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Effects of an intervention on emotional and cognitive engagement in teacher education: scientific practices concerning greenhouse gases

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Recent studies advise teachers of the need to become aware of the importance of linking the cognitive and affective in learning. During initial training, teaching approaches linked to scientific practices of inquiry and modeling can increase the emotions experienced in the teaching–learning process and encourage teachers to reflect and be aware of how they learn. This research focused on considering that scientific practices should include the environmental problems that society faces today. Thus, activities were contextualized with a theme of economic, scientific and environmental repercussions. Moreover, it promoted awareness about the important role that different scientists have played in the advancement of knowledge about the greenhouse effect and its consequences. The main objective of this research was to allow trainee teachers to become conscious of how they learn content and their relationship with the emotions experienced. The instructional sequence consisted of a set of activities (inquiry, modeling, argumentation), based on the effects of certain chemical substances responsible for the greenhouse effect, focused on promoting the active participation of students. After completion of the instructional sequence, perceptions of pre-service teachers concerning their own learning after the instruction were analyzed. The results evidenced that self-perception of learning and emotions were directly correlated. The emotions experienced during the training appeared to influence the perceptions of the activities and, consequently, their perspectives when deciding whether or not to implement such activities in the future.

KEYWORDS

carbon dioxide, chemistry, climate change, emotions, model-based inquiry, pre-service secondary teachers, scientific practice, skills development

Introduction

An emotion is a subjective reaction that depends on what is important to us and is influenced by individual and social experience (Mellado et al., 2014). Goleman (1996) established that positive motivation is linked to performance, so that people who have the capacity to motivate themselves to achieve a goal are more productive and effective. Furthermore, emotional competencies make it possible to adequately understand, express and regulate emotional phenomena and favor processes such as learning or problem solving. Specifically, emotional competencies are made up of emotional awareness and regulation, personal autonomy, interpersonal intelligence, and life and well-being skills. The acquisition of emotional competencies has positive consequences on behavior, which has contributed to increasing interest in studying its influence in the educational field (Bisquerra Alzina and Pérez Escoda, 2007).

Even though affective, attitudinal and emotional aspects influence the construction of scientific knowledge, the teaching and learning of traditional sciences tend to emphasize truth and objectivity as elements that characterize it, excluding affective, cultural and social values. Similarly, feelings and emotions have the capacity to direct cognitions (learning) and behaviors, in decision-making and conflict resolution (Vázquez Alonso and Manassero Mas, 2007).

Furthermore, learning to be a science teacher is a social practice that is impregnated with emotions (Bellocchi et al., 2014). Women tend to report positive emotions less frequently than men when teaching physics and chemistry content. This situation implies the need for them to be able to self-regulate their emotions (worry, nervousness, stress) to prevent them from blocking them when teaching science (Borrachero et al., 2014), so training emotionally competent teachers will allow them to diagnose and self-regulate their emotions (Brígido Mero et al., 2010; Costillo Borrego et al., 2013). In the case of teachers in training, specifically in the specialties of physics and chemistry, it has been identified that they present positive and negative emotions, corresponding to those felt in their student stage during secondary education toward these subjects. These emotions could be transferred from the teachers to the students, resulting in a problem for learning if they are negative emotions toward the contents. Conversely, positive emotions are associated with greater self-efficacy during initial teacher education (Mellado et al., 2014).

Despite the evidence presented, the role of emotions, commitment to scientific practices and specific connections has not been exhaustively investigated (Sinatra et al., 2015). It is necessary that teachers are aware of emotions during their training and that this awareness begins to influence their behavior. This fact is important as teachers are not usually guided by rational and conscious functions, but by certain aspects that mediate between perception and behavior, such as tacit, holistic, irrational and integral forms of information processing. That is why reflection should focus on less conscious and rational aspects, promoting consideration of the dimensions of thought, feeling, desire and action, as well as their interrelationships (Korthagen, 2010).

In this sense, practical activities during teacher training lead to dynamic emotions that entail proactive attitudes toward the subject. An example would be surprise, which would be a positive and dynamic emotion but rarely highlighted in traditional teaching. Satisfaction or boredom, which usually occur with traditional teaching, would consist of static emotions as they do not lead to needing anything else (Sanchez-Martin et al., 2018). Transmissive models lead to showing science as a set of completed truths that deprive one of experiencing the emotion of building knowledge in its corresponding historical moment (Mellado et al., 2014). It has blurred the human character of science by not considering basics aspects of education, such as emotions, feelings, morality, history or personality (Vázquez et al., 2005).

Therefore, to contribute to improving teacher training, professional development and educational materials, it is necessary to reorient teacher training programs toward teaching oriented toward emotional and cognitive engagement. Some studies show that model-based inquiry involves emotional situations that affect scientific learning, so it is pertinent to identify the relationships established when promoting this teaching approach (Milne and Otieno, 2007; Inkinen et al., 2020). Pre-service primary teachers training stand out asking questions and explaining everyday phenomena, which are very close to the characteristics of the model-based inquiry teaching approach. Moreover, it provides Pre-service teacher with alternative teaching approaches to traditional teaching practice and can serve as a model (Martínez-Chico et al., 2014; López-Banet, 2023). Current evidence shows that pre-service teachers are aware of having understood the fundamentals of scientific practice and experience positive emotions, such as satisfaction and interest, when they learn through inquiry-based teaching approaches and modeling (Jiménez-Liso et al., 2019). In this sense, the application of scientific processes entails a mixture of emotions, such as curiosity or confidence in experimentation and data representation, or joy, pride and gratification, when applying what has been learned to solve a problem (Mellado et al., 2014).

On the other hand, the presence of women in careers and jobs related to science, engineering and mathematics is significantly less than that of men. Recent studies emphasize the importance that the self-perception of our Science Technology Engineering Mathematics (STEM) capabilities appears to have for our future perspectives, which may be, to a large extent, responsible for gender disparities (Sobieraj and Krämer, 2019). This study carried out with STEM students revealed that men perceived more self-efficacy while women had a lower perception of their own competence. These results are not isolated but are repeated in other research such as that carried out by Zeldin et al. (2008) in which girls indicated having lower levels of scientific self-efficacy, or that of MacPhee et al. (2013) in which, during the admission period for STEM careers, women perceived themselves as having less academic aptitude than their male counterparts, although they did not show inferior performance. However, at the end of the degree, their academic self-concept had improved, in this case equaling that of men.

The revised literature suggested that scientific engagement and construction of scientific knowledge, including science teacher training, are influenced by affective, attitudinal and emotional aspects. Specifically, in this work, we will focus on determining the relationship between the emotions experienced and the self-perception of learning during the implementation of an initial teacher training course. The main objective of this research was to allow pre-service teachers to become aware of the teaching content (self-regulation of learning), how they learned it (leading to an explicit discussion about including scientific practices as part of the teaching and learning process) and the relationship with emotions (what emotions arose during the implementation of the activities).

Methods

There are numerous daily life situations in which people must use scientific knowledge and make decisions about certain actions that involve socio-scientific controversies. Nevertheless, citizens do not usually show active and effective participation in the discussion and decision-making on aspects related to science and technology (Reis, 2020). Scientific competence in the classroom could be developed using relevant contexts in daily life found in the cultural environment of the students, which capture their interest (Franco-Mariscal et al., 2014). In this context, the concept of scientific literacy must encompass the development of the capacity and commitment to participate responsibly and effectively in matters of social, economic, environmental and ethical-moral interest, recognizing the role of students as an important agent of change by being part of a collective, democratic negotiation process, informed by research and negotiated for the resolution of socio-environmental problems. School science practices, therefore, must include informed actions on social and environmental problems associated with the fields of science and technology, called Science, Technology, Society and Environment Controversies (CCTSA) or Socio-Scientific Controversies (CSC) (Reis, 2013). Learning chemistry with this approach not only involves understanding of scientific contents, but also how they are constructed (Martínez-Carmona and López-Banet, 2021).

There is a need for science teachers to carefully review the teaching–learning process to provide them with opportunities to develop an adequate understanding of the greenhouse effect due to the consequences of climate change. The intervention was implemented during 4 sessions of 1 h each and it consisted of a teaching unit composed of nine tasks: (T1) What scientists who have done research on the greenhouse effect do you know; (T2) How could we obtain evidence to prove that it is CO_2; (T3) Hypothesize about the effect of CO_2 on temperature; (T4) Design and evaluate experiments to test the hypothesis; (T5) Analysis of temperature data; (T6) To what extent does CO_2 contribute to temperature increase; (T7) Model to explain why the temperature in the flask rises; (T8) Usefulness of the game for self-assessment of learning; (T9) Contents of the teaching unit as a whole (Supplementary Figure S1). An initial test with 13–14 years old students made it possible to establish its suitability for this educational level, resulting in a relevant and motivating resource for the introduction of the selected contents (Martínez-Carmona and López-Banet, 2021).

Our sample was made up of men and women who had completed a scientific career related to physics or chemistry. For this, 60 teachers in training faced a sequence of activities, while they learned and reflected on: What I have learned? How have I learned? How have I felt during the implementation of the teaching sequence? The implementation in a pre-service teachers course made it possible to comprehensively measure their participation in both the cognitive and emotional dimensions. For this purpose, the last task (T10) of the instructional sequence consisted of a questionnaire that, with minimum interruption in the learning process and with meaning for teachers and students (López-Banet et al., 2021), measured *in situ* the self-regulation of learning and emotions. In this last activity, pre-service teachers selected both the emotions related to all of the tasks and their perceptions of the knowledge they had before and after carrying them out.

This article analyses the responses to the questionnaire. To study their perception of learning a descriptive analysis was conducted for the knowledge variable (minimum, maximum, median, mean, and standard deviation). Non-parametric tests were also applied due to the nature of the sample and its size. Specifically, the Wilcoxon W test was used to verify the significance of the differences between the pre and post results of the knowledge variable and the Mann–Whitney U-test was used to determine significant differences among independent samples, according to their gender. Finally, Cohen's d (effect size, ES) was calculated for the knowledge variable. In addition, a frequency analysis for the different emotions under consideration was carried out. The Spearman correlation coefficient was calculated to determine the relationship between the knowledge attained by the students in the post-test phase and the emotions experienced during the sequence.

Results

Women declared lower knowledge perception than men in all of the tasks prior to implementation. This is in line with other studies where women, despite presenting similar performance than man, declared had a lower perception of their own competence (Sobieraj and Krämer, 2019), self-efficacy (Zeldin et al., 2008) or academic aptitude (MacPhee et al., 2013). Nevertheless, no significant differences were identified based on gender for most of the tasks, except for T2, T3 and T5 (Supplementary Table S1). In these three cases, significant differences ($p = 0.005$) were found between men (T2: mean = 3.27 ± 1.28; T3: mean = 3.36 ± 1.18; T5: mean = 3.36 ± 1.40) and women (T2: mean = 2.35 ± 0.79; T3: mean = 2.53 ± 0.80; T5: mean = 2.35 ± 1.00).

Significant differences were identified between the pre- and post-assessment of the nine tasks performed (Table 1), with an increase equal to or greater than 1.3 after performing the following tasks: 1. What scientists who have done research on the greenhouse effect do you know; 2. How could we obtain evidence to prove that it is CO_2; 4. Design and evaluate experiments to test your hypothesis; 7. Model to explain why the temperature in the flask rises; and 9. Contents of the teaching unit as a whole; whose increase meant that according to the Pre-service teacher (PST) test, students perceived that they had improved their knowledge about the male and female scientists who had investigated the greenhouse effect, about how to design experiments to obtain evidence and use a model to explain why the temperature of the flask increased and how to design a teaching unit as a whole. It is interesting to note that the activity in which they considered they had improved the most was in activity 7, use of models, and that overall, they felt more competent to design a teaching unit.

Regarding the emotions they expressed throughout the teaching unit (Supplementary Figure S1), the most recurrent were interest (experienced 251 times) followed by concentration (170 times) and satisfaction (161 times). In contrast, the least experienced emotions were rejection (4 times), dissatisfaction (10 times), shame (11 times) and boredom (14 times). Interest, concentration and satisfaction were in the majority in all of the tasks. It is notable that at moment one, which scientists were known who worked on the greenhouse effect, surprisingly increased a lot and, also, that at moments two and six negative emotions were practically non-existent (Figure 1).

In order to determine the correlations between emotions and knowledge, emotions were coded dichotomously (they appeared or they did not appear). The results indicated that the relationship between knowledge and the emotions declared by the PSTs were different depending on the activity conducted (Table 2). It appears that concentration, interest, confidence and satisfaction were closely linked to knowledge since they presented a statistically significant relationship in most activities. On the contrary, rejection and shame did not seem to have an influence, and no significant relationship was found between these emotions and the moments declared in any of the activities.

TABLE 1 Perceptions of pre-service teacher's knowledge declared by the 60 participants for the nine tasks, before and after carrying them out.

Task (before/ after)	Minimum	Maximum	Median	Mean	Standard deviation	Evolution*	Z	p	ES
T1: (Before)	1	4	1.00	1.53	0.70	1.30	−6.634	0.000	1.693
T1: (After)	2	5	3.00	2.83	0.83				
T2: (Before)	1	5	2.00	2.62	1.17	1.38	−6.295	0.000	1.220
T2: (After)	2	5	4.00	4.00	1.09				
T3: (Before)	1	5	3.00	2.90	1.05	1.13	−5.779	0.000	1.097
T3: (After)	2	5	4.00	4.03	1.01				
T4: (Before)	1	5	2.00	2.53	1.13	1.30	−6.172	0.000	1.202
T4: (After)	2	5	4.00	3.83	1.03				
T5: (Before)	1	5	3.00	2.80	1.19	1.12	−5.626	0.000	0.969
T5: (After)	1	5	4.00	3.92	1.12				
T6: (Before)	1	5	3.00	3.03	1.04	1.09	−5.880	0.000	1.074
T6: (After)	2	5	4.00	4.12	0.99				
T7: (Before)	1	5	2.00	2.42	0.98	1.5	−6.119	0.000	1.515
T7: (After)	2	5	4.00	3.92	1.00				
T8: (Before)	1	5	2.00	2.15	1.12	1.27	−5.963	0.000	1.037
T8: (After)	1	5	3.00	3.42	1.32				
T9: (Before)	1	5	2.00	2.12	0.98	1.31	−6.378	0.000	1.270
T9: (After)	2	5	4.00	3.43	1.08				

The correlation is significant at the 0.05 level.

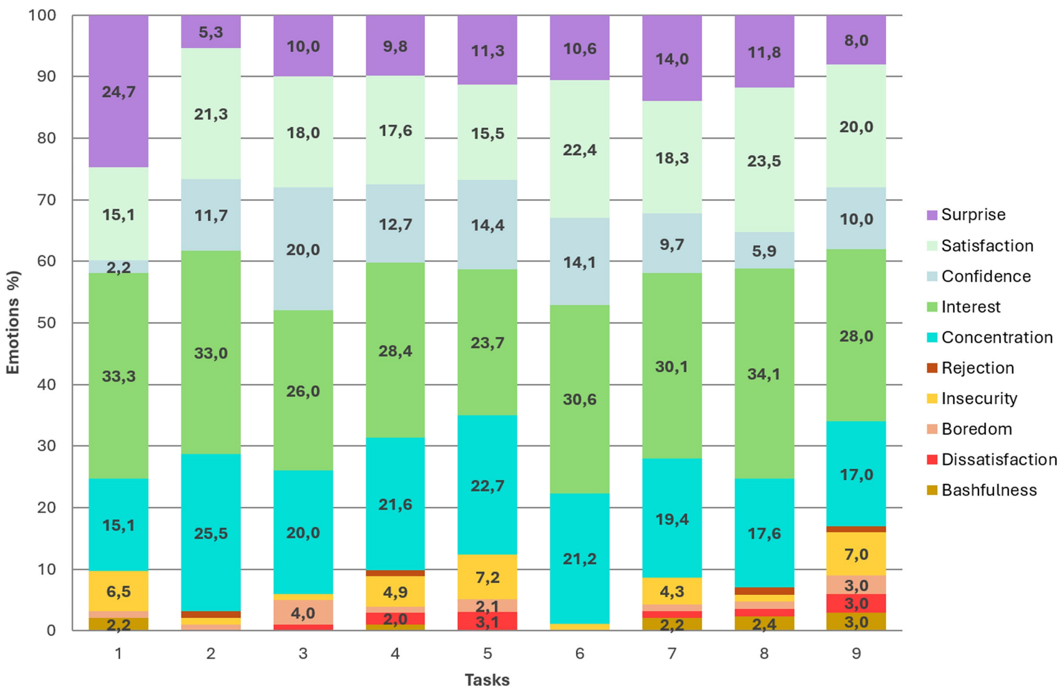

FIGURE 1
Emotions experienced by the 60 participants at each task.

The possible relationships between the emotions declared for each of the activities were analyzed. Significant correlations between emotions in all activities were found (Table 3). Concentration appeared to be closely linked to interest, confidence and satisfaction, presenting significant correlations, respectively, with items 5, 4 and 6 of the proposed tasks. It can be appreciated that concentration is

TABLE 2 Correlations between knowledge declared by the 60 participants (post-test) and emotions.

Knowledge in task	Concentration	Rejection	Insecurity	Interest	Boredom	Confidence	Satisfaction	Dissatisfaction	Bashfulness	Surprise
T1	0.351**	0.029	0.006	0.094	−0.043	0.146	0.186	0.273*	0.251	0.60
T2	0.112	0.188	−0.296*	0.170	−0.015	0.297*	0.526**	0.132	0.132	0.029
T3	0.419**		−0.137	0.454**	−0.340**	0.315*	0.475**	−0.087		0.056
T4	0.265*	−0.208	−0.094	0.223	−0.03	0.485**	0.394**	−0.055	0.012	0.212
T5	0.212		0.115	0.244	−0.196	0.493**	0.309*	0.150		0.229
T6	0.236	−0.266	0.125	0.330*	−0.154	0.433**	0.404**	0.125		0.197
T7	0.297*		−0.103	0.264*	−0.181	0.384**	0.430**	−0.153	−0.039	0.284*
T8	0.549**	−0.030	−0.023	0.424**	−0.134	0.333**	0.485**	−0.21	0.065	0.371**
T9	0.549**	−0.030	−0.023	0.424**	−0.134	0.333**	0.485**	−0.213	0.065	371**

*The correlation is significant at the 0.05 level (bilateral). **The correlation is significant at the 0.01 level (bilateral).

related to the interest in obtaining evidence that proves the nature of CO_2, in the elaboration of hypotheses about the effect that it has on the increase in the temperature of the planet, in the analysis of results, in the usefulness of the game to self-evaluate learning and in the contents of the teaching unit. Concentration was significantly related to insecurity when talking about scientists who researched the greenhouse effect and surprisingly when analyzing data and using the game to self-assess knowledge. On the contrary, there was a significant negative correlation between concentration and boredom in activities 2 and 5, that is, those students who expressed concentration to reflect on obtaining evidence to demonstrate the presence of CO_2 and analyzed the data concerning the influence of said gas in the temperature, they also claimed not to have gotten bored.

Interest appears to be linked to satisfaction since significant correlations were found in five of the nine proposed activities, specifically in the study of scientists who investigated the greenhouse effect, the development of hypotheses about the effect of the CO_2 on temperature, the analysis of temperature data, the usefulness of the game to self-evaluate learning and the contents of the teaching unit globally. As with concentration, interest was shown as an emotion opposite to boredom, obtaining significant negative correlations in the study of scientists, the design and evaluation of experiments to test their hypotheses and the analysis of the data obtained.

Confidence showed significant correlations with both satisfaction and dissatisfaction depending on the proposed activity. Dissatisfaction was present in the activity of scientists, possibly due to the realization that they did not know the majority of the men and women working in the area. The relationship between confidence and dissatisfaction was also present in the analysis of the data on the effect on temperature, which could be related to the fact that the students expected a greater difference than what was finally observed. The relationship between confidence and satisfaction was significantly appreciated in the elaboration of hypotheses, in the model to explain why the temperature in the flask increased, in the usefulness of the game to self-evaluate learning and in the contents of the teaching unit overall.

Regarding negative emotions, a significant relationship was observed between rejection and boredom in five of the proposed activities, which suggests that those students who did not enjoy the activity were also those who refused to carry it out. Among the activities that showed this relationship we found: items 1, 2, 6, 8, and 9. This feeling of rejection was also significantly related to dissatisfaction in three of the aforementioned activities and inversely with interest in two of them. Boredom was also closely related to dissatisfaction. In this sense, those students who indicated experiencing dissatisfaction in the activities of scientists, obtaining evidence, developing hypotheses, the effect of CO_2 on the increase in temperature and the contents of the teaching unit, were the same ones who expressed boredom.

Discussion and conclusion

When we analyzed the different scientific skills performed during the teaching unit, we observed that, initially, women had a lower self-perception for all aspects and felt less capacity than men in certain skills; these differences being significant in the tasks of experimental design, hypothesis development and data analysis. At

TABLE 3 Correlations between emotions declared by the 60 participants (post-test).

	Concentration	Rejection	Insecurity	Interest	Boredom	Confidence	Satisfaction	Dissatisfaction	Bashfulness	Surprise
Concentration			T1: 0.318*	T2: 0.289*; T3: 0.531**; T5: 0.497**; T8: 0.306*; T9: 0.330*	T2: −0.312*; T5: −0.287*	T1: 0.292*; T4: 0.309*; T8: 0.432**; T9: 0.484**	T3: 0.331**; T5: 0.297*; T6: 0.282*; T7: 0.382**; T8: 0.499**; T9: 382**			T5: 0.386**; T8: 0.348**
Rejection				T2: −0.322*; T8: −0.295*	T1: 0.473**; T2: 280*; T6: 487**; T8: 0.616**; T9: 0.598**			T1: 0.483**; T2: 0.701**; T8: 0.383**	T1: 280*	
Insecurity							T5: 0.260*	T5: 0.485**	T4:.358**; T7: 0.546**	T5:.574**; T6: 0.291*
Interest					T1: −0.429**; T4: −0.277*; T5: −0.329*	T9: 0.273*	T1: 0.296*; T3: 412**; T5: 0.369**; T8: 0.420**; T9: 0.275*	T8: −365**; T9: −0.402**		T5: 0.420**
Boredom						T1: 0.288	T3: −0.265*	T1: 0.473**; T2: 0.432**; T3: 0.459**; T6: 0.487**; T9: 0.255*		
Confidence							T3: 0.342**;T7: 0.309*; T8: 0.397**; T9: 0.488**	T1: 0.323*; T5: 0.277*		T5: 0.276*
Satisfaction										T5: 0.326*
Dissatisfaction									T1: 0.280*; T4: 0.567**	T5: 0.391**
Bashfulness										T4: 0.260*
Surprise										

*The correlation is significant at the 0.05 level (bilateral). **The correlation is significant at the 0.01 level (bilateral).

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the end of the proposed activities, participants reported having improved in all skills and, although men continued to show a slightly higher self-perception, there were no significant differences in their perceptions in terms of gender. This appears to indicate that, unlike men, women may lack prior self-efficacy beliefs (Sobieraj and Krämer, 2019), however, after their training they are aware of the learning acquired.

In most of the activities, there was a direct correlation between a higher self-perception of learning and the emotions of satisfaction and confidence. This may be related to the fact that those students who considered that they had learned more, felt satisfied with the process, and had the self-confidence to be able to implement it in the future. No significant correlation was observed between rejection and knowledge, which points to emotional commitment, as López-Banet et al. (2021) mentioned.

To conclude, we established that the implementation of a teaching unit mainly focused on model-based inquiry activities concerning the greenhouse effect allowed PST to reflect both on rational and emotional aspects of learning. The reflection experience should aid in developing the competence to design new proposals in the future that consider the existing correlation between emotion and learning.

Data availability statement

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

Ethics statement

The studies involving humans were approved by Research Ethics Commission of the University of Murcia. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

LL-B: Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing. MM-C: Data curation, Validation, Writing – review & editing. PR: Validation, Writing – review & editing.

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Conflict of interest

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

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1307847/full#supplementary-material

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