statistically significant differences between part-time and full-time S&T students in the subscale *making an effort* (F = 6.909; $df_1 = 1$; $df_2 = 126.715$; *p* = 0.010). Part-time S&T students (M = 4.55; SD = 0.43) are more convinced that ability grows with effort than are full-time pre-service S&T students (M = 4.33; SD = 0.57), with a small effect size $\eta^2 = 0.048$.

The Welch test for equality of means showed statistically significant differences between part-time and full-time pre-service S&T teachers in the subscale *showing stability, being flexible* (F = 11.009; $df_1 = 1$; $df_2 = 115.759$; *p* = 0.001). Part-time S&T students achieved a higher score (M = 4.01; SD = 0.47) than did full-time S&T students (M = 3.65; SD = 0.75), with a medium effect size $\eta^2 = 0.074$. Work experience could contribute to self-efficacy, because most of the part-time S&T students are employed.

CONCLUSIONS

The research has shown that pre-service S&T teachers' self-efficacy is above average. There were statistically significant differences between pre-service S&T teachers in favour of pre-service technology teachers. Problem-based learning, project-based learning and inquiry-based learning seem to be useful for developing critical, creative and design thinking, which indirectly promotes self-efficacy. Male students are more confident and they have a more positive attitude towards S&T, while female students felt more efficient in the laboratory and workshops. Mastering tasks and teaching practices are important in promoting self-efficacy.

The S&T teachers' self-efficacy, content and pedagogical knowledge seem to be crucial in effective knowledge transfer. It helps to develop higher-order thinking skills, improve academic achievement and attitudes towards S&T. Pre-service S&T teachers should be given more opportunities for active learning, collaboration and teamwork, and should be confronted to solve real-life problems. For future work it could be productive to investigate how students' attitudes towards science and technology influence their self-efficacy and how self-efficacy is related to the level of students' technological literacy.

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