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A longitudinal study during scientific teacher training: the association between affective and cognitive dimensions

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Learning processes are undoubtedly linked to affective factors. Motivation, interest, curiosity and emotions have been already detected as the core of learning processes: affective domain modulates learning. In this work, a quantitative longitudinal study (three courses) has been conducted during primary school teacher training. An initial diagnosis of affective variables (emotions and self-efficacy) and scientifical knowledge revealed that prospective teachers claim feeling negative emotions toward physics and chemistry contents whereas these students report low scientific knowledge. Therefore, a metacognitive and emotional program was implemented in order to modify these emotions and to improve learning. After three courses, emotions, self-efficacy and scientific knowledge were assessed again. The results obtained suggest that the implementation of active methodologies for teaching science could promote positive emotions, it could lead prospective teachers to improve their self-efficacy' perception and promotes their learning. The relationships between the different variables considered in the research were studied, and a significant relationship was found between the affective variables (self-efficacy and emotions) and cognitive variables. Prospective teachers involved in this research reported more positive emotions, an increase in their self-efficacy perception and an improvement in their scientific knowledge. These findings may lead to a deeper understanding of the affective role in science learning and could be extended to other content that also elicits negative emotions.

KEYWORDS

teacher in training, emotions, self-efficacy, scientifical education, higher education

1 Introduction

Neuroeducation is a new discipline that brings together knowledge from neuroscience (how the brain works), education and psychology and provide us with significant information to enhance both the learning process of students and teaching processes of teachers. Neuroeducation is based on the principle that emotional and cognitive processes are intertwined and interrelated, and that they ultimately determine how a subject behaves (Mora, 2012). When a subject is in a stimulating environment, all information is sensory and is processed by the limbic system or emotional brain, before being processed by the cerebral cortex in its association and frontal areas (mental, cognitive, strategic processes). As a result, thoughts and cognitive functions (ideas, thoughts, attention, memory, planning, behavior) are "contaminated" by emotions (memories, fears, desires, interests) (Mora, 2017).

So, the cognitive processing that produces thought is already done with the basic (abstract) elements that have meaning, pleasure or pain, good or bad, attraction or rejection. Hence the intrinsic nature of emotion in all rational processes, which implies learning. This defines the human condition as primarily emotional and secondarily rational. This depends on the emotional contamination of the person (past history, traumatic and pleasant events, personal satisfaction and anxiety) and the social–emotional context in which the person evolves, i.e., the emotional reaction. All this determines our cognitive and learning processes (Davis and Bellocchi, 2018; Code, 2020).

1.1 Emotions and its impacts in learning processes

Although the study of emotions goes back several centuries, they have only recently begun to be considered and used in educational contexts since, traditionally, the affective (emotions and affective response) and cognitive domains (attention, memory, or learning) were studied separately (Mellado et al., 2014). Nowadays, it is accepted that these two parts cannot be separated, because there is no learning without interaction with the emotional dimension (Camacho-Morles et al., 2021).

Schunk (2012) defines learning as a permanent change in behavior, or in the ability to act in a particular way, that occurs after practice, that is, involves change, persists over time and occurs through experience. For learning to be meaningful, knowledge and skills gained throughout the learning phase must be applied in new contexts and situations. The changes in the brain that produce meaningful learning can only be achieved by combining practical activities with experience and transfer to other contexts. As far as the influence of emotions on learning is concerned, it is known that emotions help to fix or hinder concepts in memory. Episodes that are associated with an emotion are easier to remember and tend to be remembered for longer (Phelps, 2006). Emotions have an impact on students' learning outcomes (Carmona-Halty et al., 2019). Combined, emotion, engagement and attention provide a comprehensive picture of the emotional and cognitive state of the student during the learning process (Ezquerra et al., 2023).

Biological research on emotions began with Darwin's publication of "The Expression of the Emotions in Man and Animals" (1872). Darwin's principles and subsequent neo-Darwinian perspectives laid the foundation for the study of emotions (Ekman and Oster, 1981; Ekman, 1992; Plutchik, 2001). However, these principles have been now refuted and recognised as myths by current trends in affective psychology (Barrett, 2020). Barrett (2020) suggests that individuals may experience the same emotion with varying physiological reactions, while different emotions may share similar responses. Furthermore, Barrett (2020) contends that if such differences manifest within the same person, achieving universality in emotional expression becomes unfeasible, as has been recognized until recently.

In this article, Bisquerra's (2015) definition is considered, defining emotions as *reactions of different intensity based on environmental information each person's subjective evaluation, and how they affect our wellbeing*. In terms of taxonomy, the most relevant epistemological emotions were selected to address the research objectives according to their valence (positive and negative) and their arousal or activation dimension (Russell and Carroll, 1999; Posner et al., 2005). Regarding the emotions in learning processes, a considerable literature has explored the emotional dimension of students engaged in learning, specifically in pre-service teachers. These investigations show that positive emotions (such as satisfaction or confidence) are correlated with understanding scientific concepts, work in groups or activities involved (Bellocchi and Ritchie, 2015). Some studies have focused on specific disciplines such as physics, chemistry or biology. The results show a tendency towards positive feelings towards biology and chemistry compared to physics (Brígido et al., 2012; Dávila-Acedo et al., 2015; Marcos-Merino et al., 2019). In addition, researchers have identified activities or teaching methods that are more likely to evoke positive emotions (Ochoa de Alda et al., 2019; Bravo-Lucas et al., 2022).

1.2 Self-efficacy

Besides emotions, there are other variables in teachers' affective domain that have a huge impact on how they teach. Together with other psychological dimensions such as intentionality, self-regulation or reflection, self-efficacy is also taken into account. Self-efficacy is defined as the belief in one's own abilities to organize and perform the necessary actions to achieve certain achievements or results. It influences one's own way of feeling, thinking, and acting (Bandura, 1997). Highly confident people see difficult tasks as challenges to be overcome rather than threats to be avoided (Bandura, 1997). But a teacher who has doubts about his own abilities will tend to avoid activities and situations that he considers beyond his capabilities. Teachers with low confidence in teaching science have particularly likely to experience learning difficulties (Gargallo and Bargalló, 2009).

Successful experiences will be a reason to increase personal self-efficacy according to Bandura (1997). Therefore, it is essential that teacher training includes experiences that enable students to increase their self-efficacy. The improvement of their psychological characteristics will also contribute to their teaching being more effective (Klassen and Tze, 2014). This is why it is so important to try to ensure that the emotions felt in the classroom while learning science are positive and help them to feel confident about doing the work. This helps them feel competent and prepared.

1.3 Science teacher education

Improving science education for primary school students has been studied for more than two decades, both in Spain and in other countries, with the aim of providing a basis for teacher training plans aimed to determine what science should be teach in primary education, and how to do so effectively (García-Carmona and Cruz-Guzmán, 2016). What is known so far is that primary school students have very positive attitudes towards science in the early years, and their emotions tend to be very positive, but, as they progress through school, they lose this attitude and there is even a known "erosion year" (Hadden and Johnstone, 1983) that coincides with the transition to secondary school: a time when emotions towards science deteriorate sharply (Speering and Rennie, 1996). These studies began to warn in the 1980's of a worrying decline in secondary students' interest in

10.3389/feduc.2024.1355359

studying science and technology subjects. Since then, this trend has worsened, partly because of the declining interest of secondary school students in science and technology subjects (Vázquez and Manassero, 2018).

Traditionally, the teaching of science has been carried out using passive methods, in which the teacher has played the main role, while the students have acted as mere recipients of information (Mellado et al., 2014). This context of globalization has demanded higher education to adapt to these new systems and modern societies, and to transform the processes of teaching and learning in the university (Romanenko et al., 2023). For decades, educational research worldwide has confirmed that education systems must be linked to the new personal, social and employment needs of citizens: communication skills, resilience, adaptation, reflection, collaboration, or creativity (Andrews and Higson, 2008). To respond appropriately to these challenges, education systems need to incorporate soft skills training for citizens into their programs (Romanenko et al., 2023). It goes beyond memorizing content and performing an activity, as they allow for lifetime learning and are transferable to address unpredictable, diverse and changing circumstances (Steffens, 2015).

What is more, university education policies in recent decades have focused on more experiential learning, where students in higher education not only learn content, but also develop certain skills and aptitudes that enable them to live and make appropriate decisions (Barth et al., 2007; Rieckmann, 2012, 2018; Steffens, 2015). Likewise, the current context of climate crisis has prompted a clear commitment to sustainability in education at all levels (UNESCO, 2015) and this is transmitted to universities (Acero-Díaz et al., 2014; Self-citation).

Identifying the difficulties encountered in teacher training during science learning and recognizing the need for a paradigm shift in the educational context, in this article, authors consider the emotional and cognitive component of prospective Primary teachers (hereinafter referred to as PPT) during science lessons. In this context, this study was designed to analyze the effects of different science teaching strategies which were carried out during teacher training. In accordance with the above justification, this article has, as a general objective, to analyze the affective and cognitive evolution experienced by Primary Education Degree students (PPT) after taking the science subjects of the aforementioned degree.

2 Materials and methods

2.1 Research questions

Hence, this study aims to answer the following research questions (RQ):

RQ 1: Does the metacognitive and emotional program during science lessons have any positive impact on the emotions, self-efficacy and knowledge of prospective teachers?[1]

RQ 2: Is it possible to find an association between the affective and cognitive variables analyzed?

2.2 Participants

The method employed to select the sample was a non-accidental convenience sample of the population of preservice teachers of the Degree in Primary Education (the easiest for the researcher to access). Our sample was made up of 144 students divided in 91 females and 53 males. These students were enrolled in the subject Didactics of matter and energy during the 2018–19 academic year (subject referred to as the sophomore year of the Degree in Primary Education, at the University of X, Faculty of Y). These students were involved in a metacognitive and emotional intervention program during science lessons. Emotional and cognitive information was collected regarding their affective and cognitive domain prior to taking the first science-related subject taught in the Primary Education Degree. Two and a half years later (three academic years), the same students, enrolled in the 4th year during the 2020/2021 academic year, were chosen again, having already taken the three subjects that deal with science content, to analyze again their emotions toward sciences, their self-efficacy and their scientific knowledge. PPT were informed that they were going to participate in a research study, its duration, the procedure and that their data would be treated anonymously. Participation was voluntary.

2.3 Instruments

Regarding the questionnaire used for the longitudinal research, it should be reiterated that it was the same in both moments of data collection: before the implementation of the interventions (and the pre-service teachers taking the science subjects), and after the implementation of the interventions and taking the science subjects. To facilitate reading comprehension, the first point of data collection, before taking the three science subjects, will be referred to as the pretest. The second moment, after completing these subjects and executing the interventions, will be called the posttest. The questionnaire (please, see Supplementary files) consisted of three different parts and its design has been established over the last decades, when our research group started to study the affective dimension during science learning (Freitas et al., 2004; Brígido et al., 2012).

The first section of the questionnaire was designed to find out the PPT's perception of self-efficacy towards science, asking them to rate numerically (from 0 to 10) their degree of competence or ability to teach each of the scientific contents proposed (please, see Supplementary files). These contents appeared in the form of statements and included a series of concepts and contents related to the different scientific areas (physics and chemistry, and biology and geology).

The second section of the questionnaire was intended to determine the emotions that PPT perceived towards the different scientific subjects. This section included a table with the different matters and emotions considered in the research. Students should mark with an X whether they feel them or not. These contents were the same as those that appear in the previous question on self-efficacy. Emotions selected in this longitudinal study appear in Table 1. The

1 The authors consider a positive effect on emotions to be when PPTs feel significantly more positive epistemic emotions after the implementation of the program. Regarding self-efficacy and scientific knowledge, the impact will be positive if these variables increase after the program.

TABLE 1 Classification of emotions used in the longitudinal study.

Positive	Negative
Confidence	Anxiety
Enthusiasm	Boring
Fun	Fear
Joy	Nervousness
Satisfaction	Rejection
Surprise	Worry

emotions selected in this work are supported by several studies in the affective area, the emotions selected have been proved to be the most significant during teaching and learning sciences (Brígido et al., 2012; Stephanou and Oikonomou, 2018; Camacho-Morles et al., 2021). In order to work by constructs of the scientific fields, it was decided to count the positive emotions (joy, confidence, enthusiasm, fun, etc.), negative emotions (anxiety, fear, nervousness, etc.) for each of the contents, and to compare the emotions felt according to the scientific field on the basis of the percentages. Each student had 9 contents in their questionnaire for physics and chemistry, and 10 for biology and geology, and for each of them they could indicate up to 6 positive emotions and 6 negative emotions. After counting the number of emotions that each student had indicated for each content, as a way to be able to make comparisons between the different scientific areas, the data were obtained as a percentage, which was the value with which the analyses described in the results section were carried out.

The third section comprised a scientifical knowledge test based on the most relevant misconceptions in science. The questionnaire included 15 multiple-choice questions (MC-Q) with only one correct answer, and 26 true-false questions (TF-Q). Therefore, it was possible to determine the average mark of each teacher in initial training for the different areas, and to establish differences according to gender or their background studies. The same questionnaire was used in the posttest, to determine whether if there was an increase in knowledge (learning), or not. This questionnaire is inspired by popular misconceptions among science subject student (−teachers) in primary and secondary schools (González, 1997; Subayani, 2016) and, above all, the Spanish Foundation for Science and Technology [FECYT]'s social perception of science and technology survey, an institutional questionnaire of the Minister of Science and Innovation of Spain which has been carried out since 2002 to measure, among other things, the level of scientific knowledge of the Spanish population [Fundación Española para la Ciencia y Tecnología (FECYT), 2024].

2.3.1 Questionnaire reliability analysis

Cronbach's alpha was calculated to determine the internal consistency of the questionnaire. For the complete questionnaire used to carry out the longitudinal study, a value of $\alpha = 0.847$ was obtained. This suggests that no item should be removed, and it can be affirmed that the questionnaire had a high internal consistency.

2.4 Procedure

The main aim of the study was to analyze the emotional and cognitive evolution which occurs during teacher education. A meta-cognitive and emotional program was designed to support PPT in knowledge, self-regulation of their emotions and teaching self-efficacy in science education, whilst improving their level of scientific knowledge. The different interventions were implemented during three consecutive academic years from 2018 to 2021. To do this, a diagnosis of affective variables (emotions and self-efficacy), and cognitive variables, was carried out when the students were in the 2nd year of the Primary Education Degree. Secondly, the design, application and evaluation of different teaching strategies and methodologies was carried out over three consecutive academic years, and in the three subjects related to natural sciences taught in the Primary Education Degree. Finally, a final diagnosis was carried out, where data on emotions, self-efficacy and scientific knowledge were collected again after the implementation of the metacognitive program. The questionnaires (pretest and posttest) were created through "Google Forms" platform, and administered remotely to the participants, through a QR Code on the screen. All participants completed the test correctly.

With regard to the interventions and resources used in the study, they have been partly published and available under Creative Common Licence (self-citation). All of them are based on the pedagogical philosophy of active methodologies and in a sustainability transversality-oriented way: Project Based Learning (PBL), Inquiry, Game Based Learning (GBL) and Service-Learning (SL) have been used. A brief description of each one is provided as follows (Table 2).

2.5 Data analysis

After obtaining the data, they were digitally processed for statistical analysis using the free and open-source software JASP (version 0.17.2, Netherlands), and the Office 365 package for graphical representation and database management. Since the data did not fit a normal distribution (p-value <0.05, Kolmogorov–Smirnov and Shapiro–Wilk normality tests), the analyses were performed using non-parametric statistics. To determine whether there were differences between two independent groups, the Mann Whitney U test was used. In addition to looking for differences between groups, significant association relationships between two variables were also searched for, using Spearman's correlation test.

3 Results

In this section the affective and cognitive variables, before and after carrying out the interventions in the science classroom, are described and analized. Firstly, a description of the sociodemographic variables gender, age and descriptive results of the academic variables of both the pretest and the posttest are shown.

3.1 Sociodemographic data

The sample of PPT analyzed in the first diagnostic study of this work consisted of a total of 144 subjects. Of these, 63% of the sample ($N = 91$) were females, with the remaining 37% ($N = 53$) being males (mean age 21 ± 3,0). With regard to their background studies, 73% of the undergraduate students studied the baccalaureate in social sciences or humanities (hereinafter referred to as SS-H), and 26% the

TABLE 2 Description on the interventions carried out during longitudinal study.

Subject	Course	Name of activity	Duration	Methodology	Description	Cite
Teaching of matter and energy	2°	Hydro rocket contest	9 h (3 sessions of 3 h, spread over three weeks)	PBL	The project consists of a rocket launching competition designed and constructed by them using recycled materials	(Hernández-Barco et al., 2021)
Earth and life science education	3°	Solving a crime in the Geology lab	3 h (one session)	GBL	In this activity students become aspirants to join a fictitious *Scientific Police School*, which access test is a practical skills exam they are asked to solve a crime using basic Geology knowledge and techniques	(Corbacho-Cuello et al., 2022)
Earth and life science education	3°	"Microorganisms in our lifes" board game	3 h (one session)	GBL	Didactic board game on microbiology, which addresses, in addition to viruses, different types of microorganisms, both beneficial and harmful, and opportunistic, as well as their characteristics and their relationship with humans	(Corbacho-Cuello et al., 2023)
Earth and life science education	3°	Inquiry botany trail	3 h (one session)	Inquiry	Students are provided with a map of the campus with a marked route. It has a guide indicating the stops to be made, a short text and activities.	(Corbacho-Cuello et al., 2024)
Knowledge of the natural environment in primary education	4°	Slow sand filter	6 h (2 sessions of 3 h, spread over two weeks)	PBL SL	Design, implementation, and testing of a Slow Sand Filter.	(Hernández-Barco et al., 2022)
Knowledge of the natural environment in primary education	4°	Solar cooking	3 h (one session)	Inquiry	Solar cooking assembly. Calculate the efficiency of the solar cooker.	(Hernández-Barco et al., 2025)

baccalaureate in science and technology (hereinafter referred to as S&T). At the end of the research, 98 subject answered the questionnaire, of these, 64% of the sample ($N = 63$) were females, with the remaining 36% ($N = 36$) being males (mean age 23 ± 2,7).

3.2 Emotional dimension

The detailed emotional analysis of each content made it possible to establish which were the most relevant contents to be considered in the interventions. Before taking the science subjects of the degree, there were large emotional differences between the different scientific areas: the contents linked to physics and chemistry had high percentages of negative emotions and low percentages of positive emotions, so the most relevant interventions of the meta-cognitive were focused on physics and chemistry contents, with the aim of modifying this emotional tendency and improving the affective dimension during science learning in teacher training (see Figure 1).

Figure 2 shows the percentages of emotions reported before and after carrying out the interventions about physics and chemistry contents. The pretest is shown in grey and the posttest in blue. Statistically different groups (Mann Whitney U, ***p-value <0.001; **p-value <0.01) are included for each of the emotions.

After the interventions in the science classroom, the PPT experienced an increase in *confidence* (from 17 to 28%) about the physics and chemistry contents (p-value <0.001), an emotion closely linked to the perception of self-efficacy. Also, after taking the different subjects, teachers felt more *satisfaction* (p-value <0.001) with the physics and chemistry contents, since initially only 12% of the participants claimed feeling satisfaction, whereas in the 4th year, up to 19% of participants felt satisfaction. For the emotion *surprise*, a significant increase was also observed (p-value <0.001), since in the pretest 7% of the students stated that they felt it, while in the posttest it increased to 17%. Students also claimed to feel more *fun* towards the physics and chemistry contents (p-value <0.01), 19% of the participants reported feeling *fun* in the posttest, whereas initially only 14% did so. On the other hand, with regard to negative emotions, there was a significant increase in the emotion of anxiety (p-value <0.001), since before taking the science subjects of the degree, 6% said they felt it, while at the end of their training it rose to 12%.

With regard to the contents of biology and geology, it has been found that some contents referring to the area of geology, such as rocks and minerals, generated a high percentage of negative emotions, so this content was selected for the design of one of the interventions (self-citation). The results obtained showed a significant emotional evolution. In addition to this, content related to botany was also selected, as it is an area of biology that usually does not arouse the same social interest as other areas, such as anatomy or zoology (self-citation). And, finally, a third content, microbiology, was chosen, due to the high number of misconceptions that exist about microorganisms (self-citation).

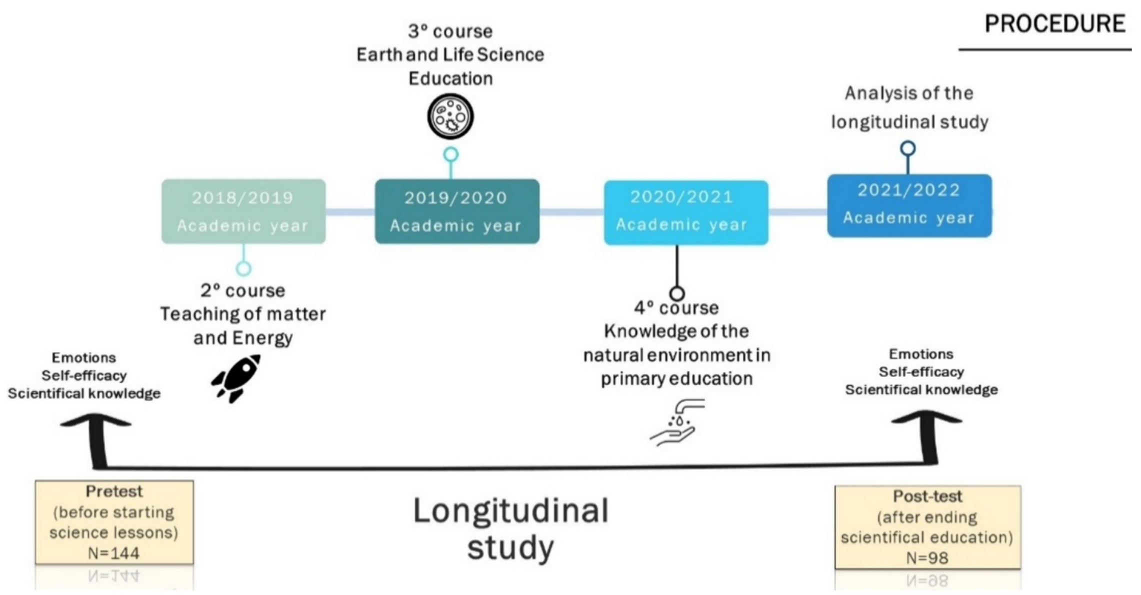

FIGURE 1
Research timetable.

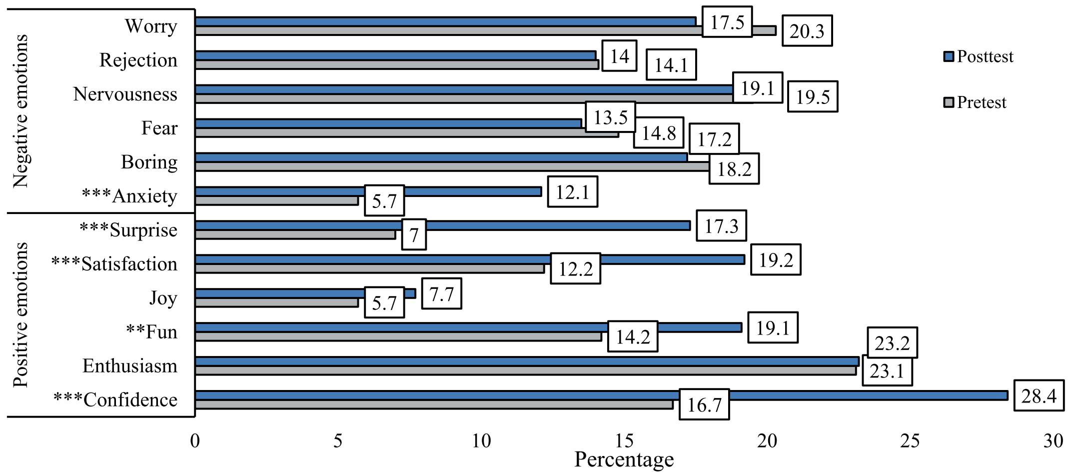

FIGURE 2
Percentage of emotions reported by prospective teachers towards physics and chemistry content before and after implementing the interventions.

Figure 3 shows the emotional evolution, in percentages, of the emotions indicated by primary school teachers in training towards the contents of biology and geology. The pretest is shown in grey, and the posttest in yellow. Statistically different groups (Mann Whitney U, ****p*-value <0.001; ***p*-value <0.01) are included for each of the emotions.

It can be seen that the future teachers, after studying the science subjects of the degree, reported feeling more *enjoyment* (*p*-value <0.01) towards the contents of biology and geology, rising from an initial 20%, to a 31% in the posttest. They also reported feeling more *surprise* (7% in the pretest and 19% in the postest, *p*-value <0.001). A significant increase in *confidence* was obtained (*p*-value <0.001), in the pretest this emotion was reported by 30% and in the posttest by 46% of the participants. Finally, there was an increase in *satisfaction* (*p*-value <0.01), which was initially reported by 21%, but in the posttest 30% said they felt it. On the other hand, there was also a decrease in *concern* (*p*-value <0.001), which was initially reported by 10% of the sample, while only 3% of the trainee teachers surveyed said they were concerned about biology and geology contents at the end of the posttest.

Initially, some significant emotional differences depending on gender were found towards physics and chemistry content. However, after taking the different science subjects of the Degree, these differences disappear. Likewise, background studies are not a variable that significantly affects the emotional dimension of pre-service teachers.

3.3 Self-efficacy in sciences

Figure 4 shows the differences in perceived self-efficacy, before and after taking the science subjects of the degree. On the left (pretest in orange, posttest in green), perceived self-efficacy towards physics and chemistry; and, on the right, towards biology and geology. The violin diagrams show the density of the data at different values. The horizontal boxes represent the distribution of the results. The vertical line within each box represents the median. The limits to the right and left of each box correspond to the 25th and 75th percentiles, and the lower and upper termination of the vertical lines approximate the 5th and 95th percentiles. The raw values were plotted as a "rainfall" under each graph. The lines joining the boxes indicate the significantly different groups (Mann Whitney U, ***p-value <0.001) of the pretest and posttest.

After completing the science subjects, PPT showed a perceived self-efficacy towards physics and chemistry of 6.5 (± 1.6) (being initially 5.2 ± 1.8), and towards biology and geology of 7.6 (± 1.4) (initially 6.7 ± 1.6). The Mann Whitney U test showed (p-value <0.001) that there were statistically significant differences between the perception of self-efficacy towards scientific contents before and after taking the degree scientific subjects.

Exploring the emotional differences considering the background studies of PPT, we conclude that, after completing the science subjects of the Degree, the background studies (SS-H nor S&T) does not influence the PPT' perception of self-efficacy.

3.4 Cognitive dimension

This section presents the results concerning the level of knowledge of prospective primary school teachers before and after taking the science subjects of the Degree in Primary Education.

Firstly, a description of the percentage of correct answers to the different scientific questions included in the questionnaire is given (see Supplementary files). These knowledge questions covered the two scientific areas analyzed: biology and geology, and physics and chemistry. These questions were worked on in the different science subjects of the Primary Education degree. Table 3 shows the percentage of correct answers before taking the science subjects of the Bachelor's Degree and after taking the subjects. Significant differences between the pre-test and the post-test are indicated (* p-value <0.05, ** p-value <0.01 or *** p-value <0.001).

In general, there was an improvement in the percentage of correct answers by PPT. In the area of physics and chemistry, as well as in biology and geology, there were initially many misconceptions. For example, there was confusion between energy sources and types of energy (90% of students got this wrong), considering that we replenish energy when we sleep (80% of the students were wrong), or identifying matter changes of state as chemical reactions (70% of the students were wrong). As for biology and geology, about half of the PPT surveyed believed that the seasons were caused by the rotation of the Earth, and almost 60% believed that the interior of the Earth was made of lava. Additionally, they related global warming to the ozone layer hole (80%).

The knowledge scores for the different areas obtained by PPT after completing the science subjects of the degree course are shown in Figure 5. Without distinguishing between genders or background studies, PPT obtained a 5.72 (±0.9) in physics and chemistry, being a significant evolution in knowledge, since initially obtained in the pretest a score of 4.74 (±1.1) (Mann Whitney U test p-value <0.001). On the other hand, regarding to biology and geology PPT obtained in the posttest a score of 5.82 (±1.5), being also a significant evolution in knowledge, since the initial PPT initially obtained a score of 5.27 (±1.4) in biology and geology (Mann Whitney U test p-value <0.05).

Considering the whole questionnaire, without splitting by areas, the students obtained in the pre-test a 4.96 (±0.9), and in the posttest a 5.77 (±0.9). To know if these differences between the areas were significant, the Mann Whitney U test was applied (p-value <0.001) (Figure 5).

After taking science subjects, PPT significantly improved their level of scientific knowledge. However, these differences, although significant, still have considerable potential for improvement.

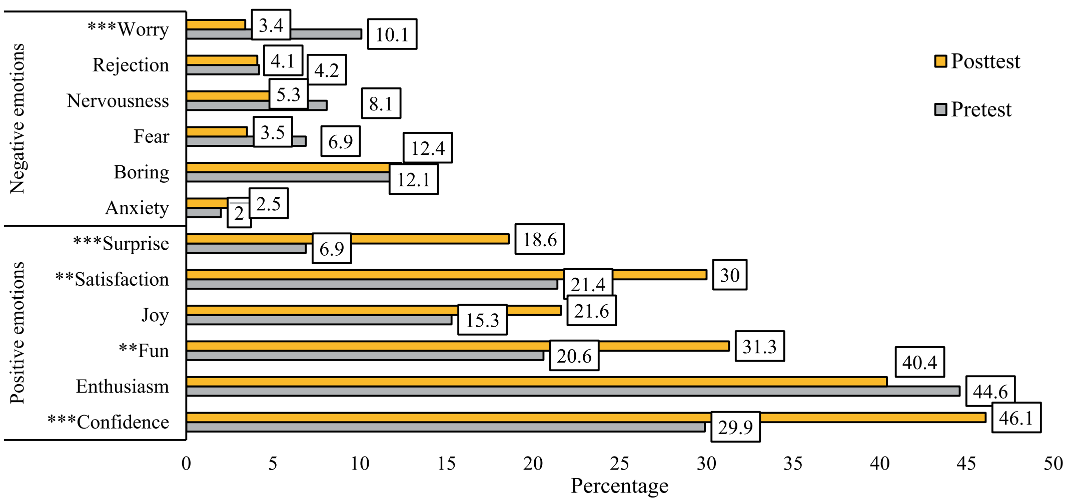

FIGURE 3
Percentage of emotions reported by prospective teachers towards biology and geology content before and after implementing the interventions.

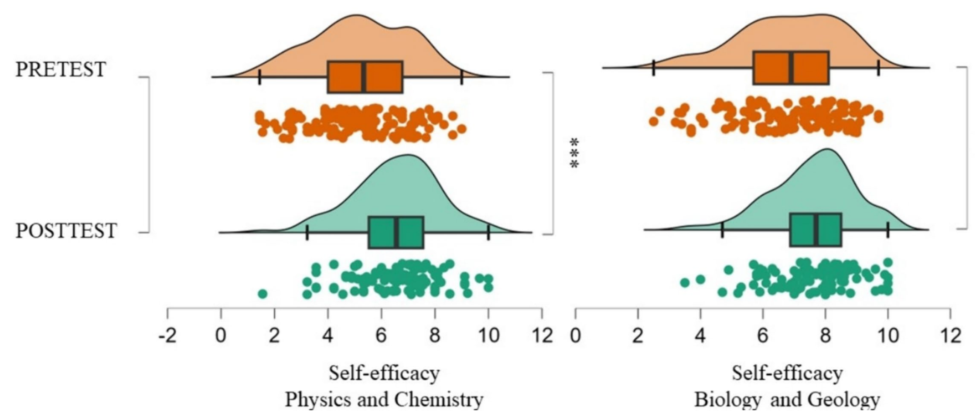

FIGURE 4
Distribution of prospective primary teachers' self-perceived self-efficacy towards physics and chemistry and towards biology and geology.

3.5 Emotional and cognitive dimension, their relation after the intervention

Correlations between the affective dimension and the cognitive dimension of primary school teachers in training were sought. To do this, firstly, the percentages of positive and negative emotions towards physics and chemistry and biology and geology were obtained. Secondly, self-efficacy and the score in the knowledge questionnaire was calculated. Thirdly, Spearman's correlation was used to explore possible associations between the variables. Figure 6 shows a heat map indicating, according to the color represented, the intensity of the associations found between emotions (positive and negative) and self-efficacy perception[2]. To illustrate the extent to which the variance of one variable is accounted for by the other, correlation coefficients appear in the figure. Negative associations are shown in red, and positive associations in purple, with stronger colours indicating a higher degree of correlation. Significance is also showed (****p*-value <0.001; ** *p*-value <0.01, **p*-value <0.05).

The results obtained suggest that there is a significant association between emotions and the perception of self-efficacy of pre-service teachers; feeling positive emotions correlates with having a high perception of self-efficacy (Spearman's rho: 0.658, *p*-value<0.001; Spearman's rho: 0.605, *p*-value<0.001, P&C and B&G respectively). Likewise, a significant association is found between having a low perception of self-efficacy and feeling negative emotions towards scientific content (Spearman's rho: −0.514, *p*-value<0.001; Spearman's rho: −0.493, *p*-value<0.001, P&C and B&G respectively).

On the other hand, Figure 7 shows a heat map indicating, according to the color represented, the intensity of the associations found between emotions (positive and negative) and knowledge scores. Again, negative associations are shown in red, and positive associations in purple, with stronger colours indicating a higher degree of correlation. Significance is also showed (****p*-value <0.001; **p*-value <0.05).

The results show the correlations between the affective domain of PPT and the science knowledge scores obtained in the questionnaires. Correlations were found between variables of the affective and cognitive domains. Thus, our results suggest a relationship of association or interdependence between emotions expressed by PPT and their scientific knowledge score. Therefore, PPT who reported feeling positive emotions will have a better grade in scientific content, thus, expressing positive emotions may be associated with the final grade obtained by the student.

In addition, self-efficacy perception and knowledge score have been also analyzed. Figure 8 shows a heat map indicating, according to the color represented, the intensity of the associations found between self-efficacy perception (toward physics and chemistry and toward biology and geology) and knowledge scores. Positive associations in purple, with stronger colours indicating a higher degree of correlation. Significance is also showed (****p*-value <0.001).

The results show the strong correlations between the self-efficacy perception of PPT and the scientific knowledge scores obtained in the questionnaires. A high perception of self-efficacy is relating to high scores.

4 Discussion

4.1 Does the metacognitive and emotional program during science lessons have any positive impact on the emotions, self-efficacy and knowledge of prospective teachers?

4.1.1 Emotions

The present study aroused as a continuation of previous works carried out by our research group, which showed that teachers in initial training feel negative and repressive emotions towards science subjects (self-citation). Their emotions are also different depending on the content they work on, being more positive towards biology and geology than towards physics and chemistry (Brígido et al., 2012; Dávila-Acedo, 2017). These emotional issues need to be addressed more thoroughly, as the memory of the emotions felt in science

2 P&C: Physics and Chemistry; B&G: Biology and Geology.

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TABLE 3 Percentage of correct answers to each of the questions on scientific knowledge (pre and posttest).

Question	Percentage of correct answers in the pretest	Percentage of correct answers in the postest	*p*-value
MC-Q1	72.9	89	*p*-value>0.05
MC-Q2	61.1	55	*p*-value>0.05
MC-Q3	89.6	89.2	*p*-value>0.05
MC-Q4	36.8	54	*p*-value<0.001***
MC-Q5	93.1	91.1	*p*-value>0.05
MC-Q6	92.3	94.1	*p*-value>0.05
MC-Q7	67.4	74.2	*p*-value>0.05
MC-Q8	68.1	67.3	*p*-value>0.05
MC-Q9	19.5	33.7	*p*-value<0.01**
MC-Q10	21.6	26.4	*p*-value>0.05
MC-Q11	25	46.3	*p*-value<0.01**
MC-Q12	10.4	36.9	*p*-value<0.01**
MC-Q13	68.1	81.3	*p*-value<0.001***
MC-Q14	65.3	69.4	*p*-value>0.05
MC-Q15	34.1	59.4	*p*-value<0.001***
TF-Q1	94.4	96	*p*-value>0.05
TF-Q2	69.4	80	*p*-value>0.05
TF-Q3	66	71	*p*-value>0.05
TF-Q4	29.9	38	*p*-value>0.05
TF-Q5	78.5	87	*p*-value>0.05
TF-Q6	61.1	70	*p*-value>0.05
TF-Q7	10.4	14	*p*-value>0.05
TF-Q8	18.1	39	*p*-value<0.001***
TF-Q9	61.1	57	*p*-value>0.05
TF-Q10	24.3	42	*p*-value<0.05*
TF-Q11	36.8	57	*p*-value<0.001***
TF-Q12	39.6	54	*p*-value<0.05*
TF-Q13	26.4	75	*p*-value<0.001***
TF-Q14	50.0	42	*p*-value>0.05
TF-Q15	47.2	35	*p*-value>0.05
TF-Q16	32.6	77	*p*-value<0.001***
TF-Q17	13.9	19	*p*-value>0.05
TF-Q18	77.1	79	*p*-value>0.05
TF-Q19	57.6	71	*p*-value<0.05*
TF-Q20	67.4	56	*p*-value>0.05
TF-Q21	46.5	62	*p*-value<0.05*
TF-Q22	38.9	46	*p*-value>0.05
TF-Q23	29.2	36	*p*-value>0.05
TF-Q24	41.7	51	*p*-value>0.05
TF-Q25	18.8	22	*p*-value>0.05
TF-Q26	59	61	*p*-value>0.05

subjects when the PPT were students is transferred to what they feel as teachers (Brígido et al., 2012).

The results obtained in this work support that the metacognitive and emotional program implemented influenced the emotions, self-efficacy and knowledge of PPT. The authors consider a positive effect on emotions to be when PPTs feel significantly more positive epistemic emotions after the implementation of the program. After its implementation, future primary school teachers reported feeling more *fun*, *surprise*, *confidence* and *satisfaction* towards scientific contents, both in the case of physics and chemistry and in the case of biology and geology. Our findings are consistent with other research that implemented interventions in teachers' science training and succeeded in changing their affective dimension during science learning (Dávila-Acedo et al., 2015; Retana-Alvarado et al., 2018). Pipitone et al. (2019) focused on the effect of teaching methodology on the emotional change of a sample of pre-service teachers after taking the subject Didactics of Matter, Energy, and Interaction, with pre-service teachers reporting *curiosity*, *interest,* and *enjoyment*. There are also longitudinal studies that describe the emotional change of pre-service teachers, where the authors link this change to the integration of emotional education in science teaching, which motivates well-being in interpersonal relationships (Retana-Alvarado et al., 2018).

Nonetheless, *anxiety* toward physics and chemistry content has also increase significantly during the program. Although anxiety is described by Bisquerra (2015) as an emotion which is placed at the antipodes of well-being, some authors have claimed that the presence of these emotions in learning could improve their outcomes. Anxiety is one of the most common emotions in learning science and mathematics, both in school-aged students and in higher education (Wahid et al., 2014; Szczygiel, 2020). Palacios et al. (2013) argue that there is an ideal level of anxiety. High levels of anxiety facilitate mechanical learning in simple tasks but lead to poorer results in creative situations. Bausela (2018) relates anxiety and performance by saying that 'a certain level of anxiety is necessary to be efficient, but exceeding this level can hinder or even negatively affect performance' (p. 169). In addition, this research was conducted during the outbreak of the COVID-19 pandemic, when lockdown measures were imposed to control the spread of disease, forcing education (at all levels) to become virtual, which had a serious impact on the emotional dimension of young people (Chandra, 2021). The results of this research may also have been influenced by a general feeling of anxiety and concern among the population about the situation at the time. Research by Niño-Carrasco et al. (2021) suggests that those university students who participated in distance learning as a result of the health emergency had different experiences to those students with planned online learning, with differences in the general evaluation of the experience, in the design of the activities and in the evaluation.

What is of interest, apart from determining whether the emotions felt by the students are positive or negative, is to reflect on whether the students have a predisposition in the classroom that leads them to be active and attentive, allowing them to develop characteristics and qualities inherent to the construction of scientific knowledge such as curiosity, rationality, uncertainty, perseverance, and scepticism…, it is not contrary to learning that students experience *frustration*, *anxiety* or *worry* about what is to come; on the other hand, students who are *confident* and *calm*, does not ensure that they will engage in learning. While Pekrun and Stephens (2010) classify *frustration* as an activating emotion, other researchers, such as Díaz and Flores (2001), include it in the taxonomy of deactivators. In the classification proposed by Díaz and Flores (2001), *rejection* (within the aversion family) is presented as a slightly activating emotion, and *uncertainty* (within the doubt family) as a highly activating emotion.

4.1.2 Self-efficacy

García-Ruiz and Sánchez (2006) showed that the problem is that teachers in general do not feel well prepared or confident to teach science. These authors highlight that it is necessary for teachers to have an adequate scientific background. This should be provided during their training. We find that, PPT report low self-efficacy, especially towards physics and chemistry. Klassen and Chiu (2011) find that self-efficacy changes with experience, being lower in the initial stages and in teacher training. Künsting et al. (2016) state that self-efficacy increases with experience until it stabilises at a point where it does not fluctuate much.

Bellová et al. (2018) explored how to increase the effectiveness of teaching natural science subjects, and revealed that understanding how science works involves a synthesis of (a) content—the knowledge of facts, concepts, ideas and theories, (b) procedural—the procedures scientists use to establish scientific knowledge, and (c) epistemic knowledge—which refers to understanding the role of specific constructs and defining characteristics that are essential to the process of knowledge construction in science. The challenge is to elicit positive emotions and make the experience exciting by initiating some of these scientific principles during the instruction of future teachers and to train future teachers who know how to do science.

The results obtained with respect to self-efficacy and emotions are shared with Stephanou and Oikonomou (2018) who find strong correlations between feeling negative emotion (such as anxiety or fear) and having a low perception of self-efficacy. Sevinç et al. (2011) find correlations between feeling positive emotions and having higher perceived self-efficacy.

4.1.3 Scientifical knowledge

With regard to the cognitive evolution experienced by prospective primary school teachers during the course of their scientific education, it can be seen that there is an increase in the level of scientific knowledge. However, this increase cannot be only attributed to the interventions carried out (each of these has been partially analysed in the studies that are part of Table 2). Science teacher training is an important topic. Whereas proper didactic knowledge of content must integrate different elements (didactic strategies, assessment strategies, knowledge of the curriculum, classroom management, etc.) an adequate knowledge of subject content is essential for effective science teaching (Kind, 2009).

In general, carrying out practical laboratories, outdoor activities, and practical interventions with teachers in training improves not only their emotional dimension, but also improves the level of

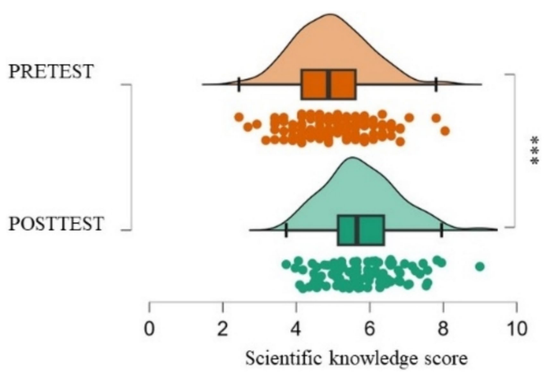

FIGURE 5
Evolution of the score obtained by prospective teachers before and after taking the science subjects of the degree course.

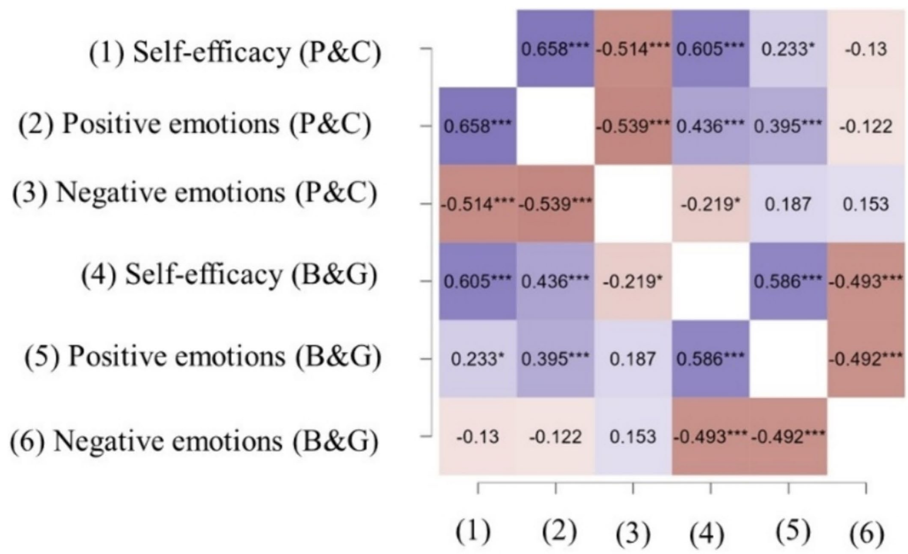

FIGURE 6
Heat map showing the correlation between emotions and self-efficacy toward sciences.

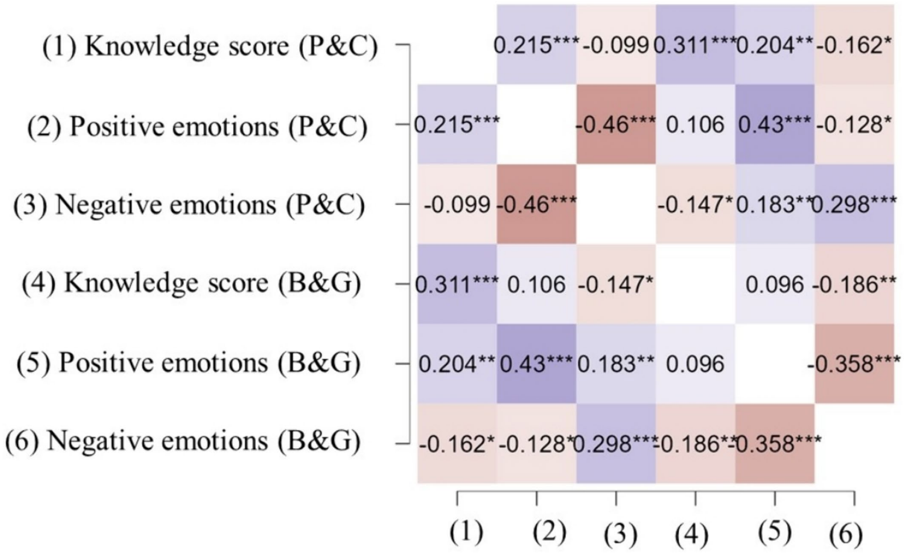

FIGURE 7
Heat map showing the correlation between the affective domain and the cognitive domain.

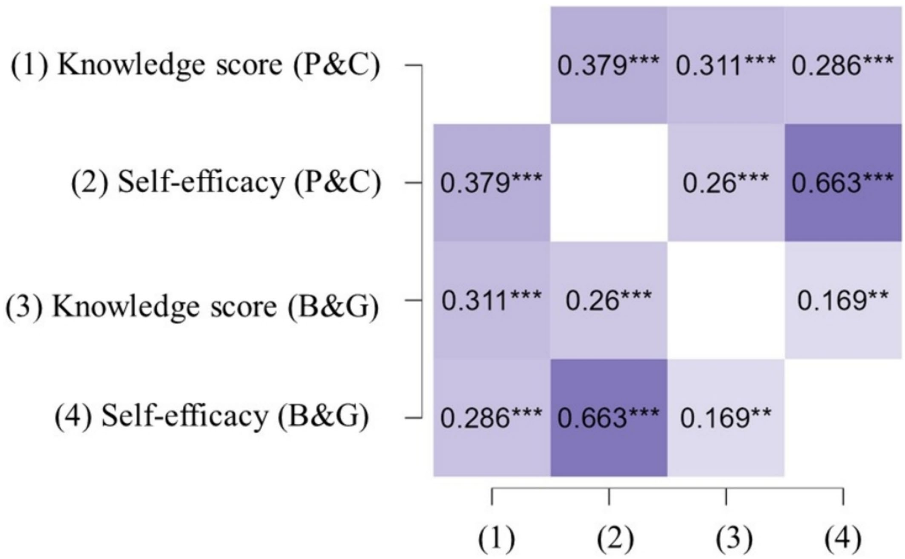

FIGURE 8
Heat map showing the correlations between the self-efficacy perception and the knowledge score.

knowledge and encourages the acquisition of scientific skills (such as the manipulation of instruments), making learning more motivating and generating greater tranquility and well-being (Dávila-Acedo et al., 2021; Bravo-Lucas et al., 2022). At the same time that they can acquire scientific skills, they can also be trained to live healthy, sustainable and complete lives. The inclusion of this type of scientific activities with teachers in training is necessary to improve environmental attitudes and behaviors (Marcos-Merino et al., 2020). Wilhelm et al. (2019) call for the development of pedagogical as well as didactic knowledge during science teacher training, as PPT must learn scientific knowledge at the same time as they must be oriented towards pedagogical learning.

4.2 Is it possible to find an association between the affective and cognitive variables analyzed?

Throughout this work, the undoubted effect of emotions on learning is argued, aiming to find out whether there is a link between affective variables (emotions and self-efficacy) and scientific knowledge. The results obtained suggest that there is a significant relationship between the level of scientific knowledge and the PPT emotions reported by PPT and their self-efficacy perception. In recent decades, researchers in the field of educational psychology have begun to investigate the functions and consequences of feeling emotions (both positive and negative) during learning; however, a full understanding of how epistemic emotions contribute to learning processes remains elusive (Nerantzaki et al., 2021; Ezquerra et al., 2023).

This research does not narrow down the effect of emotion, but works with the construct of "affect" (Barrett and Bliss-Moreau, 2009), which is a kind of conceptual umbrella that encompasses moods and emotions, where valence and level of activation matter (Russell and Carroll, 1999).

The role of emotions in learning is determined by the relationship it has with other essential aspects in the teaching and learning processes, such as curiosity, attention, motivation, or decision-making (Mora, 2012). For learning to occur, attention is required (Solís and López-Hernández, 2009). No attention, no learning (Mora, 2017). In order to acquire knowledge and learn, students need to be focused during teaching and learning activities.

Nowadays, the association between the affective and cognitive dimensions in human beings is undeniable. Emotions influence pupils' learning results (Carmona-Halty et al., 2019). Teachers with high levels of stress reported also higher levels of anxiety and depression, and that may also influence the student's affective experience in learning (Poon et al., 2019), but also a positive association between teachers and students' positive emotions have been found in science lessons (Frenzel et al., 2018): PPTs should be conscious of how they feel.

On the other hand, self-efficacy is a predictor of the academic success, and that is the consequence of the confidence and the students' beliefs that they are skilled of carried out their task (Putwain et al., 2013). Teachers, and their behavior, have an important impact in the academic goals of their students (Eccles, 2009; Eccles and Wigfield, 2020). This is the reason why authors explore affective and cognitive dimensions during prospective teaching training processes.

Our results suggest that PPTs increase their scientific knowledge after having taken science courses. However, this increase cannot only be attributed to the programme implemented. A deeper reflection should be drawn from this. Therefore, since emotions modulate memory processes (Erk et al., 2003) (although the neural substrate underlying these modulatory effects remains incompletely understood), it is necessary to consider the urgency of a methodological change in school teaching. The results obtained in this paper does not mean that students will learn more in a class that provokes intense emotions. This is due to the different memories: episodic and semantic (Tulving, 2002). The fact is that an important difference between semantic and episodic memory is that episodic memory is closely linked to a concrete context (the experience that generated it), while semantic memory is more "abstract" and free of such references. For this and other reasons, the memory-enhancing effect of intense emotional states basically influences our episodic memories, and not so much our semantic memory, which is what we are interested in strengthening in class. Thus, when students do some "exciting" activity in class, the next day they remember mostly what they did, but hardly anything of what they were supposed to learn (Ruiz-Martín, 2024). Academic results depend on other variables than emotions. An interesting topic will not be memorized by itself, on the contrary it will need to stablish a determine learning strategy, to considerate the environment of learning, the time spent on studying, the attention involved, the motivation, the interest or the distribution of resources (Fiorella and Mayer, 2016; Eccles and Wigfield, 2020; Carpenter et al., 2022; Ruiz-Martín and Bybee, 2022). Be that as it may, considering affective dimension of students is essential although learning will not depend only on it.

5 Limitations

Despite the strength of this article, which emerges after the publication of other articles, and it is produced as a compilation and unifying, our results should be interpreted in light of some limitations. The questionnaire implemented has been specifically designed for our context (a particular region with determined students with the described characteristic). The instrument used in this research has been elaborated for that context. Declarative methods have limitations in terms of participant's ability to recognize and verbalize their emotions. This research was conducted during the lockdown in Spain, the emotional dimension of PPTs could have been influenced by many other factors that have not been the subject of this article. The learning outcomes cannot be exclusively attributed to the interventions carried out in the programme as this research is spread over two and a half years and many other variables may have an impact. As declaratives methods also have limitations future studies will investigate the emotional dimension of prospective teachers using artificial intelligence (iMotions® software).

6 Implications

As already advocated by Zabalza (2022), the teaching profession is undergoing major changes and requires lifelong learning. This will be a key point in the improvement of the quality of the teaching profession. To reconstruct the figure of the teacher, the author calls for in-depth reflection. This will have to be done by the teachers themselves, but at the same time there is a need for a reform of the process by which teachers are trained in the education system. The teachers of the future will have to become experts in the didactics of the discipline. It is particularly important to consider the affective domain when training teachers, and in particular when training them in science. In this paper, the results suggest that the affective domain of prospective teachers can be modified during teacher training. These results can be extended to primary and secondary education, as these students also report high levels of negative emotions towards science. It is possible to improve the affective domain of the students through the implementation of active methodologies that include everyday problems, based on motivational methodologies and an interdisciplinary perspective.

7 Conclusion

This study provides evidence for the development of an intervention program with prospective primary teachers with and extent of two academic years and a half and the impact that the implementation of different strategies has had on their emotions, their perception of self-efficacy and their level of scientific knowledge. After taking the science subjects of the Primary Education Degree, teachers in training experience a favorable evolution in the affective dimensions analyzed, both in emotions and in the perception of self-efficacy, as well as a significant progress in scientific knowledge is obtained.

With respect to the first research question, which sought to analyze whether the implementation of the cognitive program produced any impact on the affective and cognitive dimension of teachers in initial training, it is possible to conclude that after taking the scientific subjects of the degree, teachers indicate significantly more positive emotions after taking science subjects, such us *confidence*, *surprise* or *satisfaction*. PPTs increase their perception of self-efficacy in addition to having higher levels of scientific knowledge. Thus, a deeper investigation should clarify the causes associated to that change.

Regarding the second research question, it is possible to find an association between the affective and cognitive variables analyzed. Furthermore, the enormous influence of emotions on teaching and learning processes has been confirmed several times during the recent years. Positive experiences during the learning process, which can contribute to the improvement of knowledge, could be enhanced by the implementation of active methods.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MAH-B: Formal analysis, Methodology, Writing – original draft. IC-C: Conceptualization, Investigation, Supervision, Visualization, Writing – review & editing. JS-M: Data curation, Funding acquisition, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing. FC-C: Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1355359/full#supplementary-material

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