

# IMPROVING PRE-SERVICE TEACHERS' SCIENCE SELF-EFFICACY THROUGH THE FLIPPED CLASSROOM MODEL

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## Abstract

Teacher education programmes are widely acknowledged for their pivotal role in equipping future educators with the knowledge and skills necessary to succeed in their roles. The concept of self-efficacy has emerged as a key area of interest in teacher education, due to its strong associations with teachers' performance and commitment to their profession. Consequently, there is a pressing need to cultivate the self-efficacy of pre-service teachers (PSTs). In recent years, there has been a notable increase in the popularity of the flipped classroom model (FCM) as an active learning model that has the potential to enhance students' self-efficacy when interacting with science content. The present study evaluates the impact of implementing an FCM approach on the PSTs' self-efficacy in science, specifically those enrolled in a general science course within the basic education programme. The study was conducted over a period of 14 weeks using a mixed methods approach. The quantitative dimension employed a semi-experimental design with a pretest-post-test control group and a semi-structured interview for qualitative data collection. The results demonstrated that the FCM had a statistically significant impact on enhancing the personal science teaching efficacy of the PSTs. The PSTs' *mastery experiences* during the learning process with the FCM facilitated the development of science-related knowledge and skills, the *reduction or elimination of emotional barriers* that might be perceived as inhibiting their performance, and provided *vicarious experiences* that inspired their future practice. The incorporation of the FCM into teacher education programmes confers a substantial advantage in the pedagogical training of future teachers.

Keywords: Flipped classroom model, pre-service teachers, science education, self-efficacy, teacher education.

## 1 INTRODUCTION

The concept of teacher efficacy is attracting increasing attention from scholars worldwide, as evidenced by the growing body of research investigating the efficacy beliefs of pre-service and in-service teachers at all levels of education [1], [2], [3]. These efficacy beliefs play a central role in guiding the application of professional knowledge in the classroom and significantly shape students' experiences and academic outcomes [3]. Consequently, enhancing the self-efficacy of pre-service teachers (PSTs) has been identified as a crucial aspect of teacher education [4]. In this context, high levels of science teaching self-efficacy among PSTs enable them to face challenges with confidence and facilitate effective management of the learning environment [5]. Conversely, low levels of self-efficacy in science teaching may induce anxiety in PSTs leading them to perceive tasks as personal threats.

Social learning theory provides a valuable framework for examining personal teaching self-efficacy from a cognitive perspective [6]. According to this theory self-efficacy represents an individual's personal assessment of their ability to perform tasks and the strategies needed to overcome potential challenges. People tend to engage in actions that they believe will lead to favourable outcomes (outcome expectation) and have confidence in their ability to perform these actions successfully (self-efficacy expectation) [6]. Consequently, efficacy can be conceptualised as a multifaceted construct comprising personal efficacy and outcome expectancy. Personal efficacy pertains to one's confidence in attaining a specific level of performance, whereas outcome expectancy encompasses judgements regarding the probable consequences of specific behaviours [6].

According to [7], self-efficacy perceptions originate from a multitude of sources, including (I) mastery experiences, (II) vicarious experiences, (III) verbal persuasion, and (IV) emotional and physiological states. (I) Mastery experiences are shaped by an individual's past successes and failures in similar situations, reflecting the experiences gained from tasks accomplished independently. (II) Vicarious experiences entail observing the conduct of others, considering their outcomes in analogous situations, and forming judgments accordingly. (III) Verbal persuasion encompasses both positive and negative

verbal messages received from the environment regarding task performance. (IV) emotional and physiological states are characterised by a reduction/increase in emotional barriers, which can be understood as an inability/ability to perform an action. (e.g., the psychological pressure that comes from an exam or a teacher's speech, can trigger a series of physiological reactions that the individual interprets as incompetence). The collective impact of these sources of self-efficacy influences an individual's cognitive, affective, motivational, and selective processes [7].

Researchers suggest that efficacy beliefs are particularly susceptible to change in the early stages of development [6], [8]. Furthermore, high-quality science coursework has the potential to shape pre-service teachers' science self-efficacy beliefs [9]. Consequently, in order to enhance PSTs efficacy beliefs about science teaching and learning, the instructional methodology should focus on science learning through a more inquiry-based, student-centred, and hands-on approach, while also promoting cooperative learning activities [10].

In recent years, there has been a notable increase in the popularity of the flipped classroom model (FCM) as an active learning method, especially in science, technology, engineering, and mathematics courses [11]. The FCM differs from traditional teaching formats by integrating technology to promote a dynamic and interactive learning experience [12]. Prior to in-class sessions, students receive individualised instruction via internet-connected devices, typically in the form of video lessons, then, during the in-class sessions, the focus shifts to interactive group learning activities [13]. This reversal of traditional activities has several pedagogical advantages. It places the student at the centre of the learning process and fosters a sense of responsibility for engaging with the material prior to the in-class sessions [14]. In addition, students are given the flexibility to learn at their own pace, with video lesson features such as pausing, rewinding, and fast-forwarding allowing them to take control of their learning process [15]. Furthermore, this approach encourages a shift in learning habits, as independent study prior to in-class sessions can positively impact students' ability to self-regulate their learning [16]. Perhaps most importantly, FCM optimises in-class time by providing more opportunities for peer and instructor interaction, thereby facilitating collaborative learning and the development of higher order skills [17].

Several studies have highlighted the suitability of the FCM for enhancing self-efficacy in scientific disciplines [2], [18]. Despite this, research focusing on PSTs' self-efficacy in this particular area remains limited [2]. The main objective of this study was to evaluate the impact of implementing an FCM approach on the science self-efficacy of PSTs enrolled in a general science course within the basic education programme at the School of Education of the Santarém Polytechnic University.

## **2 METHODOLOGY**

### **2.1 Design**

The study was conducted over a period of 14 weeks using a mixed-methods research approach. The quantitative dimension employed a semi-experimental pattern with a pretest-post-test control group. Qualitative data was collected through a semi-structured interview with the experimental group, which offered a subsidiary perspective that supported the quantitative data.

### **2.2 Participants and context**

The study participants were 39 PSTs from two classes enrolled in a general science course within the basic education programme at the School of Education of the Santarém Polytechnic University.

The experimental group, comprising 22 PSTs (all female), participated in a science course following the FCM. This group was exposed to an interactive and controlled online learning environment, where instructional content was delivered through video lessons and online quizzes. The weekly learning activities were structured in a sequence, with a set of non-mandatory learning activities preceding the in-class session. During the pre-class session, the PSTs were primarily engaged in exploring the educational material (e.g., educational videos) provided by the instructor and self-assessment quizzes. This process was designed to familiarise the PSTs with the basic concepts of the follow-up in-class session. Consequently, the subsequent in-class session could be focused on collaborative problem-based activities and feedback provision.

In contrast, the control group consisted of 17 PSTs (one male and 16 female) who completed a science course following the existing curriculum without any intervention. The flow of learning activities commenced with the in-class session, during which the instructor presented the new learning material

and concepts (mainly through lecture), prior to any other learning activity. During the remaining period, the PSTs engaged in collaborative problem-based activities.

The same instructor was responsible for the two classes. Both versions of the science course (for the experimental and control groups) were designed to be as similar as possible in terms of educational design elements, to minimise the possibility of biased results due to the use of vastly different teaching approaches.

## 2.3 Instruments

The Science Teaching Efficacy Belief Instrument-Pre-service (STEBI-B) [19], modified by [20], was employed in the study. The survey, adapted for use in Portuguese, comprised 23 items on a five-point Likert scale, with two scales: The Personal Science Teaching Efficacy (PSTE) and the Science Teaching Outcome Expectancy (STOE). The PSTE comprises 13 items and measures PSTs' beliefs about teaching science. The STOE comprises 10 items and measures elementary student outcomes as a result of science teaching. The instrument employs forward and reverse-phrased items. The reliability of the STEBI-B was evaluated, and the items were found to be reliable ( $\alpha = 0.80$ ), achieving the same evaluation in all its dimensions [ $\alpha$  (PSTE) = 0.78;  $\alpha$  (STOE) = 0.84].

The STEBI-B was administered electronically. Participants were given a unique code for participation in the study and to compare pre- and post-data.

Additionally, qualitative data was collected electronically. The semi-structured interview followed a script and interview questions were formulated to identify the sources of PSTs' self-efficacy in relation to science teaching and learning, using the MFC.

## 2.4 Data analysis

The questionnaire results were analysed using Jamovi ® 2.2.5.0 software. Reliability was examined by calculating Cronbach's alpha ( $\alpha$ ) in the questionnaire and its subscales. Descriptive statistics were examined, and the average score was obtained for each subscale of the questionnaire. The normality assumption of the data was checked using the Shapiro-Wilk test.

For the intergroup analyses, an independent samples t-test was used if the assumptions of normality (*Shapiro-Wilk* test) and equal variances (*Levene's test*) were met. Otherwise, the *Mann-Whitney U* test was employed.

All interviews were conducted online, with the 16 volunteers PSTs distributed into groups of three or four elements. The average duration of the interviews was approximately 30 minutes. The interviews were audio-recorded and fully transcribed for subsequent thematic content analysis. Quotes with similar meanings were synthesised into categories and grouped into the following analytical themes: mastery experiences, vicarious experiences, verbal persuasion, and emotional and physiological states.

# 3 RESULTS

## 3.1 Responses to the questionnaire

Prior to the post-test analyses, it was examined whether there was a significant difference between both the PSTE and STOE pre-test scores (Table 1). Since the pre-test data were normally distributed, t test was used for comparison. The PSTE pre-test scores demonstrated that there was no significant difference between the experimental group ( $M = 3.28$ ,  $SD = 0.52$ ) and the control group ( $M = 3.29$ ,  $SD = 0.38$ ) [ $t_{(37)} = 0.073$ ,  $p > 0.05$ ]. The STOE pre-test scores also demonstrated that there was no significant difference between the experimental group ( $M = 3.38$ ,  $SD = 0.66$ ) and the control group ( $M = 3.15$ ,  $SD = 0.65$ ) [ $t_{(37)} = -1.070$ ,  $p > 0.05$ ].

Table 1. Independent group's t-test results related to science teaching efficacy belief pre-test scores of the experimental and control groups

	Group	N	Mean	SD	Student's test		
					t	df	p
PSTE	Control	17	3.29	0.379	0.073	37	0.942
	Experimental	22	3.28	0.515			
STOE	Control	17	3.15	0.653	-1.070	37	0.292
	Experimental	22	3.38	0.665			

Table 2 shows the results of the Mann-Whitney test (data were not normally distributed) conducted to examine the difference between the PSTE and STOE post-test scores of the PSTs in the experimental and control groups. When Table 2 is examined, a significant difference exists between the PSTE post-test scores of the experimental and control group students, in favour of the experimental group ( $U = 127$ ,  $p < 0.05$ ). In this sense, it can be said that the FCM had a positive effect on PSTs' PSTE. However, no significant difference is noted in STOE post-test scores between the groups ( $U = 153$ ,  $p > 0.05$ ).

Table 2: Mann-Whitney test results related to science teaching efficacy belief post-test scores of the experimental and control groups

	Group	N	Mean	SD	Mann-Whitney U test	
					U	p
PSTE	Control	17	3.41	0.541	127	0.044
	Experimental	22	3.69	0.605		
STOE	Control	17	3.43	0.925	153	0.171
	Experimental	22	3.66	0.616		

### 3.2 Interviews

A qualitative analysis of the speeches of the interviewed PSTs (experimental group) revealed several factors that contributed to the change in their self-efficacy beliefs. The analysis in Table 3 indicates that the *mastery experiences* of the PSTs during the teaching and learning process with the FCM were positive and successful. This success was reflected in achievements, including better understanding of the content and good results in the final assessment of the semester. The aforementioned achievements were the consequence of the PSTs' genuine involvement with the pre-class tasks, active participation in in-class sessions, and overcoming difficulties with the support of their peers and teachers. The PSTs' statements related to their personal experiences in the subject's specific activities indicate that: (I) the pre-class tasks were found to be useful and helpful in improving performance in-class sessions, although they required additional effort to complete; (II) the resources provided in the pre-class were found to be respectful of the students' learning styles and rhythms and (III) the class activities were found to be complementary to the pre-class activities and allowed for a deeper understanding of the content. Furthermore, the class dynamics allowed for more interaction and peer support in overcoming difficulties.

In the discourse of the PSTs, *verbal persuasion* is associated with encouragement and support through verbal and non-verbal expressions from the teacher (behaviour and speech), colleagues and from the learning environment created by the implementation of the FCM. The PSTs' statements indicate a positive feeling towards the learning environment induced by the model, the interpersonal relationships in the in-class sessions and the teacher's attitude.

In terms of *emotional and physiological states*, a reduction or elimination of emotional barriers that could be perceived as inhibiting the performance of an action is noticeable in PST speeches. There are arguments relating to the reduction of anxiety, the absence of pressure or the existence of comfort and confidence in the performance of tasks.

Table 3: Quotes from the interviews and the possible sources of self-efficacy involved.

Interview quotes	Source of self-efficacy
<p>At first, I thought there was a lot to do, and it was difficult to manage the time. But as the tasks were posted on Fridays, I knew I had to set aside some time during the week to do them and it became a habit. After that, I even liked doing them because I could see that they were useful for my performance in class (Alice).</p> <p>I think this method made my learning a lot easier. I like taking notes and I could stop the videos as many times as I wanted until I understood. The quizzes were also useful, they helped me to get an idea of what I didn't understand so well. Later in the class I could clarify my doubts and this exchange of ideas was also very useful for me (Marta).</p> <p>There was one time at the beginning of the semester when I didn't do the preparation before class. Later in the class I immediately regretted it because I realised that it was really important. The class without the pre-class preparation wasn't as productive for me. It took me longer to understand the content and if I had learned the basics at home, I would not have started from scratch. So, for me the responsibility of preparing was really worth it (Joana).</p>	Mastery experiences
<p>In the practical activities I helped the group, and the group helped me, I think it was productive and we all felt productive because we were able to answer the questions and we thought we were doing it right (Lara).</p> <p>There was more discussion, more interaction in the class. Because we already knew something, we answered more of the teacher's questions and were able to clarify our colleagues' doubts. The teacher did something very interesting, when a colleague had doubts, the teacher gave the opportunity for the colleague's question to be answered by one of us, which was very good (Patrícia).</p> <p>I particularly liked the scenarios that the teacher set up, for example, one time we were atoms of different species and had to make simple, double and triple bonds. It's a super fun way to make us more interested and active in class. I really liked it and I think we should have more of this kind of interaction (Alice).</p>	Verbal persuasion
<p>The model gave us more confidence. In the middle school I was convinced that I didn't know anything about Physics and Chemistry. When I found out that I would be doing Physics and Chemistry in my degree course, I was confused. But during the lessons I felt that I even understood what was being done, and as the semester progressed this feeling of insecurity diminished. (Beatriz)</p> <p>Since the preparation before the class didn't count for the assessment, there was no stress of failing. In this sense, the tasks were done without pressure, as the quizzes were just warnings for us to reflect on our preparation, to understand what we need to improve, but of course we would like to have good results (Sabrina).</p> <p>I think the fact that the classes were complementary gave us comfort, because in class the teacher deepened the knowledge we had brought from home, the fact that we knew this more basic content made us feel more comfortable. Often, we already had doubts, which allowed us to discuss the content in a different, more thoughtful way, and sometimes during the class even more doubts arose that probably would not have come up if we were listening to the content for the first time (Alice).</p>	Emotional and physiological states
<p>The model is much better than traditional classes in terms of preparation for teaching and is much more useful in subjects that we find more difficult to learn, such as science and maths. I think I will use this model when I become a teacher (Sabrina).</p> <p>At first I thought I wouldn't be able to do the subject, and if I managed to get a good result, it's because the model works. I think it has improved my knowledge of science and made me more capable of teaching science to my future students. I also think that I will use the model with my students because if it has improved my knowledge and that of most of my colleagues, it will also improve my students' knowledge. (Marta).</p>	Vicarious experiences

With regard to the phenomenon of *vicarious experiences*, the inspiration provided by the teacher when utilising the FCM in their teaching process is evident in the PSTs' discourse. The experience was deemed so positive that the PSTs expressed a desire to replicate the model when they became teachers.

## 4 CONCLUSIONS

The main objective of this study was to evaluate the impact of implementing an FCM approach on the science self-efficacy of PSTs enrolled in a general science course within the basic education programme at the School of Education of the Santarém Polytechnic University.

The results demonstrated that the FCM had a statistically significant impact on enhancing the personal science teaching efficacy of the PSTs. This is consistent with previous studies which have demonstrated

that FCM has a positive effect on increasing students' self-efficacy in scientific disciplines [18] and science PSTs' self-efficacy [2].

An analysis of the interviews with the PSTs in the experimental group helps to understand this result. Of the four main sources of self-efficacy (mastery experiences, vicarious experiences, verbal persuasion, and emotional and physiological states), mastery experiences are the most important factor in the formation of a strong sense of self-efficacy [7]. The *mastery experiences* of the PSTs during the learning process with the FCM, facilitate the development of science-related knowledge and skills in a positive and successful manner (see Table 3). The characteristics of the implementation of the FCM and the performance of the teacher contributed to the success of the PSTs experience. In particular the complementarity between the pre-class and the in-class stands out. This complementarity meant that carrying out the pre-class tasks was considered useful and necessary by the PSTs, as evidenced by the following statements: *The in-class session without the pre-class preparation wasn't as productive for me .... so, for me the responsibility of preparing was really worth it* (Joana); *After that, I even liked doing them [pre-class tasks] because I could see that they were useful for my performance in class* (Alice). This interdependence fostered a sense of responsibility for engaging with the material prior to the in-class sessions [14] and was also responsible for the emotional state of general comfort and confidence, as evidenced by the following statements: *I think the fact that the classes were complementary gave us comfort* (Alice); *The model gave us more confidence* (Beatriz). These emotional and physiological states are further sources of self-efficacy [7] because they reduce or eliminate emotional barriers that might be perceived as inhibiting the performance of an action. As a result, the class became more dynamic and interactive and the PSTs became more involved in class activities, as confirmed by the following statement: *There was more discussion, more interaction in the class. Because we already knew something, we answered more of the teacher's questions and were able to clarify our colleagues' doubts* (Patrícia). Similar findings are described by [17], who consider that the most important feature of FCM is the optimization of class time to provide more opportunities for peer and instructor interaction, thereby facilitating collaborative learning.

Similarly, the teacher's performance also contributed to the development of the PSTs' self-efficacy. The discourse of the PSTs indicates positive verbal and non-verbal messages received from the teacher about how to perform a task (*verbal persuasion*), as evidenced by the following statements: *The teacher did something very interesting, when a colleague had doubts, the teacher gave the opportunity for the colleague's question to be answered by one of us, which was very good* (Patrícia); *I particularly liked the scenarios that the teacher set up...it's a super fun way to make us more interested and active in class... really liked it and I think we should have more of this kind of interaction* (Alice).

In this sense, it can be posited that the implementation characteristics of the FCM, when combined with the teacher's behaviour, played a pivotal role in enhancing the PSTs' science self-efficacy. Nevertheless, the results indicated that the FCM had no significant impact on enhancing the STOE of the PSTs. As outcome expectancy encompasses judgements regarding the capacity of teaching to bring about change in children's understanding [6], it is possible that because the PSTs are first-year students, they do not yet feel able to make judgements about the consequences of their behaviour as teachers. Thus, it can be argued that the FCM fosters higher levels of content knowledge, which in turn supports preservice teachers' confidence in their ability to teach the topic. However, perhaps due to a lack of experience, they appear to remain unsure about their ability to influence students' learning. This hypothesis is supported by [3] study, where the authors found that personal mathematics teaching efficacy was positively correlated with students' performance in mathematics, whereby students with higher prior attainment in mathematics indicated stronger self-efficacy beliefs, but there was no correlation between mathematics performance and mathematics teaching outcome expectancy. Although the quantitative results indicate that the FCM had no impact on STOE, the PSTs' discourse demonstrates their capacity to anticipate positive outcomes if they utilize the model with their students, as evidenced by the following statements:

*I think it [FCM] has improved my knowledge of science and made me more capable of teaching science to my future students... I will use the model with my students because if it has improved my knowledge ... it will also improve my students' knowledge* (Marta); *The model is much better than traditional classes in terms of preparation for teaching is much more useful in subjects that we find more difficult to learn, such as science and math. I think I will use this model when I become a teacher* (Sabrina).

Therefore, in the absence of teaching experience, PSTs may utilise the science academic results and vicarious experiences as a basis for their self-efficacy judgments. It is generally accepted that efficacy beliefs are most malleable in the early stages of a career and, once established, tend to remain relatively

stable [8]. This highlights the potential for teacher education programmes enhanced by FCM to cultivate robust personal efficacy beliefs, thereby enabling students to excel in science and inspiring their future practice as teachers.

This study has some limitations that should be considered. It is limited to the higher education level, encompassing a 14-week course duration and implementation period, specifically focusing on the general science course within the basic education program; the use of distance learning platforms, videos, and supplementary materials as instructional tools and the instruments and the responses given to those instruments.

To obtain a more comprehensive understanding of the FCM's impact on the self-efficacy of PSTs, it is recommended that a longitudinal study be undertaken with these PSTs. Such a longitudinal approach would allow for the observation and analysis of changes in self-efficacy beliefs over an extended period, providing deeper insights into the value of the FCM in fostering self-efficacy among PSTs.

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