An approach to epistemic emotions in physics’ teaching-learning. The case of pre-service teachers

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ABSTRACT

It is well established that emotions play a key role in the teaching-learning process and cognitive and affective factors should receive especial consideration. This fact becomes even more important when dealing with pre-service teachers, since their emotions towards science will be projected into their future practice as early-childhood teachers. It has been also stated the influence of the instructional approach in which the teaching-learning process is based on the emotions of students towards science. In this line, the current study aims to monitor and interpret the emotions of pre-service teachers when addressing physics content learning, namely forces, from two different instructional approaches with increasing experimentality degree and implication of students. The considered instructional approaches consisted on a theoretical problem solving one and a practical one designed in the form of inquiry-based hands-on activities. A sample size of 118 students was considered and a questionnaire was employed for in situ emotions monitorization. A decrease from 30% to 12% in negative emotions and an increase from 85% to 91% in positive emotions was detected when considering the transition from instructional approach 1 (classroom approach) to instructional approach 2 (inquiry-based hands-on approach). The whole dataset was analyzed by means of principal component analysis (PCA). PCA reveals the importance of emotions’ valence, but also their activating/deactivating character. An approach to epistemic emotions is achieved from this perspective. It has been demonstrated that the implementation of inquiry-based hand-on activities results in increased occurrence of security and trust among the students, in comparison with occurring emotions after receiving more theoretical interventions.

1. Introduction

The importance of emotions for teachers and students, with independence of the educational level is reported in the literature and there is no doubt of the existing connection between cognitive and affective processes [1]. The case of science teaching is not an exception and it has been recognized the crucial influence of the affective dimension, being the affect an emotion involved in parts of scientific processes kind of thinking, acting, knowing, and interacting [2, 3, 4].

Focusing on compulsory education levels, it has reported a higher occurrence of negative emotions towards sciences during the secondary school period than in primary education, together with the marked connotation of difficulty and the conception of sciences as boring, too theoretical, and with little practical application [5, 6]. This is not a minor issue and it has long-term consequences, as for instance this makes them to choose non-scientific career itineraries in higher courses [7]. It is reported the important role of teachers on the development of the affective domain, since for instance, the lack of practical classes turns into increased negative emotions [8]. It has been also stated that there is dependence between the scientific discipline and the emotions. Thus, biology and geology give rise to more positive emotions than physics, chemistry or mathematics [9].

The study of the affective dimension becomes especially important when dealing with pre-service teachers, since their emotions to science will have a projection in their future exercise of the teaching profession.

1.1. Affective domain consideration through the scientific learning process

Current contexts of permanent change require of a versatile and resolutive citizenship, capable of adapting to uncertain future times. A
solid basic scientific education is important to develop critical sense and also to make appropriate decisions. Educational institutions, especially universities, are responsible of providing the population with a base that enables and promotes lifelong learning. However, and despite the existing commitment with the scientific literacy of the population, it has been detected that over the last decades there has been an abuse of a positivist orientation in science teaching; traditionally, science lessons have been implemented in a very different way than what it really means to “do science” [3]. It is also important to mention that this academic approach, based on the transmission of content, has traditionally excluded the affective domain of students from the teaching processes, considering it inappropriate and unscientific [10]. This has led, on the one hand, to the appearance of numerous conceptual errors in primary and secondary students, and, on the other hand, to the development of undesirable attitudes towards science as students advance through their academic path. Even, usually the reason for students not to continue their higher studies in science, is related to the emotional rejection generated to science matters [10], which is often the result of bad experiences during schooling [11]. In science education there is a well-established trend, developed in recent decades, that addresses among its research emphasis student learning outcomes [16] and they play an important role also in directing attention, which is a requisite for learning [17], but at the same time, research is needed on the impact of the emotional domain and the need of a positive classroom climate for effective learning [18]. It is known that emotions help or obstruct the retention of concepts in the memory, since episodes associated with some emotion are easier to remember and have a longer stay in the memory. With all the above, it can be stated that certain emotions are clearly involved in teaching-learning processes, these are the so-called, epistemic emotions.

1.2. Taxonomy of epistemic emotions

The expression of emotions constitutes a human dimension inherent to its own existence. The heritage inherited from Ancient Greece is full of references to the human affective domain. Since then, emotions and reason have been confronted and placed in opposite poles, with the subsequent creation of the “body-soul” duality, with emotions being almost considered like a threat that hinder the human’s path to happiness “eudaimonia” [19].

Numerous taxonomies and classifications have been developed by different authors [20], but it is a difficult task to make a classification, collecting a moderate number of universal emotions, in which all the authors agree [21] and it is a fact that nowadays there is no agreement in the definition of emotion and its classification. In the current research, the definition of Bisquerra [22] has been considered. According to this author, emotions are reactions of different intensity according to the received information from the environment and the subjective evaluation that each person makes and how it affects the person's well-being.

Regarding the type of emotions expected to be generated in a classroom, a taxonomy based on the epistemological affective dimension constitutes the best choice, considering emotions, feelings and experiences, generated during the construction of scientific knowledge [23]. In that scenario it is important not only to detect if emotions experienced by students are positive or negative, but also to analyze if students possess the predisposition that leads them to be active and attentive, allowing them to develop features related to the construction of the scientific knowledge, like curiosity, rationality, uncertainty, perseverance or skepticism. Experiencing emotions like nervousness, expectation or anxiety is not contrary to the learning. However, when the dominant emotions are confident, tranquility and security, despite being positive emotions, it does not ensure that students are involved in learning. This points in the direction that the classification of emotions as negative or positive has limitations for the study of the influence of the emotional domain in teaching-learning processes. Thus, in this research work, the employed taxonomy considers on the one hand the valence of emotion and on the other hand its degree of activation that the emotion generates, which is in accordance with the more recent trends in the study of the affective dimension in the science classroom [23, 24, 25, 26, 27, 28]. Regarding the valence, an emotion is considered negative when it generates an undesirable sensation, like anxiety, and it is considered positive when it is linked to pleasant feelings, like joy. When the degree of activation that the emotion generates, i.e. the physiological excitation that incite to act, is considered, emotions will be grouped in activating and deactivating, like for instance, enthusiasm and boredom, respectively. Therefore, these reflections invite us to go one step forward from the classic positive/negative division of emotions, to a two-dimensional classification system for emotions considering, as stated above, the valence of the emotion and its degree of activation during the construction of scientific learning.

1.3. Emotions towards physics in pre-service teachers

As stated above, considering the affective domain in education is especially important in the case of pre-service teachers. The practice of any profession without socio-emotional skills is complicated, but in the case of teaching, these skills become essential. The teachers and their behaviors have an indisputable impact on students and their academic achievement [29]. A science teacher should be able to promote epistemological affective environments and also to generate uncertainty sensation to motivate students to get to understand the initially unknown, to select the appropriate difficulty for tasks, to awaken the student’s curiosity and to foster the development of skills that make students feel competent [26].

In general, it could be stated that teachers of initial stages do not feel comfortable or confident when teaching physics [30] and also that they consider physics as a discipline difficult to learn [31]. In fact, the scientific areas in which teachers feel more confident and comfortable to teach it are biology and geology [31]. It is reported that high school students consider physics interesting but difficult; they consider physics like an abstract science that at the same time explains real life and daily observations [32]. The knowledge of the subject is a key factor to feel competent and it becomes a must for teachers to know the content and to know how to teach that content. At the same time, it is important the occurrence of positive emotions in the classroom while teaching physics to pre-service teachers, and also the promotion of their perception of self-efficacy, making them feel competent and prepared for teaching, since it has been stated that improving their psychological features contributes to make their teaching more effective [33].

Two aspects should be developed during learning for effective acquisition of physic contents by pre-service teachers: content knowledge and process skills. On the one hand, content knowledge (or declarative knowledge) corresponds to the formalistic side and comprises theories, facts, and models that students should understand and remind. On the other hand, process skills (also known as procedural knowledge) comprises the techniques employed for the construction of scientific knowledge: observation, measurement and generation of hypothesis. Pre-service teachers should be competent in both domains to be able to understand the concepts and also to implement them [34].

A correct approach to the teaching of physics is developed under the dialectical prism of the “theory-practice” unit, involving students in typical scientific research activities, where the students are protagonists and the teacher collaborates and guides them [35]. Physics is a branch of science with a broad conceptual base, and it has been traditionally taught through formulas and mathematical calculations, making classes difficult and causing students to face numerical operations instead of concepts [36]. Physics teaching should prepare students for the societies of tomorrow, and it should be characterized by a variety of activities, the
integration with mathematical content, and a student-centered and contextualized teaching [32]. It is a must to make pre-service teachers feel prepared to teach physics, to produce a real change in physics teaching, since in their future practice only those feeling confident with their abilities will be willing to take risks of moving away from traditional methodologies [37]. For this, during their training it is highly recommended to develop physics learning experiences through active methodologies to make it easier their future implementation in their professional development. This is why the initial formation of teachers is so important, and pre-service teachers are special students, due to the enormous responsibility they will have as teachers in their future, in transmitting knowledge and emotions to primary school students.

In the experience described in this article, a learning model is implemented that encourages students to participate in the learning process in order to promote the building of knowledge without misconceptions. When students realize that their beliefs, values or knowledge contradict each other some discomfort is generated because when one firmly believes in something that turns out to be false, a conflict is experienced, this is the so-called cognitive conflict [38]. The strategy implemented in this article comprises a practical activity that promotes critical thinking in future teachers through cognitive conflicts. Teaching of physics through the implementation of practical activities helps to promote one of the main competencies that are claimed for the citizens of the 21st century: critical thinking [39, 40]. Teaching-learning strategies based on cognitive conflicts contribute to develop the critical thinking competences.

1.4. The role of active methodologies on the construction of scientific knowledge

The implementation of the European Higher Education Area (EHEA) supposed changes and a renewal of educational policies in European countries in recent decades. These contexts of globalization have required higher education to adjust to these new systems, transforming the teaching and learning processes at the university [41]. It supposed a change in the educational paradigm so that the teaching of students was adapted to the needs of the labor market, placing the student at the center of the teaching/learning process, which must promote continuous and permanent interaction between training and work (lifelong learning).

The current role of universities is not exclusively to train professionals, but also competent citizens able to face future environments and contexts, demanded by new societies. However, the structure of the curriculum does not facilitate critical, innovative, creative learning or the change in the educational paradigm so that the teaching of students was adapted to the needs of the labor market, placing the student at the center of the teaching/learning process, which must promote continuous and permanent interaction between training and work (lifelong learning).

The considered sample consisted on 118 participants (51.2% women, 48.8% men), all of them receiving the experimental approach and 75 of them receiving also the theoretical one. The different number of participants in the case of both approaches is due to the fact that attendance to theoretical whole group lessons is optional, but in the case of the experimental approach, the attendance laboratory activities is compulsory in order to achieve the portion of the grade corresponding to practical work. Participants integrating the sample were 4th-year pre-service teachers of the Faculty of Education, taking the subject Knowledge of the Natural Environment in Primary Education. This is a compulsory subject of the Degree in Primary Education, with 6 ECTS (European Credit Transfer System) distributed along the 7th semester. The subject is assigned to the Department of Science Education. The subject contents are divided in three units, containing each of them both theoretical content and practical activities, as described below:

i) Unit 1: Current challenges of science education.
   - Practical activities for unit 1: Teaching and learning activities related with science education. Study of the presence of science content in the Primary Education curriculum.

ii) Unit 2: Learn to teach sciences in Primary Education through diverse strategies.

The current piece of research constitutes a concrete study focused on physics contents with the aim of contributing to the improvement of instructions, from the emotional point of view. Namely, it is addressed the following research question: Does the implementation of manipulative activities imply an improvement of the emotional performance of pre-service teachers towards physics curricular content?

Considering the addressed problem, the main objectives of the current research could be enounced as follows:

1) To report two instructional approaches with increasing experimentality degree and implication of students to address a physical problem consisting on determination of friction coefficients on inclined planes via vector decomposition of forces.
2) To monitor students’ emotions when receiving both interventions for further analysis of the affective domain.

2. Materials and methods

It is presented an exploratory study in which it has been employed a questionnaire for quantitative data collection. Data have been further analyzed by means of Principal Component Analysis.

Ethical standards of Helsinki declaration (1964) were followed for data from individuals collection. The anonymity of individuals was guaranteed by a double-blind procedure and informed consent was obtained from all of them. The current study is considered by the corresponding ethical committee (Comisión de Bioética y Bioseguridad, Universidad de Extremadura) as those with no need for specific approval procedure.

2.1. Sample description and syllabus contextualization

This study was carried out at the University of Extremadura (Spain). The considered sample consisted on 118 participants (51.2% women, 48.8% men), all of them receiving the experimental approach and 75 of them receiving also the theoretical one. The different number of participants in the case of both approaches is due to the fact that attendance to theoretical whole group lessons is optional, but in the case of the experimental approach, the attendance laboratory activities is compulsory in order to achieve the portion of the grade corresponding to practical work. Participants integrating the sample were 4th-year pre-service teachers of the Faculty of Education, taking the subject “Knowledge of the Natural Environment in Primary Education”. This is a compulsory subject of the Degree in Primary Education, with 6 ECTS (European Credit Transfer System) distributed along the 7th semester. The subject is assigned to the Department of Science Education. The subject contents are divided in three units, containing each of them both theoretical content and practical activities, as described below:

i) Unit 1: Current challenges of science education.
   - Practical activities for unit 1: Teaching and learning activities related with science education. Study of the presence of science content in the Primary Education curriculum.

ii) Unit 2: Learn to teach sciences in Primary Education through diverse strategies.
- Practical activities for unit 2: Teaching and learning activities related with teaching and learning sciences in Primary Education. Proposal of an instructional unit for science content included in the curriculum of Primary Education.

- Unit 3: Contents of science for Primary Education. Projects and lesson plans on the curriculum of knowledge of the natural environment in Primary Education. Resources and teaching materials.

- Practical activities for unit 3: Teaching and learning activities related with contents of science education in Primary Education. Implementation of practical activities related to science contents included in the curriculum of Primary Education.

The experience presented in this article is mainly associated to unit 3 and its practical activities.

The subject is taught during a whole semester, and the time distribution for each unit and their practical activities is summarized in Table 1.

The total capacity of the class is limited to 90 students and the student’s demand is normally above it, because, as stated above, it is a compulsory subject. The whole group lessons included all the students enrolled in the subject, this was around 90 students and these lessons were developed in the classroom. To perform practical activities, the whole group was divided into three subgroups of around 30 students, to perform practical activities in the laboratory. Attendance to theoretical whole group lessons is optional, but in the case of practical activities in the laboratory, the attendance is compulsory.

The subject assessment contemplates a global evaluation system with relative weights of 60% and 40% of theoretical content and practices, respectively, on the final mark.

There are not specific course prerequisites to take this subject, but as stated above it is taught in the 7th semester of the Degree in Primary Education, when pre-service teachers have already taken the following two specific subjects related with science education: “Teaching on matter and Energy” (4th semester), and “Earth and Life Science Education” (6th semester).

Students taking the subject in which this research has been developed are extremely low motivated towards sciences. Different reasons could be cited as the causes of this low motivation, among them: their academic background, since most of them get to the University from humanities or social sciences itineraries; lack of immediate application of scientific contents under their point of view; or the perception of scientific content like out of scope for pre-service teachers training.

2.2. Instruction description

The instructional approach, sample details and followed procedure are schematically represented in Figure 1. The selected disciplinary content was related to dynamics, namely determination of friction coefficients on inclined planes via vector decomposition of forces. The selected content was addressed from two different instructional approaches. The considered approaches consisted on a theoretical problem posed to the students to be solved. In Figure 2 it can be found a typical example of problem contemplated, namely to practice with forces decomposition and to interpret friction forces.

As concepts are contemplated in class, different problems are proposed to the students to be solved. In Figure 2 it can be found a typical kind of problem contemplated, namely to practice with forces decomposition and to interpret friction forces.

Description of instructional approach 2.

The practice was mainly designed as an inquiry-based hands-on activity and although some indications were given to the students, they were encouraged to design a procedure to get to the asked results.

Students were asked to experimentally determine the static friction coefficient between a metallic plane surface and a cardboard box and between a rubber sheet and a cardboard box. They were also asked to judge, employing the provided material the influence of the following variables in the static friction coefficient: weight of the sliding object, amount of contact area among surfaces and material nature.

Students were provided with the following list of material: inclined plane (Auxilab S.L., Spain); laboratory balance; dynamometer; rubber sheet; cardboard boxes of dimensions around 10cm × 5cm × 2cm; different weights ranging between 5 g and 100 g.

One of the objectives of the practice is to familiarize students with the control of variables. In this case, the variables that can be assayed by students are:

- Sort of surfaces: metallic plane surface or rubber
- Angle of inclination of the plane: 0° to 40°
- Weights inside the cardboard boxes: 5g to 100 g
- Side of the cardboard box: side 10cm × 5cm; side 10cm × 2cm; side 5cm × 2cm

In Figure 3 it has been represented the a priori modelling of the procedure to calculate the static friction coefficient with the provided

Table 1. Subject schedule.

| Unit   | Whole group lessons (classroom). Hours: | Practical activities (laboratory). Hours: | Non-face-to-face work. Hours: |
|--------|----------------------------------------|------------------------------------------|-------------------------------|
| 1      | 12                                     | 3                                       | 20                            |
| 2      | 12                                     | 6                                       | 20                            |
| 3      | 19                                     | 6                                       | 50                            |
| Total  | 45                                     | 15                                      | 90                            |
| (150 h – 6 ECTS) |                                      |                                      |                                |
A 4-kg mass slides down an inclined plane that makes an angle of 37° with the horizontal. The mass falls with an acceleration of 1.6 m/s². Calculate the value of the kinetic friction coefficient between the mass and the plane.

**Solution:**

\[|F| = 40N\]
\[|F_x| = 40N \cdot \sin37 = 24.1N\]
\[|F_y| = 40N \cdot \cos37 = 31.9N\]

\[\text{Net force} = 4kg \cdot 1.6 \frac{m}{s^2} = 6.4N\]

\[\text{Net force} = |F_x| - |\text{Kinetic friction force}| \Rightarrow 6.4N = 24.1N - |\text{Kinetic friction force}|\]

\[|\text{Kinetic friction force}| = 24.1N - 6.4N = 17.7N\]

\[|\text{Kinetic friction force}| = \mu_{\text{kinetic}} \cdot |N| = \mu_{\text{kinetic}} \cdot |F_y| \Rightarrow 17.7N = \mu_{\text{kinetic}} \cdot 31.9N \Rightarrow \mu_{\text{kinetic}} = \frac{17.7N}{31.9N} = 0.55\]

**Figure 2.** Solved typical problem on forces decomposition and friction forces calculation proposed to students.

**Figure 3.** *A priori* modelling of the procedure.
material and to judge the influence of the variables weight, amount of contact area and sort of material.

During the development of the activity, students were asked to work by themselves and deviations from the a priori modelling were identified. The teacher acted as collaborator and guide, trying to redirect them. It was a general perception among students that they felt they were doing science and they perceived like amazing touching and practicing with a real inclined plane, something that before the experience they had seen only in schemes.

### 2.3. Research method and instrument

It was employed a custom-designed anonymous semi-open questionnaire for in situ emotions monitorization (Figure 4). The questionnaire was adapted from the originally proposed by Romero-Gutiérrez et al. [49]. Eight emotions were considered, namely, rejection, shame, boredom, insecurity, trust, concentration, interest and satisfaction. Those emotions were presented randomized in the questionnaire. The convenience and representativeness of this selection of emotions is supported in the literature [18, 25, 37]. Students were asked to anonymously fill-in the questionnaire at the end of the theoretical class session and at the end of the practical one. For each emotion students had to mark “yes” or “not” and in case of marking “yes” they could specify when they experienced the emotion and in case of marking “no” they were asked to briefly explain why they did not feel it, as shown in Figure 4.

### 2.4. Data analysis. Principal component analysis

A first transformation was performed on the collected set of data in order to make it possible to analyze it quantitatively. Takin into account the previously described questionnaire, the answers of the students were collected as “yes” or “no”; these answers were computed as 1 or 0, respectively, enabling its quantitative analysis. Then, the resulting dataset was arranged in matrix form, resulting a matrix of size $193 \times 8$ (193 answers from students and 8 monitored emotions). The resulting dataset was analyzed by means Principal Component Analysis (PCA).

PCA was carried out with the software The Unscrambler (v. 9.8, Camo AS, Oslo, Norway).

Principal Component Analysis is a statistical dimensionality reduction technique. It works mapping a certain d-dimensional space into a k-dimensional subspace, being $k < d$. In other words, PCA is able to summarize or extract the relevant information contained in the original dataset. It is especially useful when dealing with large and complex datasets. It helps for instance, to determine how similar or different are samples among them, to identify sample grouping patterns or to identify variable correlations. PCA transforms the original variables into a new set of underlying or latent variables, generated as linear combinations of the original ones, the so-called Principal Components (PC). The first PC collects the greatest amount of variance of the original dataset, the second one collects the maximum of the remaining variance, and so on.

PCA possess high potential for data visualization. The new axes system (PC) will be placed in the direction of maximum variance of the data. Results from PCA can be represented in two complementary graphs: the loadings and the scores plots. The loadings plot can be considered as a variables' map and it is useful to identify variables' correlations, considering that variables presenting high loading values for the same PC are highly correlated. The correlation is positive when the loading values have the same sign and it is negative when they have opposite signs. The magnitude of the loading of a certain variable in a certain PC is a measure of the extension in which that variable contributes to that PC. The meaning of a PC is determined by the variables with higher loading values on it. On the other hand, the scores plot is a samples' map, in which it can be visually judged how similar or different are the members of the sample among them. Briefly, sample members with close score values in a certain PC can be considered similar with regard to the variables defining the meaning of that PC. The scores plot is especially useful to identify sample patterns.

PCA is presented in the current piece of research as a novel technique for dimensionality reduction on educative data and on the basis of the related literature in related fields. In previous works it has been stated its usefulness for speech emotion recognition or human's emotional state analysis [50, 51, 52, 53]. Works have been also reported in the field of psychology demonstrating its usefulness for instance for the analysis of regulation of emotions [54, 55, 56].

### 3. Results

Initially, and in order to get a first and simple impression of the results, the totality of the experienced emotions in both phases of the intervention were analyzed from the perspective of their valence. With this purpose, rejection, boredom, shame and insecurity were treated as negative emotions while concentration, interest, trust and satisfaction were considered positive ones. Percentages for both groups of emotions in the classroom-approach and in the practical-one were directly calculated. A decrease from 30% to 12% in negative emotions and an increase from 85% to 91% in positive emotions was detected when considering the transition from instructional approach 1 (classroom approach) to instructional approach 2 (inquiry-based hands-on approach).

After this first impression was obtained, the complete dataset was analyzed by means of PCA. As stated above, the first principal component (PC1) captures the greatest amount of the variance of the original dataset, namely 82% in this case, while the second principal component (PC2) collects the maximum of the remaining variance, 7% in this case. The obtained loadings and scores plots for the plane defined by the two first PC are represented in Figures 5 and 7, respectively.

As shown in Figure 5, the emotion shame is located very close to the origin of coordinates since it presents low loading values for PC1 and PC2. This means that it contributes in a very little extension to the sample variance, and interpretations based on the obtained results for that emotion are irrelevant for the current dataset. A cluster containing emotions interest, concentration and satisfaction can be observed in the right side of the graph. These emotions present high positive loading

| REJECTION  | □ NO. Why? | □ YES, I have felt it when… |
| CONCENTRATION | □ NO. Why? | □ YES, I have felt it when… |
| INSECURITY | □ NO. Why? | □ YES, I have felt it when… |
| INTEREST | □ NO. Why? | □ YES, I have felt it when… |
| BOREDOM | □ NO. Why? | □ YES, I have felt it when… |
| TRUST | □ NO. Why? | □ YES, I have felt it when… |
| SATISFACTION | □ NO. Why? | □ YES, I have felt it when… |
| SHAME | □ NO. Why? | □ YES, I have felt it when… |

Figure 4. Extract of the employed instrument.
values for PC1. In other words, these three emotions are positively correlated. This makes sense, since students showing interest, normally experience satisfaction and concentration as well. At the same time, these emotions are negatively correlated with emotions rejection and boredom, which present low values for PC1. The emotions trust and insecurity also present high and low loading values on PC1, respectively. Thus, it can be said that PC1 represents positivity/negativity or in other words, PC1 seems to represent the emotions’ valence. On the other hand, focusing now on the second principal component (PC2), it is found that the emotion presenting the highest loading value for this PC is insecurity, followed by trust in the positive and negative sides of the axis representing PC2, respectively. The positioning of both emotions in the opposite sides of the axis means that these emotions are negatively correlated. This also makes sense, it is common that students showing insecurity do not show trust. Those emotions, insecurity and trust, have been traditionally considered as negative and positive, respectively, under the classical division which considers only their valence, but the obtained results on a real sample clearly show that their behavior is different from the rest of negative and positive emotions, respectively. Besides of being considered negative from the valence point of view, insecurity is an activating emotion, since it keeps students out of their comfort area, i.e. it contributes to keep students activated. In the same line, trust is considered a deactivating emotion. Having trusted students and the subsequent relaxed and comfortable classroom environment, might turn into a deactivated learning process. As it can be observed in Figure 5, insecurity and trust are located in opposite direction along the vertical axis (PC2), which means that both variables are negatively correlated. This makes sense since insecurity and trust are opposite emotions. If as stated above PC1 represents the valence of the emotion, PC2 seems to be related to the activating/deactivating character of them, as depicted in Figure 6.

The classification of emotions as positive and negative is a good initial approach and it might be useful for instance for emotions selection. However, a comprehensive interpretation of the results obtained with a real dataset, like the current one, cannot be performed in deep when it is exclusively based on emotions valence and the consideration of other criteria, like the activating character of emotions in this case, is a must to understand the information included in the dataset. Thus, the obtained results lead us to reflect on the taxonomy of emotions and, according to the physiological effect produced by emotions, overcome the classical positive/negative dichotomy and move closer to a taxonomy of epistemic emotions related to the reaction of students during the development science teaching-learning processes.

The analysis by means of PCA provides also a second graph, the scores plot. It is common practice to interpret it once the loadings plot has been analyzed and the meaning of each PC has been determined. As stated above, the scores plot is really useful to study how different or similar behave the sample member among them and to identify possible sample grouping. Figure 7 shows the scores plot in the plane defined by the two first principal components, PC1 and PC2. Sample members are not especially grouped along the horizontal, i.e. along PC1, however a certain separation of sample members is observed along the vertical (PC2). This sample grouping in two clusters is more obvious when sample members are labelled according to the instructional approach that they received. In this case, it is found that PC2 is able to separate students, according to the instructional approach in which the instruction they received was based on. As it is observed in Figure 7, students whose emotions were monitored after receiving the inquiry-based hands-on session are located in the bottom of the graph, while those whose emotions were monitored after the theoretical problem-solving session are located in the top of the graph. Consequently, PC2 which is related to the activating/deactivating character of emotions, performs students’ separation, according to their emotional status, as a function of the employed instructional approach. It is found that students after receiving the inquiry-based hands-on instruction present higher trust, and those whose emotions were monitored after the theoretical problem-solving session present higher insecurity. Although PC1 do not distinguish students when attending the classroom session and the lab one, it is important to notice that in the scores plot, a higher number of samples can be found at the right of the PC1 axis than at the left, which means that positive emotions are prevalent.
4. Discussion

The study of affective dimension of the sciences teaching-learning process is nowadays a well-established research line in science education. There is an important number of researchers training pre-service teachers and working on the emotions they manifest while learning science [16, 18, 57, 58, 59, 60, 61, 62, 63]. It is important to make pre-service teachers aware of their emotions in order to induce changes in their attitudes to make them feel responsible of the scientific and human development through the implementation in their future classrooms of Primary Education of positive teaching strategies [47, 57].

The emotional benefits of the implementation of active methodologies in science education of undergraduates is reported in the literature [47, 64]. Studies are also reported stating emotional improvements in pre-service teachers, after the implementation of active methodologies, highlighting the employed methodology [18].

It has been addressed in the literature [18] the emotional change of pre-service teachers when receiving lessons about the teaching of content related to physics and chemistry. An improvement in emotions and attitudes towards science was observed, associating this change with the employed methodology, which implied the assumption of a leading role by means of the student.

In the current work we were interested in differentiating the emotions experienced by pre-service teachers when employing with them different strategies for physics teaching: a purely theoretical approach and another eminently practical one. The identification of the experienced emotions is important, since it is known that experiencing positive emotions favor learning, while experiencing negative emotions limit the students’ ability to learn. The achieved results are in the line of those reported by Sarıkaya in 2007 also for physics teaching with pre-service teachers [43]. Based on the obtained results, it could be stated that practical activities might suppose an alternative to traditional teaching methods in order to overcome the establishment of misconceptions about physics in pre-service teachers training.

Previously published articles establish higher occurrence of negative emotions toward physics than to natural sciences [31]. The occurrence of negative emotions towards physics monitored in the current study, especially in the case of the theoretical approach, points in the same direction.

The implemented instructional approach is based on didactic models developed to make more effective and motivating physics’ teaching: the starting point is a scientific research and students, in a collaborative manner, participate actively in the construction of their own knowledge, acting the teacher as a guide and collaborator [35].

Research conducted by Hirça [34] shows that pre-service teachers perceive that hands-on physics experiments contribute to improve students’ scientific process skills. The implementation of inquiry-creative-process promotes critical thinking ability of physics in the case of pre-service teachers, including aspects like analysis, inference, evaluation and decision making, through the following four phases of learning: establishing problems; creating hypotheses; creatively designing of experiments; creatively solving science problems; and creatively designing products [39].

The use of mathematics to describe physics phenomena is considered a problem by physics teachers, and some of them even propose to include mathematics formation in physics courses. However, students find it more problematic the extensive curriculum and fast progression [32].

Sanchez-Martín et al. [15] analyzed the emotional responses of a sample of teachers towards different methodologies for science teaching. Emotions were monitored through oral presentation with audiovisual back-up, directed research, oral presentation, oral presentation and gamification and manipulative activities. They found significant differences in emotional responses with the different methods, with manipulative methodologies (hands-on activities) combined with gamification, being the preferred methodologies by pre-service teachers to learn science, and the ones that generated the most activating emotions.

Davila et al. [65] reported results for chemistry teaching in accordance with the ones we are presenting in the current work for physics. In their studies, the emotional effect of the implementation of active practical activities in the teaching of chemistry was analyzed with a sample of pre-service teachers similar to the one considered in the current study. It was found increased occurrence of positive emotions and a decrease in the frequency of the negative ones, as a consequence of the implemented active hands-on methodology.

Regarding hands-on activities, in the case of pre-service teachers, it is important to train them in the development of “lowcost” hands-on activities, in many cases with the use of everyday materials, instead of using expensive and sophisticated laboratory facilities. This will be especially useful for their future practice with Primary Education students [34].

Different authors [14, 65] linked positive emotions like pride or hope to performance approach goals and negative predictors like shame or hopelessness to performance-avoidance goals. However, as stated above, the classification of emotions as positive and negative is too simple in this context and all negative emotions should not be considered in the same way. Thus, for instance, emotions traditionally considered negative like nervousness or insecurity, are perfectly compatible with well-motivated students that will be able to connect with the subject and carry out the activities successfully. There are actually publications that classify insecurity as activating [24], although it has traditionally been considered as a negative emotion.

It is necessary for science teachers to promote self-regulation and emotional management for negative emotions that might arise during learning, and the teacher must take responsibility and be aware that primary school students who feel more positive emotions towards the subject will also feel more interest in those subjects. Playing with that can serve to achieve the goal of reversing those negative emotions to ensure that learning experiences are positive [11].

4.1. Research limitations and future lines of work

In the current study a sample of 118 students have been considered. It is not a small sample and it can be considered representative, however increasing the sample size would be welcome. This could be achieved for instance replicating the instruction and monitoring emotions in consecutive academic years. Considering gender of the participants and matching the number of participants receiving both approaches could be also cited as potential improvements. In future studies, it would be advisable to consider not only the valence of emotions, but also their activating or deactivating character, in the emotions selection stage. And of course, the natural future lines of work will imply addressing different science contents, relevant for preservice teachers’ formation, with the proposed approaches or addressing the curriculum contents considered in the current research with different activities.

5. Conclusions

The first conclusion that can be obtained from the presented study is that consideration should be given to the taxonomy of emotions and, according to the physiological effect produced by emotions, overcome the classical and simple positive/negative dichotomy and move closer to a taxonomy of epistemic emotions related to the reaction of students during the development science teaching-learning processes.

Secondly, it has been demonstrated that the implementation of inquiry-based hand-on activities results in increased occurrence of security and trust among the students, in comparison with occurring emotions after receiving more theoretical interventions. The implementation of this sort of didactic strategies supposes a contribution to the scientific-technologic development of the society and to the establishment of a new pedagogic paradigm that responds to contemporary demands. In this sense, reduced students’ groups should be contemplated in
the Universities, since it will enable deepening in contents and having a closer treatment with the student to implement this kind of activities.

The obtained results should make instructor to reflect, especially when designing their interventions for science teaching, since the sort of intervention will have an immediate effect on the emotional performance of the students. This fact takes particular significance when dealing with pre-service teachers, who in their future professional practice will project the experienced emotions through certain curricular context towards their pupils.

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Data availability statement

Data will be made available on request.

Declarations

Author contribution statement

Diego Airado-Rodríguez and Florencia Cañada Cañada: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Additional information

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