Heliyon 8 (2022) e12546

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Is sustainability an exhausted concept? Bridging the gap from environmental awareness to emotional proficiency in science education through integral sustainability

Hernández- Barco Míriam Andrea *, Sánchez-Martín Jesús, Corbacho-Cuello Isaac, Cañada-Cañada Florentina

University of Extremadura, Spain

ARTICLE INFO

Keywords:
Prospective teachers
Higher education
Technology
Water
Affective dimension

ABSTRACT

Sustainability has recently become a common context for science teaching due to its potential in terms of learning the content and promoting such universal values as respect for human rights and for other forms of life, the integral development of the person, or participation in democratic processes. The treatment of the Sustainable Development Goals in higher education, improving environmental awareness and promoting sustainable attitudes through didactic interventions of some depth, is the responsibility of teachers and researchers. This study describes a didactic intervention based on the design, implementation, and testing of a Slow Sand Filter. It was carried out in a science seminar with primary teacher education students (n = 69), and served to promote sustainable awareness in addition to other skills, knowledge and competencies required for the professional development of prospective teachers. The results provide evidence that prospective teachers who feel positive and activating emotions during the implementation of the program think that the experience will modify their way of teaching science when they are teachers. Through this intervention, prospective teachers face real problems, develop sensitivity and critical thinking towards problematic situations that are being experienced on the planet, and improve their environmental attitudes, scientific knowledge, and emotional dimension towards learning the sciences.

1. Introduction

There is a permanent need to consume water on the planet. However, despite the fact that 70% of the Earth's surface is covered by water, it is saline and part of the oceans. Recent reports reveal that 2.3 billion people lacked access to basic sanitation (UNICEF, 2017) and 2.1 billion (1 in 3 people in the world) lacked safe potable water services in 2015 (UNICEF, 2017, p. 29). An effective, cheap, and accessible way to achieve this goal and obtain purified water is the technique of slow filtration with sand (Islam et al., 2013). In teacher training, including an activity in which they design and optimize a filter of this type can serve as a resource to raise awareness, enhance creativity, and generate attitudinal changes that will materialize in a real penetration of the new paradigm of Integral Sustainability (IS) for prospective teachers (PTs). Thus, a cognitive and emotional intervention is proposed with the goal of fostering a raised perception of self-efficacy when carrying out laboratory activities, and of generating positive emotions when dealing with sustainability and learning scientific content related to physics and chemistry that can lead to a structural change in the way the students will teach science. The present research study stands out for (i) being an example of the penetration of Integral Sustainability in the curriculum of the Primary Education degree course, (ii) offering a creative resource that allows sustainable awareness to be promoted in a non-scientific audience, and (iii) showing the emotional benefits and cognitive aspects of its being put into practice in teacher training. The current article discusses if it is worth investing time and resources in the design of didactic interventions to reverse negative emotions towards those areas that have already been shown to generate the most negative emotions. Therefore, the research questions driving this paper are:

1. What emotions do PTs report feeling after an intervention based on Integral Sustainability?

* Corresponding author.
E-mail address: mhdelbarco@unex.es (H.B. Míriam Andrea).

https://doi.org/10.1016/j.heliyon.2022.e12546
Received 16 June 2022; Received in revised form 27 September 2022; Accepted 14 December 2022

2. What assessment do PTs of the intervention?
3. What is the relationship between the emotions, the self-efficacy perception and knowledge?

2. Theoretical background

2.1. Teaching sustainability in higher education: why do we use the problem of water as the axis for the design of our intervention?

In 2015, the United Nations set out the Sustainable Development Goals (SDGs), committing member states to undertake them without leaving anyone behind (UNESCO, 2019). One of them is ensuring global access to clean water and sanitation (SDG 6). In many areas suffering from water scarcity, slow sand filtration is used as a resource to obtain clean water (Islam et al., 2013). Slow sand filtration imitates the purification process that occurs spontaneously in nature when water gushes out from a spring, or rainwater is filtered through the different layers of the Earth's crust to reach aquifers and groundwaters. A slow sand filter (SSF) does not require chemicals or reagents to operate properly, but does require good design and proper maintenance to avoid the filter becoming clogged or declining in efficiency. In addition, the materials necessary for its construction and development do not require any large economic investment, and prospective teachers must learn to include low-cost laboratory practicals in their science classes instead of expensive laboratory equipment, so as to improve the scientific skills of their future pupils (Hırça, 2013).

It might be thought that only engineering or technology professionals need to know these principles. Nonetheless, these issues are not only addressed through scientific communities, but also require social transformation based on active citizenship (Boni and Foguet, 2006, 101–103). To achieve this, a good base could be higher education, although this would require bringing the university closer to society, and presenting current social problems in and from the university. Integral Sustainability (IS) is a new paradigm of understanding sustainability as a polyhedral concept and how sustainability can be considered under the umbrella of the SDGs, including not only environmental aspects, but also sociological, economic, that harmonically enhance the living conditions of human beings (Zamora-Polo and Sánchez-Martín, 2019).

Currently, higher education in Europe is governed by the so-called Bologna Process. These policies are aimed at placing the student at the centre of the teaching and learning processes. As well as meeting the objectives and standards of learning, the students should manage to develop critical analysis, systematic reflection, collaborative decision-making, and a sense of responsibility towards present and future generations (Agbowuro and Keswet, 2016; Hernández-Barco et al., 2020; Tang et al., 2020). Nonetheless, the pedagogical context that envelops teaching about sustainability is focused less on the students' active development of skills than on explaining to them theoretical concepts linked to contamination and practical concepts related to decision-making (Montiel et al., 2018). In this sense, teacher training requires creative and reflective learning that promotes opportunities for students to criticize and review their own teaching processes (Craft et al., 2007).

Several previous studies have pointed out two main ideas: the fact that active methods in higher education actually enhance the teaching-learning process (Jeong et al., 2016), and the idea of the need to include the SDGs in order to promote sustainability awareness (Hernández-Barco et al., 2020; Zamora-Polo and Sánchez-Martín, 2019). The present study's approach to teaching for integral sustainability coincides with what is proposed by Shrivastava (2010): acting sustainably is a consequence of feeling passion for sustainability, and this can be taught through a holistic pedagogy that integrates physical, emotional, and spiritual learning with purely intellectual learning.

2.2. Emotions and self-efficacy

Emotions are reactions of differing intensity that depend on the information received from the environment and the subjective evaluation that each person makes of it and integrates the way in which it affects their well-being (Bisquerra, 2003). In spite of teaching and learning processes that are inevitably charged with affectivity, traditionally science teaching has excluded the student's emotional dimension from the educational processes (Mellado et al., 2014).

Several studies highlight the existence of a problem whose origin might lie in the affective configuration and disposition in the science teaching experienced by the primary teachers themselves, who consider science to be boring and difficult and do not feel prepared to teach it (Menon and Sadler, 2016). In the present research study, what is of interest, beyond detecting whether the emotions that the students feel are positive or negative, is to analyse whether the students find themselves having a predisposition in class that leads them to be active and attentive, and allows them to develop characteristics and qualities for the construction of scientific knowledge such as curiosity, rationality, uncertainty, perseverance, skepticism, creativity, critical thinking, etc. This would facilitate their acquisition of the skills necessary for an IS.

The taxonomy of emotions used in this study is based on different classifications and taxonomies developed by different authors. Ekman (1992) distinguished six basic emotions (anger, disgust, fear, happiness, sadness and surprise) and defends the universality of emotions. Other authors, as Plutchik (2001), Damásio (1994), Ekman and Oster (1981), Goleman (1995) or Izard (2007) also argue for the universality of emotions with other classifications of emotions. However, current trends in psychology research argue that the universality of emotions is a myth (Barret, 2020, p. 67). These varied taxonomies have been later modified by the own experience of our research group (Brígido et al., 2013; Dávila-Acedo et al., 2022; Jeong et al., 2019). Our classification contemplates, on the one hand, the valence of an emotion (negative, if it generates an unpleasant sensation, such as *frustration*, or positive, referring to experiencing pleasant sensations, such as *joy*) and, on the other hand, the degree of arousal (i.e., the physiological arousal that prompts action, for example by feeling *enthusiasm*, or that deactivates and hinders learning, *boredom* for example). The research was based on the analysis of the academic emotions in the taxonomies and categorizations of various authors (Agen and Ezquerra, 2021; Davidson et al., 2020; Hernández-Barco et al., 2021a; Michaelian and Arango-Muñoz, 2014; Tisza and Markopoulos, 2021). The emotions used in this research are listed in Table 1.

Since the affective domain is a complex construct integrated by different domains, this study also analyses the effect that the intervention had on the perception of their teaching self-efficacy, i.e., how it influences their own perception of their ability to teach science content (Bandura, 1997). Self-efficacy dimension is correlated with both emotional and cognitive prospective teachers dimensions, since this factor is a predictor of the behaviour the teachers will have in their classrooms (Borrachero et al., 2013; Mellado et al., 2014) and has and important impact on the academic goals of their students (Eccles and Wigfield, 2002). Self-efficacy influences how we feel, think, and act. This is also related to many other dimensions, which include intentionality, self-regulation, and the reflection that allows us to control situations and has a great impact on our actions and decisions (Code, 2020). Knowledge of the material and mastery of the subject are necessary to be able to feel effective and carry out a task. It is impossible that a teacher will manage to teach something that they do not know, teachers therefore must know

Table 1. List of positive and negative emotions selected for the research study.

Positive		Negative	
Activating	Deactivating	Activating	Deactivating
Curiosity	Confidence	Nervousness	Boredom
Enthusiasm	Satisfaction	Uncertainty	Fear
Fun	Tranquillity	Worry	Insecurity
Joy		Frustration	Rejection
Surprise			

the content and know how to teach it (Mellado et al., 2014). Self-efficacy is a predictor of academic success and that is the consequence of the confidence and the students' beliefs that they are skilled to carry out their task (Putwain et al., 2013).

3. Methods

3.1. Sample

The present research study was developed at the University of Extremadura (Spain) with 69 white Caucasian PTs (52 men and 17 women, mean age = 22 years). The sample was chosen intentionally among students in the fourth year of the Bachelor's Degree in Primary Education, enrolled in the subject of Knowledge of the Natural Environment. Regarding their background studies, around 80 % of the sample had studied a modality of Humanities, Social Science or Arts in upper secondary education and 20 % of them a Science, Health or Technology path to access university studies. These students were preparing to be primary school (6–12 years old) teachers. This sample was chosen conveniently, not randomly, from the population of prospective primary teachers who voluntarily answered a questionnaire about their emotions toward the activity, self-efficacy and scientific knowledge. Written informed consent was obtained from participants and the study was authenticated by the ethical committee (Comisión de Bioética y Bioseguridad, University of Extremadura). Researchers were always present during the implementation of the survey.

3.2. Survey design and data acquisition

For data acquisition, we decided to draft two questionnaires (which are included as Supplementary files). The data was collected using the Google Forms tool. The design used was based on previous research carried out with a similar sample (Hernández-Barco et al., 2021a, 2021b). Before the intervention, a questionnaire was passed out (*pre-test*), and data were collected again after the SSF intervention (*post-test*). The *pre-test* consisted only of two sections: (i) sociodemographic data (age, gender, and background studies), and (ii) test of knowledge about alternative ideas of the physical and chemical properties of water (Giraldo-Toro et al., 2015) and sustainability issues (SDGs, water scarcity, etc.), therefore the affective dimension was not measure at this stage of the research. The *post-test* was divided into four sections: (i) sociodemographic data, (ii) issues related to the affective domain (emotions and self-efficacy perception), (iii) evaluation of the activity, and (iv) knowledge and sustainability test (see Supplementary files).

3.3. Validation and reliability of the questionnaire

The data were analysed using the JASP software package (Amsterdam, 0.16.4.0). After application of the Shapiro-Wilk test, the conclusion was that the sample did not follow a normal distribution, so non-parametric statistics were used for data analysis.

Both questionnaires, *pre* and *post-test*, have been validated by five experts in Experimental Sciences Education, who read, corrected, and suggested improvements which were then incorporated. The questionnaire was in Spanish. The knowledge questionnaire used (*pre-test* and *post-test*) is a validated questionnaire published by Giraldo-Toro et al. (2015). The emotional questionnaire used is a validated questionnaire published by authors (Hernández-Barco et al., 2021b). The value of McDonald's ω allowed us to know the questionnaire's reliability. The result was a value of $\omega = 0.814$, which corresponds to acceptable reliability since it is between 0.70 and 0.90 (Ventura-León and Caycho-Rodríguez, 2017).

3.4. Data processing and analysis

After preparing the questionnaire and selecting the sample, the questionnaire was given to all participants in online format in a regular class where they were voluntarily asked to complete it. After data collection, they were processed and statistically analysed. In order to establish correlations among the students through the intervention (*pre-test/post-test*) while preserving the anonymity of the participants, a "Pre-existing Unique Identifiers" code system was determined, consisting of the exclusive and individual assignment to each participant of a code comprised of a combination of numbers and letters (Audette et al., 2020).

Emotions and self-efficacy of prospective teachers after the SSF implementation has been assessed through the emotional question of *post-test* (see Supplementary file II, question 1) and have been complemented with their causes (see Supplementary file II, questions 2, 3, and 4). Self-efficacy dimension has been addressed through different Likert scale statements (see Supplementary file, question 7). Scientific knowledge and sustainability questionnaire have been implemented twice, before and after the PBL implementation.

Spearman correlations have been used in order to establish the relationship between emotions, self-efficacy and cognitive dimension. Correlation does not imply causation, Spearman correlations test if there are a linear relationship between the variables or not. The relationship between the two variables is denoted by the letter r and quantified with a number, which varies between -1 and $+1$. Zero means there is no correlation, where 1 means a complete or perfect correlation. The sign of the r shows the direction of the correlation, a negative r means that the variables are inversely related. The strength of the correlation increases both from 0 to $+1$, and 0 to -1 (Akoglu, 2018; Dancey and Reidy, 2011).

3.5. Description of the activity: the slow sand filter

The realization of the SSF specifically addresses the content towards which the students had previously expressed feeling more negative emotions and a lower perception of self-efficacy (Hernández-Barco, 2021b). Some of this content is related to fluids, buoyancy, procedures for measuring the mass and volume of a body, separation of components of a mixture by distillation, filtration, evaporation, or dissolution. The analysis of the results led to the following considerations, which are presented in accordance with the objectives that were set.

The activity was developed in the chemistry laboratory in two 3-hour sessions, separate one from the other for a week. *Pre-test* was conducted at the beginning of the implementation. The group-class, divided into teams of three people, had to perform out the following five activities in desired order:

Activity 1. Justify the necessity. This corresponds to the introduction. Why did we choose water as a study topic? The prospective teachers had to design a creative didactic activity aimed at sensitizing pupils from 8 to 10 years of age about the problem of water.

Activity 2. Understand the science of filtering. Scientific principles about the operation of a filter. How does a filter work? Preparation of audiovisual material to explain to a primary education child the scientific foundations of filtration (how it proceeds and what is achieved with it).

Activity 3. Plan the design in accordance with the state of the art. Elaboration of a diagram with the different types of filters, the characteristics of each one, cost estimations, and difficulty of operation.

Activity 4. Determine the operational conditions. Practical experimentation. This comprises two manipulative activities related to the key points of the SSF – on the one hand, that it is slow (it has a small flow rate) and, on the other, that it is made of sand. The first activity is about flow measurement, and consists in measuring volumes and flows of a pump, which will allow them to determine the relationships between the speeds of the pump and the volume of water it moves. The second activity is granulometry, consisting in separating the three fractions of the sand, and calculating the total thickness of the filter bed (estimated and real).

Activity 5. Construction of the prototype and start-up (see Supplementary file III). For the construction of the SSF, the materials necessary are: a 1 L bottle of water, 500 g of sand, a device to hold the filter, a peristaltic water pump, tubing, clean water, dirty water, 3 sieves, test tubes, pipettes, and a drill. In the first place, it is necessary to pierce the cap of the bottle and, using a Pasteur pipette, join the rubber tubes that will serve as pipes for the effluent of clean water. It is necessary to cut the base of the bottle, add the sand in layers (the finest in the lowest layer and the coarsest in the uppermost), and place the bottle on the support. Dirty water is fed in using the peristaltic pump, and this water will fall by gravity to flow out into a container. Subsequently, it is compared qualitatively with three samples of different turbidity (to enhance understandability, some photos of the process have been included as Supplementary files III).

4. Results

4.1. Emotions and self-efficacy

The emotions the PTs reported experiencing after performing the SSF are shown in Figure 1. There stand out *curiosity* (80.0 %) as an activating positive emotion, *satisfaction* (44.4 %) as a deactivating positive emotion, *uncertainty* (37.8 %) as an activating negative emotion, and *boredom* (15.6 %) as a deactivating negative emotion.

In general, after carrying out the activity, PTs indicated a greater proportion of activating emotions (65 %), especially *curiosity*, than deactivating emotions (35 %). The percentage of *rejection* was insignificant (4.4 %) despite the activity being unusual. One can also see that most (70 %) of the emotions indicated were positive. When asked about the causes (see Supplementary file II, questions 2 and 3), the PTs indicated that the main causes generating negative emotions were *the content* worked on (35.6 %) and *personal factors* (35.6 %), and the causes generating positive emotions were *group work* (64.4 %), the *method implemented* (40 %), and *their own attitude* (40 %). When PTs were asked if they had miss something during the SSF intervention (see Supplementary file II, question 4), 35.6 % claimed to miss a better *previous theoretical background* whereas 28.9 % missed *other PBL experiences* during their teacher training.

Self-efficacy perception had been explored through different statements related to the influence of this experience on their teacher capacities (Table 2).

Table 2. Self-efficacy perception after the SSF activity. The level of agreement was explored through a five-points Likert scale. The table offers the results of the percentage of PTs who selected each scale.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
	1	2	3	4	5
After the experience, I feel more qualified to teach science (SE1)	2.2	11.1	42.2	33.3	11.1
After the experience, I feel more qualified to implement a PBL as a teacher (SE2)	0	11.1	31.1	44.4	13.3
Having done a PBL as a student will decisively influence my way of teaching science when I am a teacher (SE3)	0	2.2	15.6	44.4	37.8
Having managed to filter water with a filter made by myself has increased my motivation in science (SE4)	0	2.2	22.2	42.2	33.3
With this project I have realized that I am capable of successfully carrying out scientific experiment (SE5)	2.2	4.4	22.2	48.9	22.2

An overall review suggests that, after the experience, PTs agreed (33.3 %) and strongly agreed (11.1 %) that they felt more qualified to teach science, and they agreed (44.4 %) and strongly agreed (13.3 %) that they felt more qualified to implement a PBL as a teacher. Around 80 % of PTs agreed or strongly agreed that this experience will decisively influence their way of teaching sciences and has increased their motivation in science. Finally, about 70 % of PTs agreed or strongly agreed that after the elaboration of an SSF they realized that they were capable of carrying out a scientific experiment successfully.

A Spearman's correlation analysis was performed to explore the emotional variables that may have a reciprocal character in some dimensions of the PTs' self-efficacy perception. Figure 2 is a colour map of the values of the significant Spearman's correlations between affective and cognitive variables. There were not found any correlation between learning and emotions nor self-efficacy statements. Thus, the emotions which has no relationship with any other item, have not been included in the figure. Those with a positive correlation between the different variables are coloured purple, and those with a negative correlation are coloured red. Significant correlations are labelled with $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

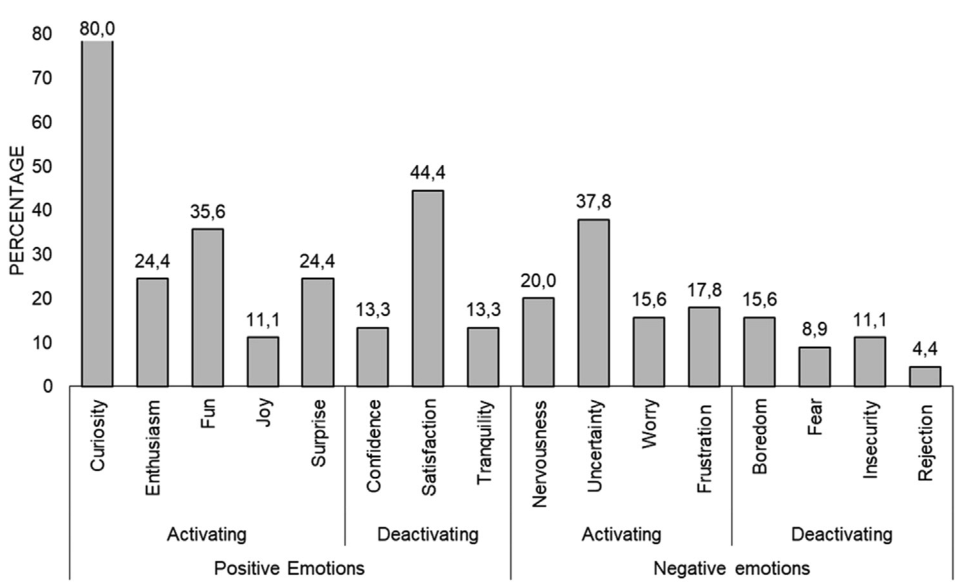

Figure 1. Percentages of positive and negative emotions selected by prospective teachers after the SSF implementation.

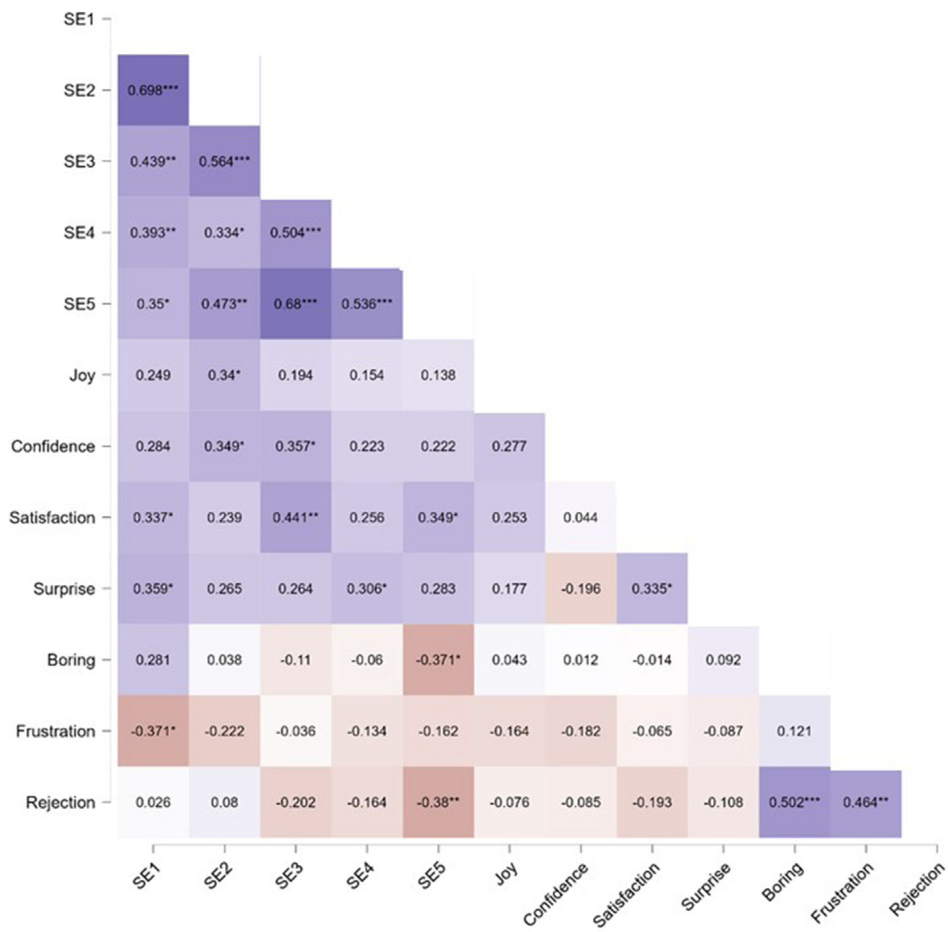

Figure 2. Spearman's correlation coefficients between the different self-efficacy statements after the elaboration of the filter, and the emotions experienced during the practical. Cells coloured purple correspond to a positive correlation, and cells coloured red correspond to an inverse correlation. The intensity of the colour indicates the strength of the correlation (*p < 0.05, **p < 0.01, ***p < 0.001). The numerical values represent Spearman's rho.

First, if we focus on the relations between the affective and cognitive variables that correlate with the item SE1, the results indicate that PTs who presented high levels of *satisfaction* ($p < 0.05$) and *surprise* ($p < 0.05$) and low levels of *frustration* ($p < 0.01$) during the construction of the SSF were also those who felt more qualified to teach science. Secondly, regarding to the SE2, the results suggest that PTs who presented high levels of *joy* ($p < 0.05$) and *confidence* ($p < 0.05$) during the construction of the SSF were also those who felt more qualified to implement a PBL as a teacher. Now, if we focus on the emotions which correlate with SE3, the results suggest that those PTs who felt *confidence* ($p < 0.05$) and *satisfaction* ($p < 0.001$) after completing the practical were those who thought that the experience will decisively influence how they teach science. Regarding to SE4, those PTs who stated feeling *surprise* ($p < 0.05$) during the SSF construction, also thought that their motivation in sciences had increased. And finally, looking at SE5, PTs who presented high levels of *satisfaction* ($p < 0.05$) and low levels of *boring* ($p < 0.05$) and *rejection* ($p < 0.01$) during the construction of the SSF also thought that they were capable of successfully carrying out a scientific experiment.

This model yields very interesting information about the activating and deactivating emotions in teaching. *Confidence*, *satisfaction*, and *frustration* are emotions that are hard to classify. Feeling *confidence* or *satisfaction* (deactivating emotions) during the performance of the activity will positively influence the PTs' self-efficacy, while *frustration* showed an inverse correlation, being therefore negative for the PTs' perception of self-efficacy. These results lead us to further research on emotional arousal. Our perception is that context should be considered for emotions taxonomy, feeling *confidence* or *satisfaction* before an implementation may act as deactivating emotions. However, feeling those emotions after an implementation can be activating.

The questions related to the PTs' self-efficacy are linked to the activating and deactivating emotions they experienced during the intervention. These results lead us to affirm that the implementation of the SSF in teacher training will stimulate the students' emotional dimension in a way that will promote their self-efficacy and influence their method of teaching science. However, it must be borne in mind that the present results only offer information about the strength of the association between the variables. They do not give any information about the direction (which variable makes the other change), and it is not possible to affirm that emotions have a decisive or causal impact on the perception of self-efficacy.

4.2. Scientifical and environmental knowledge

Not only affective but also cognitive dimension have been analysed in this intervention. The scientifical knowledge has been measured through 4 open-ended questions and 5 closed-ended, each one giving 1 point. The percentage of success rate have been included in Table 3 for each question.

The Q1 was an open question where PTs had to answer "Sustainable Development Goals" and mention some of them. In the *pre-test*, 42 % of the respondents answered correctly. Those who failed misunderstood "SDG" meaning wrote *Didactics* instead of *Development*. After the intervention, 88 % of respondents answered the question correctly. However, at the beginning (*pre-test*) only 2 PTs recognised the education goal as

Table 3. Percentage of success in the pre-test and post-test scientific and environmental questionnaire.

	Success rate (%)	
	Pre-test	*Post-test*
1.- Do you know what the SDGs are? Mention some of them (Q1)	42 % 2 %	88 % 46 %
2.- Are there any SDGs related to water? Which ones? (Q2)	5.7 %	42 %
3.- What do you think a slow sand filter can be used for? (Q3)	43 %	95 %
4.- What is the percentage of freshwater on the planet? (Q4)	47.8 %	75 %
5.- Which of the following processes, in which water is involved, are chemical?	49.3 %	53.3 %
6.- What happens when you add a detergent to water?	11.6 %	13.3 %
7.- When comparing bottled water with tap water:	62.3 %	62.2 %
8.- In rivers, the life of living beings develops. In summer, as the temperature rises, rivers contain	55.1 %	62.2 %
9.- By adding chlorine to the water	63.8 %	75.6 %
	Mean ± SD	Mean ± SD
Total score	4.3 ± 2.2	5.2 ± 2.1

SDG. In the *post-test* 46 % were capable to mention some SDG such as Goal 1: No Poverty; Goal 2: Zero Hunger; Goal 3: Good Health and Well-Being; Goal 4: Quality Education; Goal 5: Gender Equality and Goal 6: Clean Water and Sanitation.

Concerning Q2 in the *pre-test*, only 4 PTs wrote "water sanitation", which was considered the correct answer. The rest of the answers were considered wrong, PTs wrote water-related issues but do not stated any SDG, e.g. "dams and reservoirs", "turn off the tap when we brush our teeth" or "related to consumption". In the *post-test*, 42 % set out Goal 6: Clean Water and Sanitation" and Goal 14: Life Below Water.

Respecting the Q3 the answers "to purify water", "to clean impurities from water", "to clean residues contained in water" were correct. In the *pre-test* 43% of the respondents answered the question correctly. 7 % of PTs said they did not know what it could be used for, whereas 7 % PTs stated that SSF could be used for measuring time. The rest thought it could be used for filtering sand, separating sand components or separating sand from liquids. In the *post-test*, 95 % of PTs answered correctly.

With regard to the Q4, between 1% and 5 % of the answers were considered to be correct. In the *pre-test* 52 % of PTs don't know the correct answer whereas in the *post-test*, 75 % of PTs answered correctly.

Despite the increase of success rate is not quite hight (Table 3), the U de Mann Whitney analyses (*pre-test/post-test*) led us to assume a significant increase of knowledge ($p < 0.05$, r: 0.23). However, the scientifical and environmental knowledge remains very low.

Authors have explored correlations between the affective (emotions and self-efficacy) and cognitive dimensions (scientifical and environmental knowledge); however, no significant associations have been found.

4.3. Activity evaluation

Regarding to the evaluation of the SSF, PTs were asked their level of agreement to different five-points Likert scale statements. In Table 4 it is noted that 93 % of PTs agreed or strongly agreed that teaching through active methodologies enhances prospective teachers training, and that they acquire more skills as a teacher than through lectures, while about 90 % agreed or strongly agreed that PBL can develop skills and attitudes in pupils impossible with traditional methods. Also, around 90 % of PTs stated that they had known how to organize themselves during the activity. Finally, 40 % of PTs were undecided about if the inclusion and treatment of the SDGs was easy through this activity, whilst 60 % agreed or strongly agreed.

Table 4. Activity evaluation. The level of agreement was explored through a five-points Likert scale. The table offers the results of the percentage of PTs who selected each scale.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
	1	2	3	4	5
I believe that working through active methods prepares you better and you acquire more skills as a teacher than through traditional classes	0	4.4	2.2	44.4	48.9
I think that I, personally, have known how to organize myself and correctly carry out the tasks proposed	0	6.7	28.9	42.2	22.2
Through project-based learning, skills and attitudes can be developed in pupils, which is impossible with traditional methods	0	2.2	11.1	46.7	40
The inclusion and treatment of the SDGs is easy through this activity	0	0	40	42.2	17.8

5. Discussion

Didactic interventions with PTs in teaching physics and chemistry have already been shown to have a significant impact on their emotions. The studies of Pipitone et al. (2019) carried out with PTs sample, showed how *curiosity* increased from 36 % to 58% after carrying out an intervention. Likewise, Pipitone et al. (2019) analysed the causes and motivating agents of the emotions. The classroom method was indicated by 63 % of the participating PTs as being the main motivating agent of change, and 32 % found the teacher-student bonds to be an emotional promoter.

De Orta et al. (2016) analysed the emotions that different types of activities arouse. The greatest percentage of negative emotions (with *boredom* standing out at 48.9 %) appears when the work is done through traditional and written activities. However, manipulative and investigative activities generate more positive than negative emotions, with *fun* and *joy* standing out. These results are also in line with those of Retana-Alvarado et al. (2018) who describe the emotional change in a sample of PTs after conducting an inquiry intervention in science. They observed how this type of strategy favours the increase of activating positive emotions (such as *interest* and *enthusiasm*) and decreases the deactivating negative emotions (such as *boredom* or *rejection*).

It is important to work on the affective component during PTs' science learning since they do not feel comfortable when teaching sciences (Yates and Goodrum, 1990). The knowledge of the subject is a key factor to feel competent and it becomes a must for teachers to know the content and how to teach it. Besides, it is important the occurrence of positive emotions in the classroom while teaching science during teacher training and also the promotion of their self-efficacy perception, 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 (Klassen and Chiu, 2011; Klassen and Tze, 2014). The challenge is to generate stronger activating and positive emotions that reverse the bad experiences and negative emotions that they felt during their time as schoolchildren and which now prevent them from learning science motivationally and enthusiastically. The next challenge is that when they exercise their profession, they can manage to maintain an emotional climate in class that encourages scientific vocations from an early age.

In our results emotions such as *frustration* or *rejection* showed inverse correlations with increased perception of self-efficacy. 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. We see *nervousness* as having a positive correlation with a high perception of self-efficacy, despite it being classified as a negative emotion. The establishment of a taxonomy of emotions was not one of the objectives of the present study, but to investigate the effect of emotions as a motor for learning and a stimulator in the classroom. Contrary to what might be expected, feeling *rejection*, *frustration*, or *uncertainty* may the PTs to successfully carry out the task and increase their perception of self-efficacy. Therefore, one has to adopt an attitude of defence against these emotions, which initially were categorized as negative. Depending on the tasks to carry out and the obstacles encountered along the way, these emotions will have profound effects on the interest the student feels to continue the project, their motivation to persist, and the strategies they implement to achieve their goal (Pekrun and Stephens, 2010).

The own PTs experience as students (lessons, lectures, methodologies…) led them to construct their model of science (and how to teach it). In general, pupil-centred methods manage to generate more positive and less negative emotions than those with a traditional teaching approach (Jeong et al., 2016). Implementing them in teacher training can promote this change and have repercussions on the PTs' affective domain since success in direct experiences will be a reason to strengthen their personal self-efficacy (Bandura, 1997). Therefore, including this activity in teacher training may be useless both for improving the affective domain (emotions and self-efficacy) and for its repercussions on the cross-cutting training of such necessary skills as critical thinking. Research conducted by Hirça (2013) shows that PT's perceive that hand-on scientific experiments promotes aspects like analyses, inference, evaluation through the following four phases of learning: establishing problems; creating hypotheses; creatively designing of experiments; creatively solving science problems; and creatively designing products.

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., 2009, 2018). Those who feel better prepared are more comfortable in class, feel more positive emotions while teaching, and are more willing to implement methods in class that are distant from the traditional textbook (Borrachero et al., 2013). Through interventions such as that described here, the intention is to generate comfortable classroom climates that allow prospective teachers to feel well-prepared and willing to include integral sustainability as an organizing principle in the day-to-day life of their primary education classrooms. Indeed, that is the great challenge. Wolff et al. (2017) find two reasons why including sustainability in teacher training is a complex issue. Firstly, it conflicts with most political and social trends. And secondly, teacher training is done at universities, and is based on separate academic disciplines. The present study's proposal is to take an interdisciplinary approach that also allows coverage of the skills required in the current context of our century – critical thinking, creativity, collaboration, and communication (Tang et al., 2020), all closely related to IS. Zamora-Polo and Sánchez-Martín (2019) stated that university can be used to extend the concept of IS, which addresses five different dimensions into the key concept of sustainability including spiritual development, equity and global ethics, environmental awareness, development cooperation and global environmental policies. The present study is concordant with the work of Wolff et al. (2017). If we do not educate our PTs in IS, it will be hard for them to be able themselves to educate in that context. We would be making a serious mistake if we were to allow prospective teachers to enter the labour market without the knowledge and skills that education for an IS requires. Promoting critical thinking during the scientific training of teachers allows for the development of other types of competencies that are necessary to achieve IS, such as problem solving or creative thinking (Fitriani et al., 2019; Wahyudi et al., 2019). For this, it is necessary to modify the didactic strategies traditionally used in the teaching of science in higher education (and more specifically in teacher training), implementing new methods that consider the affective domain and generate positive emotions during learning. This is particularly relevant in teacher training due to the important repercussions that their future teaching jobs will have (Jeong et al., 2016).

6. Limitations

Our study has certain limitations regarding the characteristics of the sample of the subject. The number of participants involved in the research was limited (n = 69). What is more, all the prospective teachers belonged to the same University, which significantly reduces the extrapolation of our conclusions to other contexts. Regarding to the questionnaires implemented, they are self-administered, and the veracity of the data depends on the degree of honesty with which each student has answered. Besides, unfortunately, emotional *pre-test* is not available due to this, some tests are not feasible. Finally, activating/deactivating emotional dimension are not enough discussed in the literature, this paper aims to fill this gap partially.

7. Conclusions

This article has described an emotional and metacognitive didactic intervention consisting of the construction of a model SSF with a strong IS component. It is offered as a didactic resource for teaching science in the Bachelor's Degree in Primary Education. The study highlights the importance of designing specialized content activities for improving preservice teachers affective and cognitive dimension while demonstrating pedagogic alternatives that could be applicable in their future classrooms. Alternatives were proposed to overcome some of the challenges that arise in teacher training. These were based on the implementation of active methods to generate positive emotional experiences and meaningful learning. By integrating affective and cognitive aspects which promote autonomous and collaborative learning, this approach is far removed from the traditional teaching model. The inclusion of the SSF as a resource for teaching science to a non-scientific audience proved to be a useful resource for teaching scientific content and generating positive emotions, such as curiosity, satisfaction or fun, that will condition the PTs' teaching practice. The obtained results should make reflect about the taxonomy of emotions and, according to the physiological effect produced by emotions overcome the classical positive/negative dichotomy. After the intervention, PTs feel more qualified to teach science, and they reckon that this experience will decisively influence their way of teaching sciences and has increased their motivation in science. Correlation analyses revealed a significant relationship between the emotions and the self-efficacy perception, however no relationship between emotion and knowledge have been reported. Continuing to invest time and effort in the design of stimulating scientific activities in teacher training that generate attitudinal and awareness changes will lead to competent citizens who are scientifically literate and with the capacity to take decisions. Generating positive emotions during science learning is therefore decisive. The conclusion is that the time and effort dedicated to research in didactics for an integral sustainability are indeed worthwhile.

Declarations

Author contribution statement

Miriam Andrea Hernández-Barco: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Jesús Sánchez-Martín: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Isaac Corbacho-Cuello; Florentina Cañada-Cañada: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This work is only supported by Spain's Ministry of Science, Innovation and Universities [PID2020-115214RB-I00/AEI/10.13039/501100011033].

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no competing interests.

Additional information

Supplementary content related to this article has been published online at https://doi.org/10.1016/j.heliyon.2022.e12546.

Acknowledgements

Míriam Hernández-Barco thanks Spain's Ministry of Science, Innovation and Universities for her pre-doctoral Grant (BES-2017-081566).

References

Akoglu, H., 2018. User's guide to correlation coefficients. Turk. J. Emerg. Med. 18, 91–93.
Agbowuro, C., Keswet, L.A.M., 2016. Critical thinking and creativity in science and technology education for sustainable development. Int. J. Innov. Res. Adv. Stud. 3 (12), 73–78.
Agen, F., Ezquerra, Á., 2021. Análisis de las emociones en el trabajo de indagación: "La Caja Negra. Invest. Esc. 3, 125–138.
Audette, L.M., Hammond, M.S., Rochester, N.K., 2020. Methodological issues with coding participants in anonymous psychological longitudinal studies. Educ. Psychol. Meas. 80 (1), 163–185.
Bandura, A., 1997. Self-efficacy: the Exercise of Control. Macmillan.
Barrett, L.F., 2020. How Emotions Are Made. PAIDÓS.
Bisquerra, R., 2003. Educación emocional y competencias básicas para la vida. Rev. Invest. Educ. 21 (1), 7–43.
Boni, A., Foguet, A.P., 2006. Construir la ciudadanía global desde la universidad: propuestas pedagógicas para la introducción de la educación para el desarrollo en las enseñanzas científico-técnicas. Intermón Oxfam.
Borrachero, A.B., Brígido, M., Costillo, E., Bermejo, M.L., Mellado, V., 2013. Relationship between self-efficacy beliefs and emotions of future teachers of Physics in secondary education. Asia Pac. Forum Sci. Learn. Teach. 14 (2), 1–11.
Brígido, M., Couso, D., Gutiérrez, C., Mellado, V., 2013. The emotions about teaching and learning science: a study of prospective primary teachers in three Spanish universities. J. Baltic Sci. Educ. 12 (3), 299–311.
Craft, A., Cremin, T., Burnard, P., Chappell, K., 2007. Teacher stance in creative learning: a study of progression. Think. Skills Creativ. 2 (2), 136–147.
Code, J., 2020. Agency for learning: intention, motivation, self-efficacy and self-regulation. Front. Edu. 5 (19), 1–15.
Dancey, C., Reidy, J., 2011. Statistics without Maths for Psychology. Prentice-Hall.
Damásio, A., 1994. El error de Descartes. La razón de las emociones. Editorial Andrés Bello.
Davidson, S.G., Jaber, L.Z., Southerland, S.A., 2020. Emotions in the doing of science: exploring epistemic affect in elementary teachers' science research experiences. Sci. Educ. 104 (6), 1008–1040.
Dávila-Acedo, M.A., Sánchez-Martín, J., Airado-Rodríguez, D., Cañada-Cañada, F., 2022. Impact of an active learning methodology on students' emotions and self-efficacy beliefs towards the learning of chemical reactions—the case of secondary education students. Educ. Sci. 12 (5).
De Orta, Á., Reyes, R., de las Heras, M.Á., 2016. Repercusiones de la forma de enseñar: emociones que despiertan diferentes tipos de actividades. Campo Abierto 35 (1), 189–204.
Díaz, J.L., Flores, E.O., 2001. La estructura de la emoción humana: un modelo cromático del sistema afectivo. Salud Ment 24 (4), 20–35.
Eccles, J.S., Wigfield, A., 2002. Motivational beliefs, values, and goals. Annu. Rev. Psychol. 53, 109–132.
Ekman, P., 1992. An argument for basic emotions. Cognit. Emot. 6 (3), 169–200.
Ekman, P., Oster, H., 1981. Facial expressions of emotion. Estud. Psicol. 2 (7), 115–144.
Fitriani, H., Asy'ari, M., Zubaidah, S., Mahanal, S., 2019. Exploring the prospective teachers' critical thinking and critical analysis skills. Jurnal Pendidikan IPA Indonesia 8 (3), 379–390.
Frenzel, A.C., Becker-Kurz, B., Pekrun, R., Goetz, T., Lüdtke, O., 2018. Emotion transmission in the classroom revisited: a reciprocal effects model of teacher and student enjoyment. J. Educ. Psychol. 110 (5).
Frenzel, A.C., Goetz, T., Lüdtke, O., Pekrun, R., Sutton, R.E., 2009. Emotional transmission in the classroom: exploring the relationship between teacher and student enjoyment. J. Educ. Psychol. 101 (3), 705–716.
Goleman, D., 1995. Inteligencia Emocional. Kairós.
Hernández-Barco, M., Sánchez-Martín, J., Blanco-Salas, J., Ruíz-Téllez, T., 2020. Teaching down to Earth. Service-learning methodology for science education and sustainability at university level. A practical approach. Sustainability 12 (542), 1–23.
Hernández-Barco, M., Sánchez-Martín, J., Corbacho-Cuello, I., Cañada-Cañada, F., 2021a. Emotional performance of a low-cost eco-friendly project based learning methodology for science education : an approach in prospective teachers. Sustainability 13 (3385), 1–19.
Hernández-Barco, M., Cañada-Cañada, F., Corbacho-Cuello, I., Sánchez-Martín, J., 2021b. An exploratory study interrelating emotion, self-efficacy and multiple intelligence of prospective science teachers. Front. Edu. 6, 604791.
Hırça, N., 2013. The influence of hands-on physics experiments on scientific process skills according to prospective teachers' experiences. Eur. J. Phys. Edu. 4 (6), 1–9.
Islam, A.M., Sakakibara, H., Karim, R., Sekine, M., 2013. Potable water scarcity: options and issues in the coastal areas of Bangladesh. J. Water Health 11 (3), 532–542.
Izard, C.E., 2007. Basic emotions, natural kinds, emotion schemas, and a new paradigm. Perspect. Psychol. Sci. 2 (3), 260–280.
Jeong, J.S., González-Gómez, D., Cañada-Cañada, F., 2016. Students' perceptions and emotions toward learning in a flipped general science classroom. J. Sci. Educ. Technol. 25 (5), 77–758.
Jeong, J.S., González-Gómez, D., Cañada-Cañada, F., Gallego-Picó, A., Bravo, J.C., 2019. Effects of active learning methodologies on the students' emotions, self-efficacy beliefs and learning outcomes in a science distance learning course. J. Technol. Sci. Educ. 9 (2), 217.
Klassen, R.M., Chiu, M.M., 2011. The occupational commitment and intention to quit of practicing and pre-service teachers: influence of self-efficacy, job stress, and teaching context. Contemp. Educ. Psychol. 36 (2), 114–129.
Klassen, R.M., Tze, V.M.C., 2014. Teachers' self-efficacy, personality, and teaching effectiveness: a meta-analysis. Educ. Res. Rev. 12, 59–76.
Menon, D., Sadler, T.D., 2016. Preservice elementary teachers' science self-efficacy beliefs and science content knowledge. J. Sci. Teach. Educ. 27 (6), 649–673.
Michaelian, K., Arango-Muñoz, S., 2014. Epistemic feelings, epistemic emotions: review and introduction to the focus section. Philosophical Inquiries 2 (1), 97–122.
Montiel, I., Antolin-Lopez, R., Gallo, P.J., 2018. Emotions and sustainability: a literary genre-based framework for environmental sustainability management education. Acad. Manag. Learn. Educ. 17 (2), 155–183.
Pekrun, R., Stephens, E.J., 2010. Achievement emotions: a control-value approach. Social Personal. Psychol. Comp. 4 (4), 238–255.
Plutchik, R., 2001. The nature of emotions: human emotions have deep evolutionary roots, a fact that may explain their complexity and provide tools for clinical practice. Am. Sci. 89 (4), 344–350. http://www.jstor.org/stable/27857503.
Pipitone, C., Guitart, J., Agudelo, C., García, À., 2019. Favoreciendo el cambio emocional positivo hacia las ciencias en la formación inicial del profesorado. Ápice. Revista de Educación Científica 3 (1), 41–54.
Poon, C.Y.S., Hui, V.K.Y., Yuen, G.W.C., Kwong, V.W.Y., Chan, C.S., 2019. A well-slept teacher is a better teacher: a multi-respondent experience-sampling study on sleep, stress, and emotional transmission in the classroom. PsyCh J. 8 (3), 280–292.
Putwain, D., Sander, P., Larkin, D., 2013. Academic self-efficacy in study-related skills and behaviours: relations with learning-related emotions and academic success. Br. J. Educ. Psychol. 83 (4), 633–650.
Retana-Alvarado, D.A., de las Heras-Pérez, M.Á., Vázquez-Bernal, B., Jiménez-Pérez, R., 2018. El cambio en las emociones de maestros en formación inicial hacia el clima de aula en una intervención basada en investigación escolar. Rev. Eureka sobre Enseñanza Divulg. Ciencias 15 (2), 2602.
Shrivastava, P., 2010. Pedagogy of passion for sustainability. Acad. Manag. Learn. Educ. 9 (3), 443–455.
Tang, T., Vezzani, V., Eriksson, V., 2020. Developing critical thinking, collective creativity skills and problem solving through playful design jams. Think. Skills Creativ. 37, 100696.

Tisza, G., Markopoulos, P., 2021. FunQ: measuring the fun experience of a learning activity with adolescents. Curr. Psychol.

UNESCO, 2019. Informe Mundial de las Naciones Unidas sobre el Desarrollo de los Recursos Hídricos 2019. In: Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura. http://www.unwater.org/publications/world-water-development-report-2019/.

UNICEF, 2017. Progresos en Materia de agua potable, saneamiento e higiene. Informe de actualización de 2017 y línea de base de los ODS. In: Grojec, A. (Ed.), Organización Mundial de la Salud.

Ventura-León, J.L., Caycho-Rodríguez, T., 2017. El coeficiente Omega: un método alternativo para la estimación de la confiabilidad. Revista Latinoamericana de Ciencias Sociales, Niñez y Juventud 15 (1), 625–627.

Wahyudi Verawati, N.N.S.P., Ayub, S., Prayogi, S., 2019. The effect of scientific creativity in inquiry learning to promote critical thinking ability of prospective teachers. Int. J. Emerg. Technol. Learn. 14 (14), 122–131.

Wolff, L.-A., Sjöblom, P., Hofman-Bergholm, M., Palmberg, I., 2017. High performance education fails in sustainability? —a reflection on Finnish primary teacher education. Educ. Sci. 7 (32), 1–22.

Yates, S., Goodrum, D., 1990. How confident are primary school teachers in teaching science? Res. Sci. Educ. 20, 300–305.

Zamora-Polo, F., Sánchez-Martín, J., 2019. Teaching for a better world. In: Sustainability and Sustainable Development Goals in the Construction of a Change-Maker University. Sustainability, 11, p. 4224.