Design and validation of the scales of a Spanish-adapted questionnaire to measure pre-service teachers' perceptions about inquiry-based science education

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This research focused on the pre-service science teachers' perceptions of Inquiry-Based Science Education (IBSE) in Spanish-speaking contexts. Drawing on the PRIMAS questionnaire and extensive adaptations, the PTIP questionnaire, a 25-item instrument was developed to gauge pre-service teachers' perspectives on IBSE. The questionnaire effectively measures four dimensions through rigorous statistical validation: IBSE teaching practice, IBSE students' applicability, and internal and external difficulties associated with the inquiry approach. Employing *K*-means cluster analysis, three distinct profiles emerged, elucidating pre-service teachers' varying perceptions and readiness to embrace IBSE. Profile A embodies fervent advocates of IBSE, while profile B and C showcases strong support with moderate reservations about its challenges and a more ambivalent stance, respectively. This research contributes a valuable tool for understanding and enhancing pre-service teacher **education**, fostering the adoption of IBSE.

Keywords: inquiry-based science education; validity based on internal structure; pre-service teachers

Subject classification codes: include these here if the journal requires them

Introduction

The OECD recently published a report addressing proposals for reducing school dropout rates in Spain (OECD, 2023a), urging the country to consider socio-emotional competencies in the selection processes for access to teaching positions and the initial **education** for pre-service teachers (PSTs). The report acknowledges the socio-emotional competencies of students already included in various educational curricula; therefore, considering these aspects among teachers should be the next step. The widespread repercussions of the report have shed light on this aspect, which **has gradually emerged** in educational research.

Perceptions, which encompass attitudes, beliefs, views, emotions, and conceptions, significantly impact teaching practices (McKeown et al., 2015). Specifically in Science Education, they have been proposed as a priority for study due to their influence on teaching practices and their direct impact on the teaching-learning process and its success (Abril et al., 2014). A critical aspect of these perceptions is science teaching self-efficacy beliefs and confidence, which profoundly influence teaching methods, persistence, and the ability to face educational challenges (Kelly & Cunningham, 2019).

Defined as a future-oriented belief concerning an individual's competence in a given educational situation (Tschannen-Moran & Hoy, 2001), self-efficacy is especially vital in the realm of inquiry-based methods, which are often **characterised** by their inherent uncertainties and complexities (Kaya et al., 2021). Moreover, the impact of self-efficacy extends to teachers' responses to their students (Smolleck et al., 2006). Teachers with solid self-efficacy beliefs are more inclined to adopt constructivist teaching methods, creating a more engaging and exploratory learning environment and encouraging resilience and persistence in the face of educational challenges (Kaya et al., 2021). Conversely, teachers with lower levels of self-efficacy might lean towards more traditional, teacher-centred approaches, often avoiding the challenges of inquiry-based methods (Markic & Eilks, 2012). This avoidance risks depriving students of hands-on, experiential learning opportunities that foster **a** more profound understanding and interest in science.

Teachers' perspectives, both in-service and during initial **preparation**, and **intentions** regarding their future practice often align with their own experiences as students (Pérez et al., 2019). Many of them continue to practice a teacher-centred approach throughout their careers despite the substantial international recommendations

advocating for the use of constructivist methodologies in teaching**. This adherence to traditional methodologies, in turn, reinforces negative perceptions of science and its learning, perpetuating issues such as frustration, anxiety and boredom.**

However, even when practising teachers are open to implementing new methodologies, they are often more confident in carrying them out from a teacher-centred perspective rather than a student-centred one (Kaya et al., 2021). **Consequently, the pre-service teacher preparation period becomes crucial to challenge and overcome previous ideas and conceptions associated with traditional teaching methods that future teachers may carry from their own educational baggage. This period should facilitate their transformation into the type of teacher they aspire to be (Luehman, 2007) and guide them toward more constructivist teaching approaches (Buldur, 2017; Pérez et al., 2019), such as inquiry-based science education (IBSE).**

As the influence of perceptions on teaching practices gains prominence, the role of pre-service **preparation programs** becomes paramount, and so **does** the development of an instrument linked to the evolving landscape of teacher **education** and the pressing need to enhance pedagogical practices. It is evident that a comprehensive assessment of PSTs' perceptions of IBSE, considering its utility in addressing curricular aspects and fostering scientific competencies, plays a fundamental role in shaping their pedagogical decisions regarding IBSE (van Aalderen-Smeets et al., 2017). **Therefore, our research delves into the realm of PSTs' perceptions about IBSE, an area crucial for nurturing a new generation of teachers proficient in constructivist methodologies and well-equipped to navigate the complexities of modern teaching, thus ensuring that future teachers are prepared to guide students towards a more engaging and effective scientific learning journey.**

Theoretical framework

Importance of the perceptions of inquiry-based science education

IBSE represents a fundamental shift in science teaching and learning, emphasising active engagement and investigation over traditional lecture-based methods. It encompasses a series of methodologies focused on students, who socially construct and reconstruct their learning through interaction with the environment (Pedaste et al., 2015). **It includes resolving** real and contextualized problems through **identifying** assumptions, **using** critical and logical thinking, and **considering** alternative explanations (National Research Council [NRC], 1996).

The impact of inquiry-based methods on students' cognitive and attitudinal outcomes has been a significant focus in scientific education literature. Research has consistently shown that inquiry-based approaches positively influence students' knowledge acquisition, reasoning skills, and attitudes towards science (Marshall & Alston, 2014), enhancing students' understanding of scientific concepts and fostering positive emotions towards science (Chen et al., 2014). This is crucial, as encouraging interest and positive attitudes can increase inclination towards scientific and technological careers (Sjøberg, 2019).

From the "Rocard Report" (Rocard et al., 2007), which underscored how IBSE contributes to the development of critical thinking and stimulates positive attitudes toward science, the latest European recommendations have reinforced the importance of inquiry and scientific methods in nurturing scientific literacy. As PISA 2022 recognised (OECD, 2023b), scientific literacy places significant emphasis on scientific inquiry, encompassing aspects like formulating questions, employing methods, and addressing solutions, all while highlighting the crucial role played by the establishment and

confidence in scientific knowledge.

By adopting IBSE, teachers can facilitate an environment where students are actively involved in their learning process, mirroring the practices of genuine scientific inquiry. This approach enhances the transfer of knowledge and allows teachers to observe and support the development of their students' scientific skills and understanding first-hand. As Abd-El-Khalick et al. (2004) point out, inquiry-based methods can transform the classroom into a dynamic learning environment, fostering a deeper appreciation and understanding of science for students and teachers, and integrating science into school life, making it more accessible, relevant, and engaging for all involved.

In this context, the initial **education** of prospective teachers can significantly influence their perception of IBSE. While several **preparation** programs have successfully introduced IBSE to PSTs (Authors, **2022**; Herranen et al., 2019; Nicol, 2022), the perceptions formed during this initial stage can determine whether these future educators become authentic promoters of the inquiry-based approaches (Abril et al., 2014), impacting their likelihood of implementing it effectively in the classroom (**Authors**, **2021a**).

Recognising the intricate nature of defining perceptions (Mansour, 2015), we consider them as the unique collection of thoughts that influence teaching practices, encompassing not only an understanding of the inquiry process but also self-efficacy beliefs, attitudes, perspectives and conceptualizations (McKeown et al., 2015). **Accordingly, understanding these perceptions among PSTs is of paramount importance. Recent studies have gathered crucial insights that support effective inquiry preparation programs, with some review articles summarising the main understandings (Authors, 2021a), which are discussed below.**

Another critical aspect concerns the challenges perceived when implementing IBSE in the classroom, encompassing the management of scientific knowledge and logistical considerations such as school schedules, class sizes, and the support of colleagues and administration (Abril et al., 2014; Romero-Ariza, 2017). **While various variables may potentially influence PSTs perceptions of IBSE, including teaching and research experience, gender, age, and other demographic factors (Watters & Diezmann, 2015), research on the impact of these factors remains limited.**

Assessing pre-service teachers' perceptions of IBSE

In the last decades, numerous publications (Eltanahy & Forawi, 2019; Herranen et al., 2019; Lee et al., 2018; Seung et al., 2019, to name a few) have delved into the use of different ways to analyse perceptions of Primary and Secondary PSTs regarding IBSE utilising quantitative and qualitative **approaches** or a combination of both.

Research employing qualitative instruments such as interviews, journal observations and participants' essays (Herranen, 2019; Lotter, 2004)~~,~~ or mixed-methods approaches that combine both (Elster et al., 2014; Kim et al., 2011; Romero-Ariza et al., 2020) has sought to provide insights into how IBSE is perceived. Nevertheless, the qualitative approach might introduce complexity when applied to large samples (Lederman et al., 2002) since it poses challenges for participants in expressing their thoughts within a limited timeframe (Chen, 2006). It also might present limitations regarding validation through statistical analysis (Shaakumeni, 2019).

Turning our focus to studies of a quantitative nature within specific geographic or cultural contexts, we find research conducted by Twahirwa et al. (2022), who employed the 3STQ questionnaire to examine perceptions related to usefulness, usage and difficulties of IBSE. Similarly, **Ramnarain** (2014), developed a 46-item questionnaire **to analyse** perceptions **implementing** IBSE and its relationship with

curriculum content or lesson planning, among other factors. In a more local context, Sáez et al. (2019) designed a questionnaire targeting Primary Education PSTs with the aim of understanding their perceptions regarding scientific content knowledge, methodological aspects, and challenges encountered when implementing IBSE. Interestingly, these authors also conducted a profile analysis, categorising PSTs based on their inclination towards assessing IBSE in either an innovative manner, **emphasising** processes and final products (profile A) or a more traditional approach, centred on reproductive process and the mastery of specific concepts, discrete evaluations, or isolated knowledge (profile C), with a profile B underlying among the other two.

Considering the scope in terms of **the** number of participants and geographical contexts, one notable instrument for assessing inquiry perceptions is the PRIMAS questionnaire (Engeln et al., 2013), developed within a European project aimed at promoting IBSE. As part of this initiative, the partnership designed a questionnaire targeting in-service science and mathematics teachers, which was administered to 1219 in-service teachers across 12 European countries. Frameworked within a multi-faceted approach to IBSE, considering not only the process of inquiry but putting a greater focus on having a meaningful context and on students constructing meanings, it analyses teachers' orientation and use of IBSE, expected problems to face during implementation, and current teaching practice. The questionnaire, composed of 34 items organised throughout 11 scales (routine use, orientation, motivation, classroom management, resources, system restrictions, interaction, application, hands-on, investigation and exercise), served the dual purpose of measuring the status of inquiry-based teaching in these countries and evaluating the impact of the other project interventions on practising teachers.

Leaving aside this dual objective, this questionnaire seeks to provide a comprehensive diagnosis from a multifaceted perspective of IBSE, including not only educational aspects of the inquiry but also considerations related to its assessment, classroom management, the role of teachers, and the use of tools for its implementation. In that way, results exposed in the PRIMAS (Engeln et al., 2013) reveal that teachers' acceptance and use of IBSE vary significantly by country and subject. Despite a generally positive attitude towards IBSE, practical implementation is hindered by systemic barriers and the availability of resources rather than classroom management issues, pointing out the need for tailored IBSE strategies that address both the external challenges and the diverse educational traditions across Europe.

Justification and purpose of the study

Even though science education research has experienced a significant surge in international collaboration among researchers, fostering the sharing of diverse approaches and instruments (Chiu & Duit, 2011), the sensitivity of instruments, such as the questionnaire proposed in the PRIMAS project, which can be effectively applied in various educational settings, demands a complex process of adaptation when utilised in a context different from their original development (Authors, **2021b**). Consequently, the process of translation and adaptation must extend beyond grammatical aspects to encompass sociocultural factors. This is particularly critical due to difficulties related to idiosyncratic expressions, the multiple meanings of terms, and the absence of equivalent words in the target language (Kaplan & Grabe, 1991).

This challenge becomes particularly evident with closed questionnaires, where maintaining conceptual equivalence for each item is crucial, and literal translations are often insufficient (Muñiz et al., 2013). Furthermore, social values and customs

significantly influence respondents, even when high-quality translations are used (Beauford et al., 2009). Cultural lenses shape how individuals interpret and respond to questionnaire items, as their thoughts are influenced by the societies to which they belong. To address this issue, Solano-Flores and Nelson-Barber (2001) propose the concept of "cultural validity," recognising that effective communication may require different approaches when making generalizations about students from diverse cultural backgrounds.

Hence, adapting measurement instruments for science education research goes beyond achieving linguistic precision; it requires a deep understanding of sociocultural influences on individuals' perceptions. Achieving cultural validity in translation and adaptation is essential to ensure accurate and meaningful data, enabling researchers to gain valuable insights from students hailing from diverse cultural contexts (Krell et al., 2020; Villablanca et al., 2020). Embracing these considerations enhances the quality and reliability of international science education research, fostering inclusive and meaningful contributions to the field.

Considering all these social and cultural factors and building upon the questionnaire implemented in the PRIMAS project (Engeln et al., 2013), as well as the Spanish version of some of the items (Abril et al., 2014), both of which were targeted at in-service teachers, we have developed the PSTs' IBSE perception (PTIP) questionnaire, a comprehensive Spanish-adapted version for PSTs, aimed to analyse their prior perceptions and preferences regarding the practice of IBSE.

Methodology

Our initial PTIP questionnaire structure closely aligns with the one developed in the PRIMAS questionnaire (Engeln et al., 2013), intending to ensure minimal divergence

from the original version. To evaluate the suitability of each item for PSTs, we conducted an initial analysis with a small panel of experts consisting of three researchers and teachers in Science Education with extensive experience in the field of IBSE.

The items were presented in random order and categorised by their proposed dimension. We ask the experts to assess the clarity and relevance of the translated adapted version, considering its alignment with the Spanish curricular context and incorporating necessary adjustments related to the non-professional practice of teachers. Based on this initial analysis and feedback, our proposed questionnaire comprised 28 items, phrased positively and negatively, rated on a 4-point Likert-type scale (see Authors, **2021a**). Thus, respondents were required to indicate their level of agreement on a scale ranging from 1 (totally disagree) to 4 (totally agree).

Accordingly, the classroom interactions (INT) (items 2C, 2F, 2H, which consider the relevance given to class dynamics such as discussions and debates) and classroom management (MNG) (items 4B, 4E, 4H, 4I, which includes aspects related to teachers' self-efficacy, such as confidence in their teaching) dimensions remained unchanged compared to the original scale proposed in the European project.

We adapted the motivation (MOT) (items 3A and 3B, related to the appropriateness of IBSE to overcome students' learning and motivation problems) dimension by removing one item from the original version since it appeared overly generic in the Spanish translation. We proceed similarly in the experimental activity (EXA) (items 2A and 2D, about the importance of developing practical activities), the system restriction (SYS) (items 4A, 4D, 4G and 4N, stating difficulties attributed to the educational ecosystem such as time and assessment), the inquiry (INQ) (items 2B, 2E and 2G, related to the nature of the inquiry process) and the resources (RES) (items 4C,

4F, 4L and 4M, associated to the access to materials and **preparation**) dimensions, by removing or replacing some of the items from the original questionnaire into more appropriate categories. Lastly, we also added some contributions from the MASCIL questionnaire (Maass & Engeln, 2014) and the work from Authors (2017), including dimensions relating to the knowledge dependence (KNO) (items 4J and 4K, related to the assumption that a high knowledge is needed when performing inquiry) and the scientific competencies (SCC) (items 3C to 3F, which associated the development of critical thinking or scientific attitudes to the application of IBSE), respectively.

Research context

The introduction and subsequent emphasis on (IBSE) in the Spanish educational curriculum **have** been a notable development in recent years, gaining even more significance with the enactment of the LOMLOE law in 2023 (Organic Law 3/2020). This legislative reform represents a substantial endorsement of the IBSE approach, encouraging science teachers to foster a scientific culture rooted in inquiry. The philosophy behind this approach is to cultivate critical, thoughtful citizenship and the capacity to make informed decisions in various aspects of life, be it personal, social, or educational.

The emphasis on IBSE in the curriculum and its endorsement by legislative reforms underscore the need for PSTs to be well-versed in inquiry-based methodologies. Therefore, we focused our research context on PSTs enrolled in two key initial teacher **preparation** programs in Spain, the four-year Degree in Primary Education and the one-year Master in Secondary Education Teacher **Preparation** (from now on, MEd). These programs are essential prerequisites for those aspiring to teach in the country's Primary or Secondary Education institutions.

Participants

Given the specific focus of our questionnaire on IBSE, we strategically chose participants from the third year of the Degree in Primary Education, marking the point at which they first engage with a Science Education subject. Similarly, within the MEd, we targeted participants from science-specialized tracks, specifically Biology and Geology, and Physics and Chemistry, which also encountered Science Education for the first time. This approach ensured a relevant and informed participant pool for our study. Consequently, a total of 306 PSTs (230 from the Degree and 76 from the MEd) voluntarily contributed to our research across four academic years, from 2018/2019 to 2021/2022. While none of the participants possessed prior professional teaching experience, it is important to note that Secondary Education PSTs, who had already obtained a scientific or technological degree (a prerequisite for enrolling in the MEd program), surpassed their third-year Primary Education counterparts in terms of scientific knowledge. However, they did have a more limited pedagogical content knowledge, potentially resulting in differences in their perceptions of IBSE. Out of the participants, 195 identified as female and 111 as male, with options for non-binary and other genders also available. More information on the profile of the participants can be found in Table 1.

Table 1. PSTs' profile.

Data analysis

For data analysis, we utilised a combination of the R-based free software (R Core Team, 2021), JAMOVI version 2.3.21 (The Jamovi Project, 2022), and JASP version 0.17.2.1 (JASP Team, 2023). This approach allowed us to leverage the advantages offered by both software packages while addressing their limitations. Additionally, the choice of

R-based software was motivated by the recent adoption of the Open-Science National Strategy within the R&D system, which aims to promote the proper management of research data generated under the FAIR (Findable, Accessible, Interoperable, Reusable) principles. These principles facilitate the location, accessibility, interoperability and reusability of research data. As a result, all anonymous and coded data, along with the analysis, are available to the research community in an open-resource repository at the University of XXX (Authors, 2023).

As previously mentioned, our questionnaire included items framed both positively and negatively. This approach was employed to mitigate the tendency of participants to respond with "totally agree", regardless of the question or their actual thoughts and feelings, a phenomenon known as "acquiescence" (Breakwell, 2000). Consequently, as a first step in the analysis, we re-coded the scores for the reverse-worded items. All items phrased in a negative sense (items 4A to 4N) were inverted to maintain consistency in the direction of responses. In the re-coded items, a "totally disagree" score now signifies a stronger agreement with the negatively expressed statement, ensuring uniformity in interpretation even for negatively framed items that were initially presented in a positive tense.

Results

Descriptive analysis and refining process of the questionnaire

Table 2 presents a descriptive analysis of the initial 28 items that comprised the PTIP questionnaire. This analysis provides information on item scores' mean and standard deviation, skewness, and kurtosis values. Additionally, results from the normality test (Shapiro-Wilk test) are included.

Table 2. Exploratory analysis.

The means for the items range from 3.89 (item 2A) and 2.08 (item 4B). Skewness values are negative for 20 out of the 28 items, indicating shifts in response frequency, with some exhibiting pronounced asymmetry, such as item 2A (-4.35416). Conversely, the highest skewness values are observed for item 2D (0.68156). Regarding kurtosis, there is greater variability in values, with item 2A again displaying one of the extreme values (23.7409) while the recoded item 4D indicates the other extreme (-0.6453). The normality test results demonstrate that all values significantly deviate from normality ($p<0.001$).

Following the procedure outlined by Authors (**2021b**), and with the aim of identifying the most optimal items and initiating an assessment of the construct's internal validity, we calculated the discrimination index or item-rest correlation index (R_{IX}) for each item. The R_{IX} estimates the internal correlation of the item within its respective original dimension (Authors, **2021a**). Hence, in this initial purification process, we followed the guidelines given in the literature (Elosua, 2005), with a lower R_{IX} limit of 0.3 considered as good and values greater than 0.4 classified as very good. Items that did not exceed the threshold of 0.3 were eliminated, resulting in a total of 25 items in the questionnaire. Given the previous construction of scales as discussed in PRIMAS, we proceeded to conduct an internal reliability analysis of the remaining eight dimensions, following the criteria established by Elosua (2011).

Confirmatory factor analysis (CFA)

The validation process of the PTIP instrument (see Appendix 1 and 2) involved conducting Confirmatory Factor Analysis (CFA) (Brown, 2014; Kline, 2016; Rosseel, 2012) to evaluate the factor structure of the 25-item questionnaire scores. In this analysis, each item was loaded onto the factor corresponding to its dimension. It was necessary to seek a solution that was as parsimonious and balanced as possible. The

high number of scales mentioned above indicated difficulties in achieving such a solution, and this intuition was confirmed by models that were not well-adjusted or balanced.

Due to the non-normality of the variables, we employed the Diagonal Weighted Least Squares (DWLS) method with robust indicators. Thus, our analysis focused on a model consisting of 4 first-order factors (Figure 1), which yielded satisfactory model fit results, following guidelines by Hu & Bentler (1999) and Kline (2016). All standardised factor loadings were statistically significant (> 0.50). The Root Mean Square Error of Approximation (RMSEA) hovered around 0.050 (Brown, 2006), while the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) exceeded 0.95 and 0.90, respectively. These values indicated an excellent fit of the data, well within the acceptable limit (Hu & Bentler, 1999; Kline, 2016). Thus, our model (χ^2 = 391, df = 224, p = <0.001; $\chi 2/df$ = 1.745; CFI = 0.984; TLI = 0.982; RMSEA = 0.050, 90% CI 0.041-0.058) further validated the construct validity of the measurements.

Figure 1. Standardised estimates for the four factors, 23-items questionnaire.

To achieve this model, we made *post-hoc* adjustments by removing items 4I and 4J after analysis. The elimination of these items aligned with theoretical considerations. In the Spanish translation, item 4I was redundant with item 4B, referring to group management, while item 4J exhibited redundancy with item 4K, addressing students' performance. Table 3 displays standardised parameter estimates in the four-factor measurement model we applied. It also includes ordinal alpha, analogous to Cronbach's alpha, for assessing the internal reliability of the factors. Ordinal alpha was calculated using polychoric correlation coefficients, which are more appropriate for ordinal measures like Likert-type items. Given the ordinal nature of the variables and the

available number of responses, we also calculated McDonald's omega, the most suitable indicator for measuring the internal consistency of each factor.

Table 3. Results of the confirmatory factor analysis.

In this sense, the dimension named ***IBSE teaching practice (F1)*** included 6 of the 15 items from the PRIMAS questionnaire's *Description of current teaching practice* section, those that could be applied to PSTs, which delved into aspects related to classroom interactions, experimental activities, or importance of inquiry. ***IBSE students' applicability (F2)*** dimension included items that focused on understanding the connection between IBSE and student motivation. In order to streamline this dimension for PSTs and enhance its relevance, we added **four** new items relating to the potential contribution of IBSE to the development of scientific competencies as outlined in the Spanish science curriculum (Authors, 2017).

Finally, we decided to split the PRIMAS dimension related to difficulties into two sub-dimensions. One assessing ***IBSE difficulties related to personal aspects (F3),*** such as classroom management and students' knowledge, while the other addresses ***IBSE external difficulties aspects (F4)***, such as system restrictions and resource shortages.

Cluster analysis and IBSE profiles comparison

After determining the scales of the PTIP questionnaire, we finally conducted a *K*-means cluster analysis (see Appendix 3 and 4 for statistical results). This approach enables unbiased classification of participants into categories identifiable by shared characteristics in their responses (Shavelson, 2006). We first applied the Hartigan-Wong algorithm (Seol, 2023) to assess whether participants could be categorised into three different groups exhibiting significant differences in their perception of IBSE. The

results are presented in Figure 2. We then performed a one-way ANOVA test to verify the distinctions among clusters within each factor. The level of significance was consistently below 0.01 in all cases. Furthermore, the effect size, measured by η^2, was notably high across all levels (Cohen, 1988). Following Blanca et al. (2017), we should also indicate that the robustness of the ANOVA test is not affected by the non-normal data distribution. Finally, to identify significant differences between the clusters group for each factor, we continued applying the *Scheffé* test, a *post hoc* one-step multiple comparison procedure, that **states** the difference between the means when the significance is lower than 0.05.

Figure 2. Cluster analysis and *post hoc Scheffé* test results for PSTs.

As we can observe, the *K*-means cluster analysis effectively reveals the categorization of the PSTs into three different profiles, providing valuable insight into PSTs' diverse perspectives and challenges regarding IBSE. Profile A (named "*Highly favourable perception of IBSE"* and representing the minor group of the sample, with *N* = 80) showcases PSTs with a notably positive perception of the IBSE regarding its teaching practice and students' applicability (F1 and F2), and a minimal recognition of associated difficulties (F3 and F4), consistently scoring the highest across all four factors. In contrast, profile B (named "*Favourable perception of IBSE*" and representing the major group of the sample, with *N* = 123) encompasses PSTs who hold a highly favourable view of IBSE in terms of teaching practice and students' applicability (with no significant differences from profile A for these two categories, F1 and F2) but acknowledge more associated difficulties than profile A. Lastly, profile C (named "*Moderately favourable perception of IBSE*", with *N* = 103) represents PSTs with a lower perception of both IBSE teaching practice, students' applicability and its difficulties (F1 to F4). It is worth noting that these latter two groups exhibit differing

perceptions of internal and external difficulties. While profile B show higher means in the first three factors, it also demonstrates a greater concern **for** external difficulties (F4) than profile C.

Concerning potential differences stemming from the participants' profiles, whether they had completed a scientific or technological degree in the case of Secondary Education PSTs or possessed greater pedagogical content knowledge as in the case of Primary Education PSTs, we conducted independent cluster analysis for both groups, as indicated in Figure 3 (see Appendix 3 and 4 for statistical results).

Figure 3. Cluster analysis and *post hoc Scheffé* test results for Secondary and Primary Education PST.

We can discern notable distinctions primarily associated with the perception of challenges when it comes to implementing IBSE. While both groups exhibit a profile A (*Highly favourable to IBSE*), characterized by a highly positive view of teaching practices and the practicality for students (F1 and F2) with minimal recognition of associated difficulties (F3 and F4), Secondary Education PSTs tend to acknowledge a higher number of internal and external obstacles (lower mean values for F3 and F4) compared to their counterparts in Primary Education. In both groups of PSTs, profile C (*Moderately favourable to IBSE)* develops similarly, with a lower perception of IBSE teaching practices, students' applicability, and the difficulties involved (F1 to F4). However, it is profile B (*Favourable to IBSE*), the one that intertwines between Secondary and Primary Education teachers. While in Secondary Education PSTs this profile behaves moderately compared to profiles A and C, profile B in Primary Education PSTs exhibits the greatest concerns about external difficulties (F4). This comparison highlights how PSTs across educational levels perceive and engage with

IBSE, underscoring the importance of tailored instructional approaches to cater to their specific needs and perspectives.

Discussion

The PRIMAS questionnaire (Engeln et al., 2013) supposed an extensive European investigation into how in-service teachers developed their teaching around IBSE. Nevertheless, the project left behind a significant gap in understanding how PSTs perceived IBSE, which might be critical in the complex landscape of science education. We aimed to fill this gap by designing the PTIP questionnaire for Spanish-speaking PSTs. Doing so, we reach to the Spanish public and the presentation in English of this paper is only with international publication effects, not pretending to be functional to English-speaking PSTs.

Although the questionnaire was applied in Spanish, the effort made in such adaptation is formed by various stages that transcend the mere translation. Hence, the adaptation to PSTs involved a turn to a more focused vision in their perceptions since, at this **preparation** stage, the IBSE application in their teaching is still limited. Moreover, including some aspects of the current national science curriculum was key to illuminating issues related to scientific competencies (Authors, 2017; van Aalderen-Smeets et al., 2017).

Our analysis demonstrated that the Spanish-adapted questionnaire effectively measures various aspects of the IBSE perceptions in pre-service science teachers. The four proposed dimensions cover a wide range, from the understanding of inquiry and science teaching through it to the difficulties in their implementation. While we aimed to follow the structure proposed in PRIMAS, the distinction between in-service and PSTs prompted some modifications, excluding certain items and introducing new perspectives within the dimensions. Nevertheless, these four dimensions still have a

direct theoretical correlation with the main points addressed in PRIMAS. In any case, the process for validating the proposed scales has been satisfactory.

Before the statistical analysis, consultation with an expert panel was crucial in constructing the scales. The panel ensured the correct translation of each item, assessed its relevance to its dimension, and evaluated its overall alignment with IBSE. **A few minor modifications were made based on the panel's feedback.**

Afterwards, we administered the PTIP questionnaire over three consecutive courses, collecting a total of 306 valid responses. Data analysis began once we had enough valid responses. The statistical analysis confirmed the theoretical basis of our questionnaire construction, albeit with some changes that did not affect the primary structure.

Three of the initial 28 items were eliminated during the first stage due to their poor homogeneity with the rest of the items in their respective dimension. After their removal, the initial CFA model slightly exceeded the recommended RMSEA threshold. To balance this, we examined modification indexes, leading to the elimination of two more redundant items. Following this model adjustment, we assessed the scales' internal reliability through ordinal alpha and omega, both of which demonstrated good consistency. This concluded the validation of the scales.

We then decided to go further on our research, following the approach of Sáez et al., (2019), to conduct cluster analysis based on the validation of the scales. These findings, representing teachers' eagerness to adopt IBSE in their professional practice, could shed some light on why inquiry is still limited in science education. Accordingly, by categorising these perceptions, our research could empower PSTs to recognise them and, if needed, adjust their personal views on education.

The results revealed three profiles similar to those exposed by Sáez et al. (2019).

Profile A stands out as the PSTs most eager to IBSE since they displayed a highly favourable vision for the inquiry as a valid approach to teaching, giving little attention to the possible difficulties of its implementation and not identifying the tensions that commonly narrow inquiry activities in the classroom. Profile B offer a mixed vision. While PSTs composing this cluster also have a highly favourable vision of IBSE, they are more reserved regarding the difficulties, identifying a higher degree of them than profile A. Precisely, they recognise more external difficulties than profile C (such as lacking materials or time). Finally, for this C profile, the benefits of the IBSE are more moderate, and the difficulties are more significant than in the other clusters, except the external ones in comparison with profile B. In any case, this profile offers a more doubting vision in general.

We identify the same profile when we compare the cluster analysis conducted independently for Primary and Secondary Education PSTs. However, **it is** worth noting that in profile C, Secondary Education PSTs express more pronounced concerns, and there is a reduced balance **between** the benefits and challenges associated with implementing IBSE. These results, in turn, show the discrepancy in self-efficacy perceived by both groups. This might be associated with the relatively limited pedagogical content knowledge received by Secondary Education PSTs compared to their counterparts in Primary Education (who complete a four-year degree with a deep focus on this regard), and therefore, greater efforts must be done in their teacher **preparation programs** to enhance self-efficacy and provide them with tools to confront teachers' tensions.

Considering that the implementation of IBSE is deeply intertwined with cultural backgrounds and school subjects, relevant country-specific differences about IBSE made cultural adaptations of the common international concept necessary (**Engeln** et al.

2013), therefore leaving room for a specific adaptation. This observation is particularly relevant in Spain, where the unique cultural and educational landscape has paved the way for a distinct approach that is more relatable and effective for Spanish educators. This tailored adaptation underscores the flexibility and universal applicability of IBSE, proving its potential to be effectively integrated into diverse educational systems while maintaining its core principles of inquiry and exploration.

We recognise that the different regions of the Spanish-speaking world may need some adaptations. However, a first attempt at assessing cultural adaptation was carried out with PSTs at some Chilean universities we collaborated with (Authors, **2021c**). The results were similar regarding IBSE teaching practice and students' applicability, but we registered some significant differences in associated difficulties, as we observed when considering Secondary or Primary education PSTs. Hence, although we have not yet received evidence of a more extended application within the Latin-American context, this first Chilean approach might be a reasonable starting point for probing the cultural validity of the **PTIP**.

Conclusions

Through adaptation and contributions from various sources (Authors, 2017; Maass & Engeln, 2014), particularly the PRIMAS questionnaire (Engeln et al., 2013), we have developed the PTIP questionnaire, a valuable instrument for assessing the perceptions of Spanish-speaking PSTs regarding IBSE. This questionnaire serves as a starting point for interventions aimed at improving attitudes towards inquiry teaching and its potential implementation. This was the main goal that moved us to start this work from the beginning.

Comprising 23 items, the PTIP questionnaire has been internally validated through statistical analysis. It successfully measures various aspects related to IBSE

teaching practice, IBSE students' applicability, as well as internal and external difficulties with the inquiry approach. **Furthermore, cluster analysis identified three general profiles of IBSE perceptions, allowing the identification of concerns that pre-service science teachers identify as obstacles and the eagerness to apply IBSE in their future professional practice.**

The discussion of this study's findings must be contextualized within the framework of certain limitations, the most significant being the limited number of participants. Our sampling method was incidental and non-probabilistic, which, combined with the voluntary nature of participation for PSTs, may have impacted the representativeness of the results. This limitation is noteworthy because it suggests that the findings might not fully encapsulate the broader population of PSTs in Spain. Consequently, while the insights garnered provide valuable initial understandings, they should be interpreted cautiously regarding their generalizability.

Despite the PTIP questionnaire, in similarity to the PRIMAS, covers a set of teachers' perceptions, in terms of self-efficacy and conceptualization of the inquiry, assuming the richness and complexity of the term perceptions, we consider that aspects related to emotions and beliefs are overlooked, and data related to these should be collected through more specific instruments. Furthermore, it is essential to recognize the need for additional research to validate and expand upon these findings. Future research endeavours should aim to administer the tool to larger and more diverse groups for a more robust validation of the results. This expanded approach should include PSTs from various Spanish-speaking contexts, notably those in Latin American regions, with whom we collaborate through the XXX network.

This approach will not only validate the tool more comprehensively but also provide deeper insights into PSTs' perceptions regarding IBSE in various cultural and

educational settings. It will support university educators in designing activities to enhance knowledge and application of IBSE. It will also lead to tailored **preparation** programs addressing the benefits and tensions emerging from each cultural context.

Ethics statement

The authors stated that the University of XXX did not have specific protocols for this type of study when this research was carried out. Informed consent was obtained from the participants. The data was treated as confidential information used exclusively for research purposes, assuring the anonymous and confidential character of all the participants' data.

Declaration of interest

The authors declare no competing interest.

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Table 1. Pre-service teachers' profile

General participants profile					
Educational level					
Students enrolled at the Degree				230	75
Students enrolled at the MEd				76	25
Gender					
Female				195	64
Male				111	36
Age					
< 25				61	20
25-30				220	72
> 35				25	8
Participants profile by degree					
Students enrolled at the Degree	**N**	**%**	Students enrolled at the MEd	**N**	**%**
Gender			*Gender*		
Female	152	66	Female	43	57
Male	78	34	Male	33	43
Age			*Age*		
< 25	36	16	< 25	25	33
25-30	185	80	25-30	35	46
> 35	9	4	> 35	16	21
Baccalaureate of access to the Degree	3	1	*Degree of access to the MEd*		
Arts	13	6	Biochemistry/Pharmacy	10	13
Engineering and Technology	42	18	Biology	14	18
Health Sciences	37	16	Chemical/Mechanical engineering	10	13
Humanities/Social Sciences	135	59	Chemistry	18	24
			Environmental sciences	19	25
			Others	5	7

Table 2. Descriptive analysis.

					Skewness		Kurtosis			
Dim	**Item**	***M*[a]**	**SD**	**Var**	**Statistic**	**Standard error**	**Statistic**	**Standard error**	**W[b]**	**R_{IX}[c]**
EXA	2A	3.89	0.38	0.145	-4.354	0.139	23.741	0.278	0.316	0.172
EXA	2D	3.30	0.66	0.433	-0.682	0.139	0.624	0.278	0.765	0.172
INQ	2B	3.39	0.57	0.329	-0.381	0.139	-0.097	0.278	0.723	0.525
INQ	2E	3.58	0.55	0.298	-0.912	0.139	0.501	0.278	0.666	0.583
INQ	2G	3.71	0.51	0.258	-1.683	0.139	2.897	0.278	0.577	0.539
INT	2C	3.85	0.40	0.157	-2.868	0.139	10.454	0.278	0.417	0.545
INT	2F	3.71	0.52	0.267	-1.822	0.139	4.161	0.278	0.573	0.659
INT	2H	3.71	0.52	0.267	-1.678	0.139	2.807	0.278	0.582	0.729
MOT	3A	3.41	0.57	0.322	-0.408	0.139	-0.104	0.278	0.715	0.558
MOT	3B	3.39	0.58	0.337	-0.419	0.139	-0.099	0.278	0.727	0.558
SCC	3C	3.66	0.52	0.271	-1.303	0.139	1.564	0.278	0.618	0.575
SCC	3D	3.57	0.57	0.325	-1.021	0.139	0.649	0.278	0.677	0.626
SCC	3E	3.63	0.54	0.286	-1.184	0.139	1.169	0.278	0.639	0.569
SCC	3F	3.47	0.61	0.374	-0.869	0.139	0.633	0.278	0.720	0.602
SYS	4A	2.35	0.68	0.464	0.307	0.139	0.034	0.278	0.811	0.243
SYS	4D	2.48	0.87	0.749	0.071	0.139	-0.645	0.278	0.875	0.461
SYS	4G	2.35	0.78	0.615	0.199	0.139	-0.324	0.278	0.855	0.427
SYS	4N	2.30	0.79	0.616	0.159	0.139	-0.377	0.278	0.856	0.398
MNG	4B	3.01	0.73	0.538	-0.512	0.139	0.273	0.278	0.818	0.514
MNG	4E	2.94	0.73	0.528	-0.375	0.139	0.050	0.278	0.826	0.527
MNG	4H	2.41	0.82	0.668	0.217	0.139	-0.432	0.278	0.862	0.496
MNG	4I	2.70	0.82	0.671	-0.179	0.139	-0.471	0.278	0.864	0.573
RES	4C	2.45	0.76	0.570	0.087	0.139	-0.313	0.278	0.849	0.454
RES	4F	2.64	0.82	0.670	-0.008	0.139	-0.570	0.278	0.865	0.354
RES	4L	2.66	0.77	0.586	0.001	0.139	-0.434	0.278	0.851	0.501
RES	4M	2.08	0.80	0.635	0.589	0.139	0.158	0.278	0.830	0.446
KNO	4J	2.92	0.74	0.551	-0.309	0.139	-0.171	0.278	0.836	0.380
KNO	4K	3.22	0.68	0.458	-0.612	0.139	0.536	0.278	0.783	0.380

Note: (*) $p < 0.001$

[a]Scores on reverse-worded items have been recoded, inverting the values

[b]Shapiro-Wilk test of normality

[c]Item-rest correlation coefficient $R_{IX} > 0.3$

Table 3. Results of the confirmatory factor analysis.

Factors	Item	*Factor loadings*[a]	*Ordinal alpha*[b]	*Ordinal omega*[c]
IBSE teaching practice (F1)	2B	0.748	0.906	0.950
	2C	0.814		
	2E	0.795		
	2F	0.837		
	2G	0.786		
	2H	0.860		
IBSE students' applicability (F2)	3A	0.702	0.884	0.938
	3B	0.698		
	3C	0.835		
	3D	0.777		
	3E	0.758		
	3F	0.780		
Internal difficulties associated with the inquiry approach (F3)	4B	0.705	0.729	0.771
	4E	0.722		
	4H	0.580		
	4K	0.554		
External difficulties associated with the inquiry approach (F4)	4C	0.705	0.819	0.880
	4D	0.735		
	4F	0.550		
	4G	0.575		
	4L	0.652		
	4M	0.601		
	4N	0.625		

[a]All values are significant at $p = 0.001$

[b]Equivalent to Cronbach's alpha but calculated using polychoric correlation coefficients, which are more appropriate for ordinal measures such as Likert-type items

[c]Equivalent to McDonalds' omega but calculated using polychoric correlation coefficients, which are more appropriate for ordinal measures such as Likert-type items

Figure 1. Standardised estimates for the four factors, 23-items questionnaire.

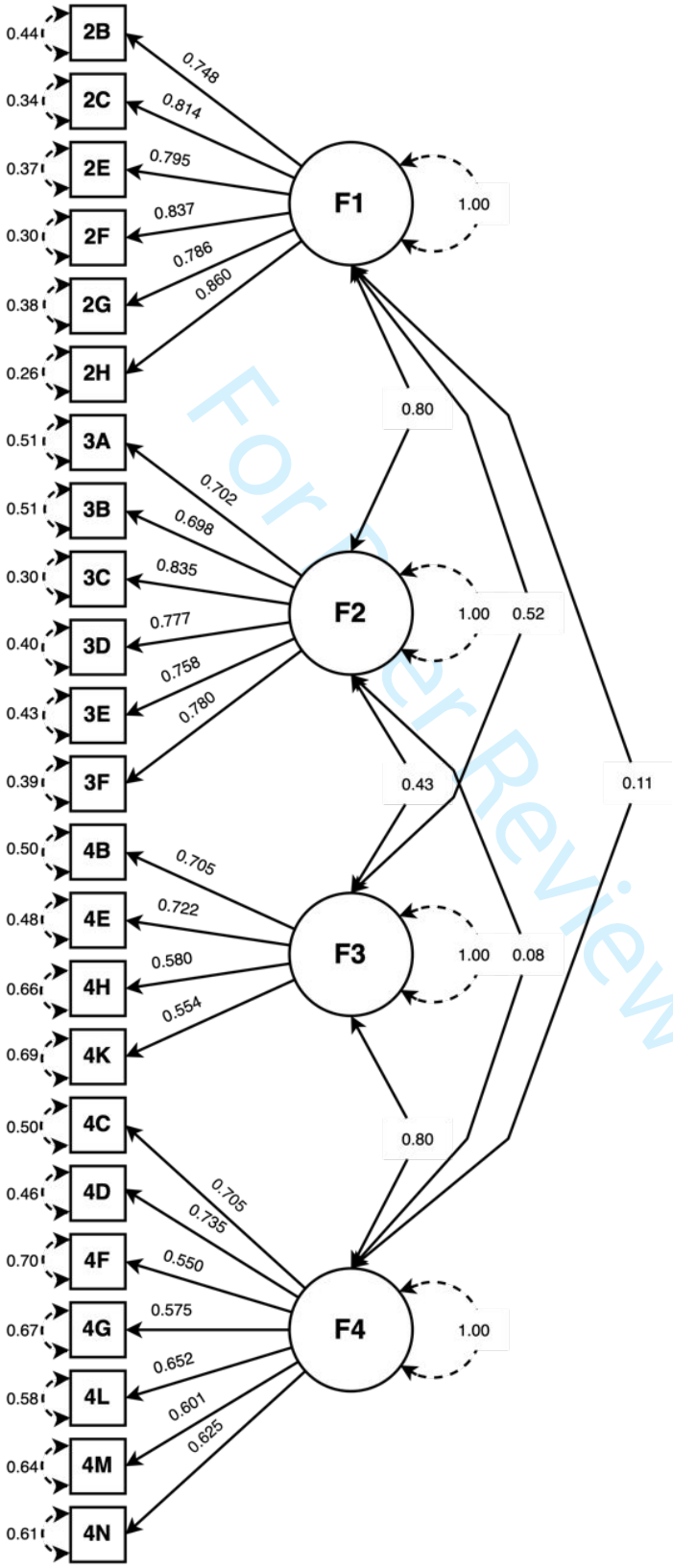


Figure 2. Cluster analysis and *post hoc Scheffé* test results for PSTs.

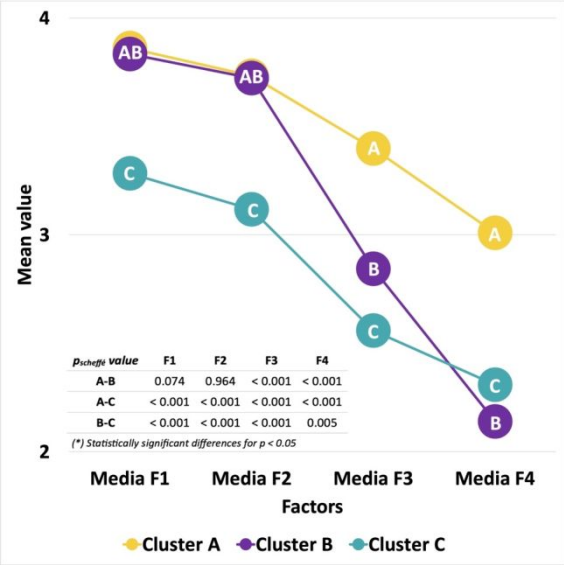
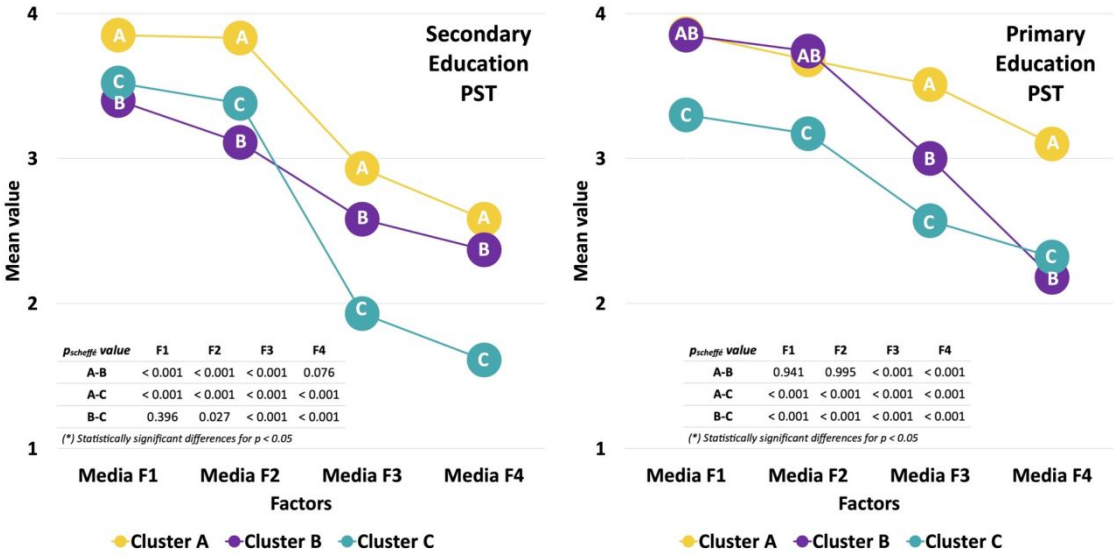


Figure 3. Cluster analysis and *post hoc Scheffé* test results for Secondary and Primary Education PST.



Appendix 1. PTIP questionnaire (Spanish version).

II. EL PROCESO DE ENSEÑANZA-APRENDIZAJE				
2. ¿En qué medida estás de acuerdo con las siguientes afirmaciones?	**TD**	**D**	**A**	**TA**
2b Es fundamental que el alumnado diseñe sus propios experimentos/investigaciones.	☐	☐	☐	☐
2c Hay que proporcionar oportunidades al alumnado para que exprese y explique sus propias ideas.	☐	☐	☐	☐
2e El alumnado debe realizar investigaciones/experimentos para demostrar/comprobar sus propias ideas.	☐	☐	☐	☐
2f Considero necesario que el alumnado tenga discusiones/debata sobre el tema que estemos trabajando	☐	☐	☐	☐
2g Es fundamental que el alumnado obtenga conclusiones a partir de los experimentos/simulaciones/modelos que ha realizado	☐	☐	☐	☐
2h Es importante que el alumnado participe en el debate y las discusiones que se establezcan en clase.	☐	☐	☐	☐
III. TU VISIÓN COMO FUTURO DOCENTE				
3 Creo que la enseñanza-aprendizaje de las ciencias por indagación…	**TD**	**D**	**A**	**TA**
3a es adecuado para afrontar problemas de motivación del alumnado.	☐	☐	☐	☐
3b es apropiado para abordar los problemas de aprendizaje del alumnado.	☐	☐	☐	☐
3c desarrolla el pensamiento crítico del alumnado.	☐	☐	☐	☐
3d favorece la adquisición de actitudes y valores científicos y hacia la ciencia.	☐	☐	☐	☐
3e promueve el desarrollo de la autonomía y la iniciativa personal.	☐	☐	☐	☐
3f ayuda a visibilizar el papel de la ciencia en la sociedad.	☐	☐	☐	☐
4 Creo que a la hora de poner en práctica la enseñanza-aprendizaje de las ciencias por indagación, encontraría dificultades porque …	**TD**	**D**	**A**	**TA**
4b me preocupa que empeore el comportamiento de mi alumnado.	☐	☐	☐	☐
4c no dispondría de materiales didácticos adecuados.	☐	☐	☐	☐
4d no habría tiempo suficiente para cumplir la programación.	☐	☐	☐	☐
4e no me siento segura(o) con esta metodología.	☐	☐	☐	☐
4f no está incluido en los libros de texto.	☐	☐	☐	☐
4g las evaluaciones a las que se enfrenta mi alumnado no tienen en cuenta todos los aspectos de la indagación	☐	☐	☐	☐
4h me preocupa que mi alumnado se pueda sentir perdido y frustrado en su aprendizaje.	☐	☐	☐	☐
4k no es efectiva en alumnado de bajo rendimiento	☐	☐	☐	☐
4l necesitaría acceso a programas de formación específicos del enfoque de indagación.	☐	☐	☐	☐
4m no se suele disponer de suficientes recursos, como ordenadores o laboratorios.	☐	☐	☐	☐
4n el número de alumnado por clase es habitualmente demasiado elevado para que la práctica de la indagación sea efectiva.	☐	☐	☐	☐

TD: totalmente en desacuerdo; **D**: en desacuerdo; **A:** de acuerdo; **TA**: totalmente de acuerdo

Appendix 2. PTIP questionnaire (English version).

II. TEACHING-LEARNING PROCESS				
2. To what extent do you agree with the following statements?	**TD**	**D**	**A**	**TA**
2b It is essential that students design their own experiments/investigations.	☐	☐	☐	☐
2c It is important to provide opportunities for students to express and explain their own ideas.	☐	☐	☐	☐
2e Students should conduct investigations/experiments to test their own ideas.	☐	☐	☐	☐
2f I consider it necessary for students to have discussions/debates on the topic we are working on.	☐	☐	☐	☐
2g It is essential that students draw conclusions from the experiments/simulations/models that they have carried out.	☐	☐	☐	☐
2h It is important that students participate in the debate and discussions that take place in class.	☐	☐	☐	☐
III. YOUR VISION AS A FUTURE TEACHER				
3 I think that IBSE…	**TD**	**D**	**A**	**TA**
3a is well suited to overcome problems with students' motivation.	☐	☐	☐	☐
3b is well suited to overcome students' learning problems.	☐	☐	☐	☐
3c develops critical thinking in students.	☐	☐	☐	☐
3d favours the acquisition of scientific attitudes and values towards science.	☐	☐	☐	☐
3e promotes the development of students' autonomy and personal initiative.	☐	☐	☐	☐
3f helps to make the role of science visible in society.	☐	☐	☐	☐
4 I would have difficulties in implementing IBSE, because…	**TD**	**D**	**A**	**TA**
4b I would worry about students' discipline being more difficult in IBST lessons.	☐	☐	☐	☐
4c I would have a lack of adequate teaching materials.	☐	☐	☐	☐
4d there is not enough time in the curriculum.	☐	☐	☐	☐
4e I wouldn't feel confidents with IBSE.	☐	☐	☐	☐
4f IBST is not included in textbooks.	☐	☐	☐	☐
4g my students have to take assessments that don't reward IBSE	☐	☐	☐	☐
4h I would worry about my students getting lost and frustrated in their learning.	☐	☐	☐	☐
4k is not effective in underperforming students	☐	☐	☐	☐
4l I would need access to any adequate training program involving IBST.	☐	☐	☐	☐
4m I wouldn't have sufficient resources such as computers, laboratory, etc.	☐	☐	☐	☐
4n the number of students per class is usually too high for IBSE practice to be effective.	☐	☐	☐	☐

TD: totally disagree; **D**: disagree; **A:** agree; **TA**: totally agree

Appendix 3. Cluster analysis and ANOVA test results

Cluster analysis and ANOVA test for PSTs (MEd & Degree students)

Factor	Cluster	N	*M*	Df[a]	Mean Square	η^{2b}	*F*[c]	*p value*
F1	A	80	3.86	2	10.764	0.506	155	<.001
	B	123	3.83					
	C	103	3.28					
F2	A	80	3.73	2	12.720	0.505	154	<.001
	B	123	3.72					
	C	103	3.12					
F3	A	80	3.40	2	16.077	0.382	93.8	<.001
	B	123	2.84					
	C	103	2.56					
F4	A	80	3.01	2	19.362	0.463	131	<.001
	B	123	2.14					
	C	103	2.31					

Cluster analysis and ANOVA test for Secondary Education PSTs (MEd)

Factor	Cluster	N	*M*	Df[a]	Mean Square	η^{2b}	*F*[c]	*p value*
F1	A	38	3.85	2	2.192	0.602	55.2	<.001
	B	27	3.44					
	C	11	3.44					
F2	A	38	3.83	2	4.724	0.693	82.3	<.001
	B	27	3.11					
	C	11	3.38					
F3	A	38	2.93	2	2.226	0.267	13.3	<.001
	B	27	2.58					
	C	11	1.93					
F4	A	38	2.58	2	3.911	0.437	28.3	<.001
	B	27	2.37					
	C	11	1.61					

Cluster analysis and ANOVA test for Primary Education PSTs (Degree)

Factor	Cluster	N	*M*	Df[a]	Mean Square	η^{2b}	*F*[c]	*p value*
F1	A	54	3.86	2	8.653	0.491	110	<.001
	B	96	3.85					
	C	80	3.30					
F2	A	54	3.68	2	8.191	0.446	91.4	<.001
	B	96	3.74					
	C	80	3.17					
F3	A	54	3.51	2	12.954	0.417	81.2	<.001
	B	96	3.00					
	C	80	2.57					
F4	A	54	3.10	2	15.643	0.479	104	<.001
	B	96	2.18					
	C	80	2.32					

[a]Degrees of freedom [b]Effect size [e]ANOVA F-statistic, rate between variability between groups and variability inside the group

Appendix 4. *Post hoc Scheffé* test

***Post hoc Scheffé* test for PSTs (MEd & Degree)**

Factor	Cluster comparison	Mean differences	Std. Error	*t*	$p_{scheffe}$[a]
F1	A-B	-0.027	0.038	-0.72	0.774
	A-C	0.577	0.039	-14.71	**< 0.001**
	B-C	0.550	0.035	15.64	**< 0.001**
F2	A-B	-0.011	0.041	-0.27	0.964
	A-C	-0.617	0.043	-14.42	**< 0.001**
	B-C	0.606	0.038	15.08	**< 0.001**
F3	A-B	-0.553	0.060	-9.31	**< 0.001**
	A-C	-0.839	0.062	-13.60	**< 0.001**
	B-C	0.285	0.055	5.16	**< 0.001**
F4	A-B	-0.870	0.055	-15.74	**< 0.001**
	A-C	-0.701	0.057	-12.33	**< 0.001**
	B-C	-0.169	0.051	-3.28	**0.005**

***Post hoc Scheffé* test for Secondary Education PSTs (MEd)**

Factor	Cluster comparison	Mean differences	Std. Error	*t*	$p_{scheffe}$[a]
F1	A-B	0.445	0.059	7.61	**< 0.001**
	A-C	-0.331	0.080	-4.16	**< 0.001**
	B-C	0.114	0.083	1.37	0.396
F2	A-B	0.713	0.068	10.43	**< 0.001**
	A-C	-0.446	0.093	-4.79	**< 0.001**
	B-C	0.268	0.097	2.75	**0.027**
F3	A-B	0.344	0.085	4.05	**< 0.001**
	A-C	-0.973	0.116	-8.41	**< 0.001**
	B-C	-0.629	0.121	-5.20	**< 0.001**
F4	A-B	0.214	0.093	2.31	0.076
	A-C	-0.969	0.126	-7.68	**< 0.001**
	B-C	-0.755	0.132	-5.73	**< 0.001**

***Post hoc Scheffé* test for Primary Education PSTs (Degree)**

Factor	Cluster comparison	Mean differences	Std. Error	*t*	$p_{scheffe}$[a]
F1	A-B	-0.016	0.046	-0.35	0.941
	A-C	0.583	0.044	13.22	**< 0.001**
	B-C	-0.598	0.048	-12.48	**< 0.001**
F2	A-B	0.005	0.049	0.10	0.995
	A-C	0.575	0.047	12.26	**< 0.001**
	B-C	-0.570	0.051	-11.17	**< 0.001**
F3	A-B	-0.554	0.065	-8.56	**< 0.001**
	A-C	0.305	0.063	4.87	**< 0.001**
	B-C	-0.859	0.068	-12.61	**< 0.001**
F4	A-B	-0.894	0.063	-14.25	**< 0.001**
	A-C	-0.239	0.061	-3.94	**< 0.001**
	B-C	-0.655	0.066	-9.92	**< 0.001**

[a]All values are significant at $p < 0.05$ (in bold)

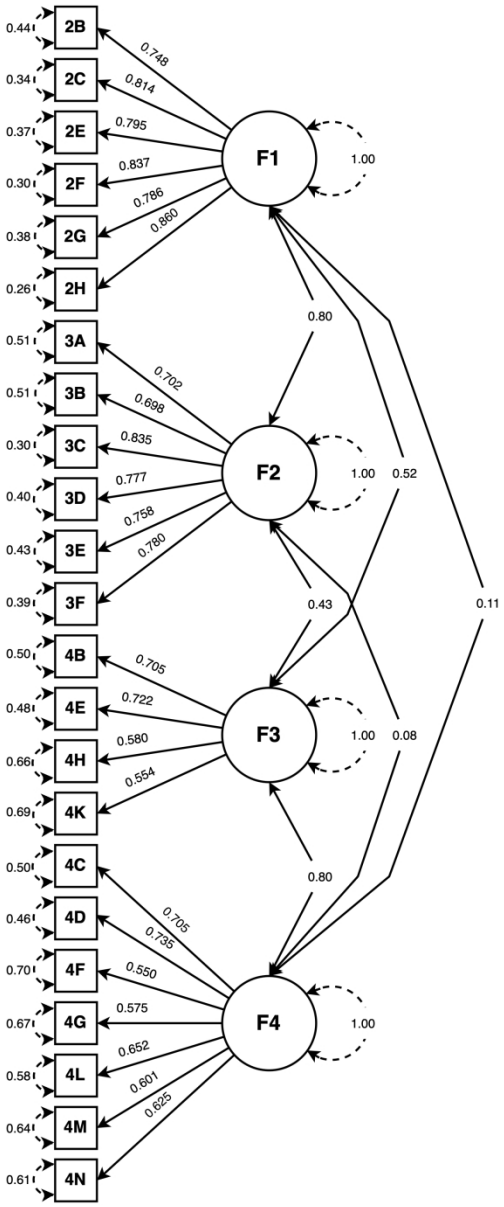
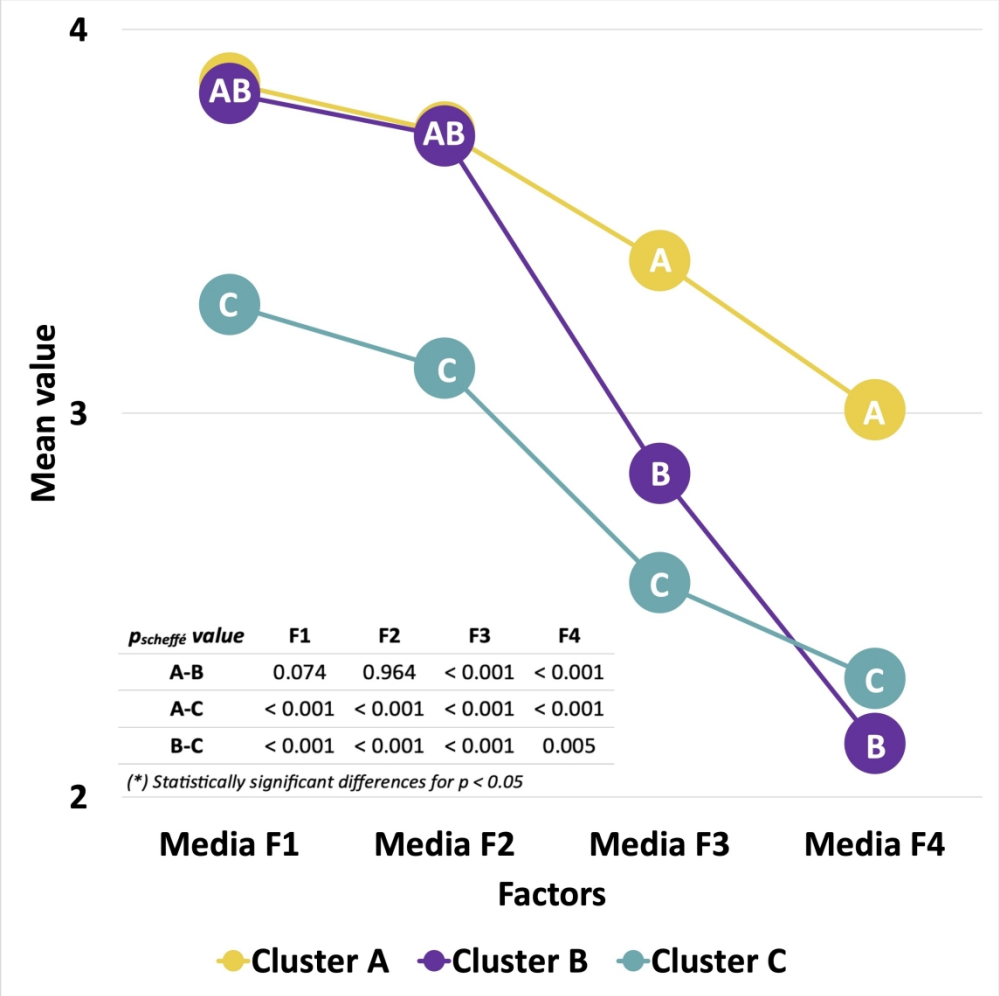


Figure 1. Standardised estimates for the four factors, 23-items questionnaire.

529x1212mm (72 x 72 DPI)



$p_{scheffé}$ value	F1	F2	F3	F4
A-B	0.074	0.964	< 0.001	< 0.001
A-C	< 0.001	< 0.001	< 0.001	< 0.001
B-C	< 0.001	< 0.001	< 0.001	0.005

(*) Statistically significant differences for p < 0.05

Figure 2. Cluster analysis and post hoc Scheffé test results for PSTs.

958x958mm (72 x 72 DPI)

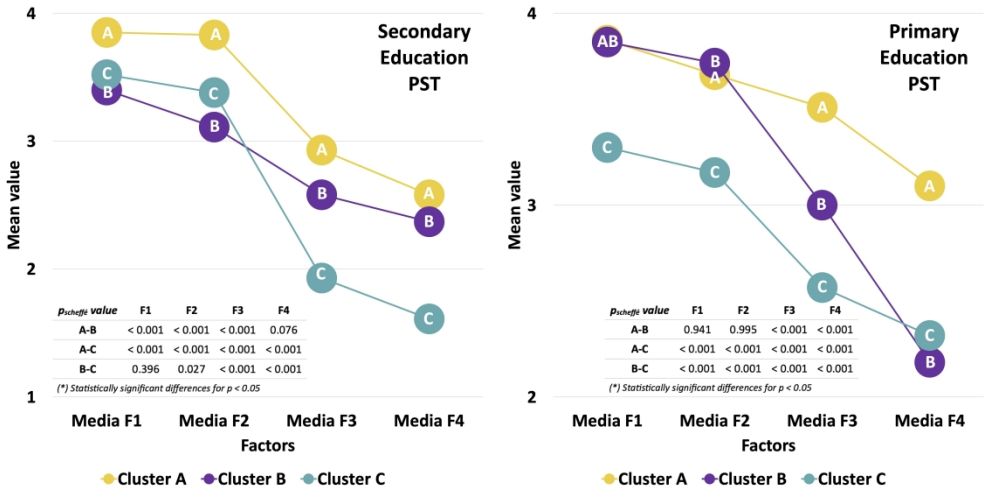


Figure 3. Cluster analysis and post hoc Scheffé test results for Secondary and Primary Education PST.

1918x955mm (72 x 72 DPI)

Appendix 1. PTIP questionnaire (Spanish version).

II. EL PROCESO DE ENSEÑANZA-APRENDIZAJE				
2. ¿En qué medida estás de acuerdo con las siguientes afirmaciones?	**TD**	**D**	**A**	**TA**
2b Es fundamental que el alumnado diseñe sus propios experimentos/investigaciones.	☐	☐	☐	☐
2c Hay que proporcionar oportunidades al alumnado para que exprese y explique sus propias ideas.	☐	☐	☐	☐
2e El alumnado debe realizar investigaciones/experimentos para demostrar/comprobar sus propias ideas.	☐	☐	☐	☐
2f Considero necesario que el alumnado tenga discusiones/debata sobre el tema que estemos trabajando	☐	☐	☐	☐
2g Es fundamental que el alumnado obtenga conclusiones a partir de los experimentos/simulaciones/modelos que ha realizado	☐	☐	☐	☐
2h Es importante que el alumnado participe en el debate y las discusiones que se establezcan en clase.	☐	☐	☐	☐
III. TU VISIÓN COMO FUTURO DOCENTE				
3 Creo que la enseñanza-aprendizaje de las ciencias por indagación…	**TD**	**D**	**A**	**TA**
3a es adecuado para afrontar problemas de motivación del alumnado.	☐	☐	☐	☐
3b es apropiado para abordar los problemas de aprendizaje del alumnado.	☐	☐	☐	☐
3c desarrolla el pensamiento crítico del alumnado.	☐	☐	☐	☐
3d favorece la adquisición de actitudes y valores científicos y hacia la ciencia.	☐	☐	☐	☐
3e promueve el desarrollo de la autonomía y la iniciativa personal.	☐	☐	☐	☐
3f ayuda a visibilizar el papel de la ciencia en la sociedad.	☐	☐	☐	☐
4 Creo que a la hora de poner en práctica la enseñanza-aprendizaje de las ciencias por indagación, encontraría dificultades porque …	**TD**	**D**	**A**	**TA**
4b me preocupa que empeore el comportamiento de mi alumnado.	☐	☐	☐	☐
4c no dispondría de materiales didácticos adecuados.	☐	☐	☐	☐
4d no habría tiempo suficiente para cumplir la programación.	☐	☐	☐	☐
4e no me siento segura(o) con esta metodología.	☐	☐	☐	☐
4f no está incluido en los libros de texto.	☐	☐	☐	☐
4g las evaluaciones a las que se enfrenta mi alumnado no tienen en cuenta todos los aspectos de la indagación	☐	☐	☐	☐
4h me preocupa que mi alumnado se pueda sentir perdido y frustrado en su aprendizaje.	☐	☐	☐	☐
4k no es efectiva en alumnado de bajo rendimiento	☐	☐	☐	☐
4l necesitaría acceso a programas de formación específicos del enfoque de indagación.	☐	☐	☐	☐
4m no se suele disponer de suficientes recursos, como ordenadores o laboratorios.	☐	☐	☐	☐
4n el número de alumnado por clase es habitualmente demasiado elevado para que la práctica de la indagación sea efectiva.	☐	☐	☐	☐

TD: totalmente en desacuerdo; **D**: en desacuerdo; **A:** de acuerdo; **TA**: totalmente de acuerdo

Appendix 2. PTIP questionnaire (English version).

II. TEACHING-LEARNING PROCESS				
2. To what extent do you agree with the following statements?	**TD**	**D**	**A**	**TA**
2b It is essential that students design their own experiments/investigations.	☐	☐	☐	☐
2c It is important to provide opportunities for students to express and explain their own ideas.	☐	☐	☐	☐
2e Students should conduct investigations/experiments to test their own ideas.	☐	☐	☐	☐
2f I consider it necessary for students to have discussions/debates on the topic we are working on.	☐	☐	☐	☐
2g It is essential that students draw conclusions from the experiments/simulations/models that they have carried out.	☐	☐	☐	☐
2h It is important that students participate in the debate and discussions that take place in class.	☐	☐	☐	☐
III. YOUR VISION AS A FUTURE TEACHER				
3 I think that IBSE…	**TD**	**D**	**A**	**TA**
3a is well suited to overcome problems with students' motivation.	☐	☐	☐	☐
3b is well suited to overcome students' learning problems.	☐	☐	☐	☐
3c develops critical thinking in students.	☐	☐	☐	☐
3d favours the acquisition of scientific attitudes and values towards science.	☐	☐	☐	☐
3e promotes the development of students' autonomy and personal initiative.	☐	☐	☐	☐
3f helps to make the role of science visible in society.	☐	☐	☐	☐
4 I would have difficulties in implementing IBSE, because…	**TD**	**D**	**A**	**TA**
4b I would worry about students' discipline being more difficult in IBST lessons.	☐	☐	☐	☐
4c I would have a lack of adequate teaching materials.	☐	☐	☐	☐
4d there is not enough time in the curriculum.	☐	☐	☐	☐
4e I wouldn't feel confidents with IBSE.	☐	☐	☐	☐
4f IBST is not included in textbooks.	☐	☐	☐	☐
4g my students have to take assessments that don't reward IBSE	☐	☐	☐	☐
4h I would worry about my students getting lost and frustrated in their learning.	☐	☐	☐	☐
4k is not effective in underperforming students	☐	☐	☐	☐
4l I would need access to any adequate training program involving IBST.	☐	☐	☐	☐
4m I wouldn't have sufficient resources such as computers, laboratory, etc.	☐	☐	☐	☐
4n the number of students per class is usually too high for IBSE practice to be effective.	☐	☐	☐	☐

TD: totally disagree; **D**: disagree; **A:** agree; **TA**: totally agree

Appendix 3. Cluster analysis and ANOVA test results

Cluster analysis and ANOVA test for PSTs (MEd & Degree students)

Factor	Cluster	N	*M*	Df[a]	Mean Square	η^{2b}	*F*[c]	*p value*
F1	A	80	3.86	2	10.764	0.506	155	<.001
	B	123	3.83					
	C	103	3.28					
F2	A	80	3.73	2	12.720	0.505	154	<.001
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	C	103	3.12					
F3	A	80	3.40	2	16.077	0.382	93.8	<.001
	B	123	2.84					
	C	103	2.56					
F4	A	80	3.01	2	19.362	0.463	131	<.001
	B	123	2.14					
	C	103	2.31					

Cluster analysis and ANOVA test for Secondary Education PSTs (MEd)

Factor	Cluster	N	*M*	Df[a]	Mean Square	η^{2b}	*F*[c]	*p value*
F1	A	38	3.85	2	2.192	0.602	55.2	<.001
	B	27	3.44					
	C	11	3.44					
F2	A	38	3.83	2	4.724	0.693	82.3	<.001
	B	27	3.11					
	C	11	3.38					
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	B	27	2.58					
	C	11	1.93					
F4	A	38	2.58	2	3.911	0.437	28.3	<.001
	B	27	2.37					
	C	11	1.61					

Cluster analysis and ANOVA test for Primary Education PSTs (Degree)

Factor	Cluster	N	*M*	Df[a]	Mean Square	η^{2b}	*F*[c]	*p value*
F1	A	54	3.86	2	8.653	0.491	110	<.001
	B	96	3.85					
	C	80	3.30					
F2	A	54	3.68	2	8.191	0.446	91.4	<.001
	B	96	3.74					
	C	80	3.17					
F3	A	54	3.51	2	12.954	0.417	81.2	<.001
	B	96	3.00					
	C	80	2.57					
F4	A	54	3.10	2	15.643	0.479	104	<.001
	B	96	2.18					
	C	80	2.32					

[a]Degrees of freedom [b]Effect size [e]ANOVA F-statistic, rate between variability between groups and variability inside the group

Appendix 4. *Post hoc Scheffé* test

***Post hoc Scheffé* test for PSTs (MEd & Degree)**					
Factor	**Cluster comparison**	**Mean differences**	**Std. Error**	***t***	$p_{scheffe}$[a]
F1	A-B	-0.027	0.038	-0.72	0.774
	A-C	0.577	0.039	-14.71	**< 0.001**
	B-C	0.550	0.035	15.64	**< 0.001**
F2	A-B	-0.011	0.041	-0.27	0.964
	A-C	-0.617	0.043	-14.42	**< 0.001**
	B-C	0.606	0.038	15.08	**< 0.001**
F3	A-B	-0.553	0.060	-9.31	**< 0.001**
	A-C	-0.839	0.062	-13.60	**< 0.001**
	B-C	0.285	0.055	5.16	**< 0.001**
F4	A-B	-0.870	0.055	-15.74	**< 0.001**
	A-C	-0.701	0.057	-12.33	**< 0.001**
	B-C	-0.169	0.051	-3.28	**0.005**
***Post hoc Scheffé* test for Secondary Education PSTs (MEd)**					
Factor	**Cluster comparison**	**Mean differences**	**Std. Error**	***t***	$p_{scheffe}$[a]
F1	A-B	0.445	0.059	7.61	**< 0.001**
	A-C	-0.331	0.080	-4.16	**< 0.001**
	B-C	0.114	0.083	1.37	0.396
F2	A-B	0.713	0.068	10.43	**< 0.001**
	A-C	-0.446	0.093	-4.79	**< 0.001**
	B-C	0.268	0.097	2.75	**0.027**
F3	A-B	0.344	0.085	4.05	**< 0.001**
	A-C	-0.973	0.116	-8.41	**< 0.001**
	B-C	-0.629	0.121	-5.20	**< 0.001**
F4	A-B	0.214	0.093	2.31	0.076
	A-C	-0.969	0.126	-7.68	**< 0.001**
	B-C	-0.755	0.132	-5.73	**< 0.001**
***Post hoc Scheffé* test for Primary Education PSTs (Degree)**					
Factor	**Cluster comparison**	**Mean differences**	**Std. Error**	***t***	$p_{scheffe}$[a]
F1	A-B	-0.016	0.046	-0.35	0.941
	A-C	0.583	0.044	13.22	**< 0.001**
	B-C	-0.598	0.048	-12.48	**< 0.001**
F2	A-B	0.005	0.049	0.10	0.995
	A-C	0.575	0.047	12.26	**< 0.001**
	B-C	-0.570	0.051	-11.17	**< 0.001**
F3	A-B	-0.554	0.065	-8.56	**< 0.001**
	A-C	0.305	0.063	4.87	**< 0.001**
	B-C	-0.859	0.068	-12.61	**< 0.001**
F4	A-B	-0.894	0.063	-14.25	**< 0.001**
	A-C	-0.239	0.061	-3.94	**< 0.001**
	B-C	-0.655	0.066	-9.92	**< 0.001**

[a]All values are significant at $p < 0.05$ (in bold)

Table 1. Pre-service teachers' profile.

General participants profile	**N**	**%**
Educational level		
Students enrolled at the Degree	230	75
Students enrolled at the MEd	76	25
Gender		
Female	195	64
Male	111	36
Age		
< 25	61	20
25-30	220	72
> 35	25	8

Participants profile by degree					
Students enrolled at the Degree	**N**	**%**	Students enrolled at the MEd	**N**	**%**
Gender			*Gender*		
Female	152	66	Female	43	57
Male	78	34	Male	33	43
Age			*Age*		
< 25	36	16	< 25	25	33
25-30	185	80	25-30	35	46
> 35	9	4	> 35	16	21
Baccalaureate of access to the Degree	3	1	*Degree of access to the MEd*		
Arts	13	6	Biochemistry/Pharmacy	10	13
Engineering and Technology	42	18	Biology	14	18
Health Sciences	37	16	Chemical/Mechanical engineering	10	13
Humanities/Social Sciences	135	59	Chemistry	18	24
			Environmental sciences	19	25
			Others	5	7

Table 2. Descriptive analysis.

Dim	Item	*M*[a]	SD	Var	Skewness		Kurtosis		W[b]	R_{IX}[c]
					Statistic	Standard error	Statistic	Standard error		
EXA	2A	3.89	0.38	0.145	-4.354	0.139	23.741	0.278	0.316	0.172
EXA	2D	3.30	0.66	0.433	-0.682	0.139	0.624	0.278	0.765	0.172
INQ	2B	3.39	0.57	0.329	-0.381	0.139	-0.097	0.278	0.723	0.525
INQ	2E	3.58	0.55	0.298	-0.912	0.139	0.501	0.278	0.666	0.583
INQ	2G	3.71	0.51	0.258	-1.683	0.139	2.897	0.278	0.577	0.539
INT	2C	3.85	0.40	0.157	-2.868	0.139	10.454	0.278	0.417	0.545
INT	2F	3.71	0.52	0.267	-1.822	0.139	4.161	0.278	0.573	0.659
INT	2H	3.71	0.52	0.267	-1.678	0.139	2.807	0.278	0.582	0.729
MOT	3A	3.41	0.57	0.322	-0.408	0.139	-0.104	0.278	0.715	0.558
MOT	3B	3.39	0.58	0.337	-0.419	0.139	-0.099	0.278	0.727	0.558
SCC	3C	3.66	0.52	0.271	-1.303	0.139	1.564	0.278	0.618	0.575
SCC	3D	3.57	0.57	0.325	-1.021	0.139	0.649	0.278	0.677	0.626
SCC	3E	3.63	0.54	0.286	-1.184	0.139	1.169	0.278	0.639	0.569
SCC	3F	3.47	0.61	0.374	-0.869	0.139	0.633	0.278	0.720	0.602
SYS	4A	2.35	0.68	0.464	0.307	0.139	0.034	0.278	0.811	0.243
SYS	4D	2.48	0.87	0.749	0.071	0.139	-0.645	0.278	0.875	0.461
SYS	4G	2.35	0.78	0.615	0.199	0.139	-0.324	0.278	0.855	0.427
SYS	4N	2.30	0.79	0.616	0.159	0.139	-0.377	0.278	0.856	0.398
MNG	4B	3.01	0.73	0.538	-0.512	0.139	0.273	0.278	0.818	0.514
MNG	4E	2.94	0.73	0.528	-0.375	0.139	0.050	0.278	0.826	0.527
MNG	4H	2.41	0.82	0.668	0.217	0.139	-0.432	0.278	0.862	0.496
MNG	4I	2.70	0.82	0.671	-0.179	0.139	-0.471	0.278	0.864	0.573
RES	4C	2.45	0.76	0.570	0.087	0.139	-0.313	0.278	0.849	0.454
RES	4F	2.64	0.82	0.670	-0.008	0.139	-0.570	0.278	0.865	0.354
RES	4L	2.66	0.77	0.586	0.001	0.139	-0.434	0.278	0.851	0.501
RES	4M	2.08	0.80	0.635	0.589	0.139	0.158	0.278	0.830	0.446
KNO	4J	2.92	0.74	0.551	-0.309	0.139	-0.171	0.278	0.836	0.380
KNO	4K	3.22	0.68	0.458	-0.612	0.139	0.536	0.278	0.783	0.380

Note: (*) $p < 0.001$

[a]Scores on reverse-worded items have been recoded, inverting the values

[b]Shapiro-Wilk test of normality

[c]Item-rest correlation coefficient $R_{IX} > 0.3$

Table 3. Results of the confirmatory factor analysis.

Factors	Item	*Factor loadings*[a]	*Ordinal alpha*[b]	*Ordinal omega*[c]
IBSE teaching practice (F1)	2B	0.748	0.906	0.950
	2C	0.814		
	2E	0.795		
	2F	0.837		
	2G	0.786		
	2H	0.860		
IBSE students' applicability (F2)	3A	0.702	0.884	0.938
	3B	0.698		
	3C	0.835		
	3D	0.777		
	3E	0.758		
	3F	0.780		
Internal difficulties associated with the inquiry approach (F3)	4B	0.705	0.729	0.771
	4E	0.722		
	4H	0.580		
	4K	0.554		
External difficulties associated with the inquiry approach (F4)	4C	0.705	0.819	0.880
	4D	0.735		
	4F	0.550		
	4G	0.575		
	4L	0.652		
	4M	0.601		
	4N	0.625		

[a]All values are significant at $p = 0.001$

[b]Equivalent to Cronbach's alpha but calculated using polychoric correlation coefficients, which are more appropriate for ordinal measures such as Likert-type items

[c]Equivalent to McDonalds' omega but calculated using polychoric correlation coefficients, which are more appropriate for ordinal measures such as Likert-type items