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Initial validation of scales measuring trust and attitudes toward (educational) science in Belgium

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Introduction: This study is part of a broader effort to validate psychometric scales translated and adapted to the French-speaking Belgian teacher education context. It examines the factor structure and internal consistency of several instruments measuring preservice teachers' attitudes toward science and educational research and their perceived scientific skills.

Method: Following the methodological recommendations on validation processes, the study focused on item development (translation, contextual adaptation, expert review), scale development (cognitive pretesting, exploratory factor analysis), and initial evaluation through confirmatory factor analysis. Six translated scales were first administered to an exploratory sample of 186 pre-service teachers, and the instruments with the most promising psychometric properties were subsequently examined on a confirmatory sample of 523 students. Exploratory factor analyses (parallel analysis, MAP, EGA, minimal residual extraction with oblique rotation), confirmatory factor analyses with WLSMV for ordinal data, and reliability indicators (McDonald's omega) were used to evaluate the dimensional structure and internal consistency of the scales.

Results: Three scales (BISS, SESCI, and P-TATER) showed interpretable factor structures with adequate internal reliability (ω between 0.83 and 0.96), while three others (ATOSS, Adapted Barometer, and TPACI) did not meet the basic criteria for sampling adequacy and structural stability. The combination of exploratory and confirmatory analyses provided initial evidence for a one-dimensional solution for the BISS, a two-factor solution for the SESCI, and a three-factor solution for the P-TATER, despite strong correlations between the dimensions.

Conclusion: This study provides preliminary evidence of the psychometric quality of three instruments for assessing preservice teachers' attitudes toward science and educational research in the French-speaking Belgian context. It also highlights the limitations and contextual fragility of the other translated scales. The results remain partly provisional, particularly for the IRS, which has only been subjected to exploratory analysis, and require further confirmatory work. Nevertheless, the study provides an initial basis for the development of a set of stable and context-appropriate measurement tools that meet contemporary psychometric standards and support research-based teacher training.

KEYWORDS

attitudes, educational research, exploratory factor analysis, preservice teachers, scale translation and adaptation, science

1 Introduction

Various surveys have shown that citizens express more confidence in science institutions (Cologna et al., 2025; European Commission, 2021; Gauchat, 2012) than in political or military institutions (Reid et al., 2023; Valgarðsson et al., 2025). Despite this, some researchers persist in claiming that we are experiencing an "erosion" (Holden Throp, 2024) or a "crisis" (Saltelli and Funtowicz, 2017) of public trust in science. This crisis takes multiple forms. First, people may temporarily show reduced trust in science as a by-product of media debates (Hendricks et al., 2016; Klein, 2020; Ritchie, 2020) related to scientific discoveries that challenge what was previously considered to be true, events that highlight the potential harms of scientific advances, or cases of scientific misconduct. For example, the Pew Research Center surveys have shown that Americans' trust in science declined during the COVID pandemic (Tyson and Kennedy, 2024). Second, researchers point out that there is a gap between people's stated trust in science and their actual beliefs. In fact, several studies have shown that many misconceptions proven false by science remain widespread (Grospietsch and Lins, 2021; Hornsey et al., 2018; Rousseau, 2024; Spreen and Klimmt, 2024; Torrijos-Muelas et al., 2021), especially in populations characterized by strong skepticism (Rutjens et al., 2021; Thomm et al., 2021). Third, international surveys show substantial differences between countries in terms of citizens' trust in science (Opinionway, 2025). Cologna et al. (2025) explain these differences by the moderator effect of demographic characteristics, ideological views, attitudes, and country-level indicators. They show that more conservative ideologies and populist attitudes are negatively correlated with trust in scientists. Fourth, public confidence in science can vary depending on the research field. In France, the Critical Thinking Barometer (Dubois et al., 2025) showed that citizens had more confidence in medicine (74%) than in sociology (34%). This disciplinary gap is particularly significant for fields such as education, which, like other social sciences, must continually demonstrate the credibility and practical relevance of their research (Slavin, 2007).

Thus, efforts are still needed to strengthen the legitimacy of scientific processes and institutions among the broader public. In this respect, teachers play a central role in promoting scientific literacy. Their relationship to science is twofold: science constitutes both a subject to be taught (Özmutlu, 2022) and a resource for informing pedagogical decision-making through evidence-informed reasoning (Greisel et al., 2022; Knogler et al., 2025). Although related, these functions rely on partly distinct forms of knowledge and epistemic orientations (Greisel et al., 2022). Teachers are therefore expected not only to mediate scientific knowledge for students, but also to engage with educational research in ways that can inform their professional practice.

Recent studies suggest that attitudes toward research and evidence play an important role in this process. Drawing on the Theory of Planned Behaviour (Ajzen, 1991), Greisel et al. (2022) showed that preservice teachers' attitudes toward evidence-informed reasoning are associated with their intention to use scientific theories when analyzing teaching problems. Similarly, perceived utility of educational research has been linked to greater engagement with research evidence among preservice teachers (Knogler et al., 2025; Rochnia et al., 2025). This issue is particularly important given that several meta-analyses have identified positive effects of research-based instructional approaches, such as inquiry-based learning, on students' critical thinking skills (Abrami et al., 2015; Firman et al., 2019; Furtak et al., 2012; Niu et al., 2013). However, the effective implementation of such approaches likely depends on teachers' capacity and willingness to engage in research-based pedagogical decision-making. This, in turn, requires not only a general understanding of research methods, but also a disposition to view educational research as a meaningful resource for practice (Kansanen, 2006).

However, despite this evidence, a gap between research and practice in education (Coburn and Stein, 2010; Dachet and Baye, 2024) often hinders the uptake of research-based approaches in teaching. Research suggests several reasons to explain this gap. On the one hand, some research evidence causes professional resistance because it contradicts initial teacher beliefs about teaching and learning (Munro, 2010). These misconceptions (Anderson and Arsenault, 2005) are well established because they are shaped by teachers' apprenticeship of observation — i.e., their own experience as students (Gravé et al., 2020; Lortie, 1975) — and influenced their own professional practices (Gauthier, 2023; Huberman, 1983; Lacot et al., 2017; Vause, 2009). Therefore, the use of educational research to inform educational practices remains unsystematic (Lysenko et al., 2014). Recent research confirms that these barriers remain persistent. Beyond structural obstacles, preservice teachers tend to prefer experiential knowledge over scientific evidence, perceiving the latter as insufficiently relevant to "real-life" classroom situations (Knogler et al., 2025; Rochnia et al., 2025). These epistemic barriers seem to explain variation in the use of research findings more than skill-based barriers (Lysenko et al., 2014). When preservice teachers perceive limited utility value for their future teaching practice—that is, limited relevance for understanging or addressing classroom situations –, they are less likely to engage with it (Knogler et al., 2025). On the other hand, teachers report a lack of access (availability and clarity) to scientific literature (Behrstock et al., 2009; Drill et al., 2013; Gaussel, 2020; Hemsley-Brown and Sharp, 2004; Nguyen et al., 2022; Seberová, 2008; Wahlgren and Aarkrog, 2021), a lack of time to devote to reading scientific articles (Behrstock et al., 2009; Nguyen et al., 2022; Sayac, 2019) and a lack of articulation between research and practice (Coen et al., 2010; Hemsley-Brown and Sharp, 2004; Joram et al., 2020; Nguyen et al., 2022).

Teacher education could therefore represent a powerful lever in this regard (Özmutlu, 2022), as it may foster teachers' capacity to engage with and produce knowledge through scientific approaches (Sahan and Tarhan, 2015). More specifically, professional development (PD) programs may influence teachers' knowledge, beliefs, and practices (Comon and Corpuz, 2024; Gaussel, 2020; You et al., 2025). Studies have shown that training teachers "in" and "through" scientific research would enable them to base their teaching on empirical data and legitimize their practices (Ciraso-Calí et al., 2022; Munthe and Rogne, 2015; Toom et al., 2010; Westbury et al., 2005). This kind of program not only meets society's need for highly qualified specialists (Koletvinova and Bichurina, 2019) but also addresses the complexity of the teaching profession. The primary mission of teaching is to promote student learning, which requires to navigate a constantly growing body of knowledge (Ciraso-Calí et al., 2022; Munthe and Rogne, 2015). When they participate in PD that integrates research and collaboration with researchers, teachers recognize that research contributes to the development of their critical thinking skills (You et al., 2025). In the era of accountability (Slavin, 2007), teachers must also make informed and responsible decisions, for instance regarding instructional choices, student support, and the interpretation of learning outcomes (Byman et al., 2009). In this context, teacher training is no longer limited to the acquisition of basic pedagogical skills, such as classroom management, lesson delivery, or the application of routine teaching procedures. Teacher training is now conceived as a process that fosters the development of expertise, developed through the interaction between practice, reflection, and research (Schröder et al., 2023; Taber, 2010).

Yet, despite this growing body of evidence on barriers to research use by teachers and on the promising effects of PD programs integrating scientific research, teachers' attitudes toward science and educational research are rarely examined (Chastenay et al., 2024; Sahan and Tarhan, 2015). However, these attitudes have been identified as potential predictors of their use of research evidence in practice (Dagenais et al., 2010; Lysenko et al., 2014), which makes the measurement of such attitudes particularly relevant for evaluating the impact of research-based teacher education programs. These attitudes are multidimensional and not reducible to a single construct. As noted above, the TPB framework and the findings of Greisel et al. (2022) suggest that attitudes, self-efficacy, and subjective norms each operate as distinct predictors of research engagement. This theoretical framework informed the selection of instruments covering complementary dimensions of teachers' attitudes toward science and educational research: general beliefs about science (Dagnall et al., 2019), trust in institutions and information sources (Brossard et al., 2005; Smith and Son, 2013), endorsement of rational thinking (Ståhl et al., 2016), perceived research self-efficacy (Betz et al., 2003), and attitudes toward the relevance of educational research for teaching practice (Gonyea, 2013).

The present validation process addresses the lack of validated French-language instruments covering this constellation of constructs among preservice teachers. This article describes the process of translating, adapting, and analyzing the psychometric properties of several instruments selected for this purpose. Specifically, this study examines whether instruments measuring beliefs in science, trust in scientific institutions and information sources, endorsement of rational thinking, perceived competence in educational research, and attitudes toward educational research demonstrate satisfactory factorial structure and internal consistency when translated and adapted for use with French-speaking Belgian preservice teachers. In this regard, this study is part of both an initial validation process in the French-speaking Belgian teacher education context and a replication effort (Baye et al., 2019; Plucker and Makel, 2021) of previous psychometric work.

2 Materials and methods

2.1 Design

This validation study adopts a cross-sectional design with two independent samples of preservice teachers recruited from French-speaking Belgian teacher education institutions. To follow a rigorous approach to scale development and validation, the methodological framework proposed by Boateng et al. (2018) was applied. This framework distinguishes three main phases, subdivided into nine steps: (1) an item development phase, which includes item generation and content validation; (2) a scale development phase, focused on initial testing of the psychometric properties of the instrument; and (3) a scale evaluation phase, which aims to confirm the structure, reliability, and validity of the scale across different samples and contexts of use (Boateng et al., 2018). In the present study, the first two phases were fully implemented, and the third phase was initiated through dimensionality tests (CFA on an independent sample) and internal reliability analyses.

This first phase aimed to translate and to adapt the selected instruments to the French-speaking Belgian context and to the targeted population. The French-speaking Belgian context has specific features that require more than just linguistic adaptation. Since September 2023, teacher training programs have been reformed with the introduction of a four-year master's degree. Previously focused on higher education teachers, university involvement now extends more specifically to common core teachers. Among other things, their mission is to train students in (the findings of) and through (the methods of) educational research. Furthermore, the French-speaking Belgian education system divides schooling into two networks: the official (and secular) system and the Catholic system. This means that preservice teachers have been trained in diverse institutional environments, with varying relationships to science and religion. This could influence how items referring to research training, institutional trust, and the epistemic role of science are likely to be interpreted. This made local validation necessary. Considering this contextual information and in accordance with the recommendations of Boateng et al. (2018), this study combined direct translations, expert proofreading, and contextual revisions to address three critical criteria for cross-cultural scale adaptation: linguistic equivalence (semantic fidelity to the original items) and contextual relevance (adaptation to the French-speaking Belgian educational context and target population) (Vallerand, 1989), and construct equivalence (preservation of the theoretical meaning of each item across contexts) (Boateng et al., 2018). A working group comprising three bilingual experts,—two in education sciences and one in linguistics specializing in English language teaching (ELT) –, was responsible for the translation. The linguist and one of the education sciences experts produced concurrent translations, while the second education sciences expert compared both versions and identified inconsistencies. Discussions among the three members allowed careful examination of each item, ensuring semantic equivalence and avoiding individual bias (Vallerand, 1989). Disagreements were resolved by consensus during these discussions, moderated by the second expert. This process also included adjustments for contextual relevance, where items whose wording or content did not fully correspond to the local educational context were adapted (see Section 3.1 for scale-specific examples). Five experts in education sciences external to the working group were then contacted to assess the content of the translated and adapted instruments (Rust et al., 2014). Written comments were requested for each item, with a focus on clarity, semantic equivalence, and contextual relevance (scale-specific outcomes are reported in Section 3.1). This step aimed to ensure the conceptual relevance of items while remaining adapted to the context (Boateng et al., 2018).

The second phase aimed to assess the face and construct validity (Anthoine et al., 2014) of the translated and adapted scales. First, qualitative pretesting, including cognitive laboratories, was conducted to determine whether respondents' answers yield valid measurements (Boateng et al., 2018). We used the concurrent (Noushad et al., 2023) thinking-aloud methodology (Beatty and Willis, 2007) with eight preservice teachers. This procedure provided information on the ease of use and understanding of the tool by encouraging participants to verbalize their thoughts while answering the survey. The specific adaptations made to each scale are presented in Section 3.2.1. Second, a quantitative pilot study was conducted to explore the factorial structure of the scales and to perform a first item reduction. Because some instruments were substantially modified during translation, the adapted versions cannot be considered direct equivalents of the original scales. This lack of full construct equivalence justified the methodological choice to begin with exploratory factor analyses (Boateng et al., 2018; Vallerand, 1989). The exploratory factor analyses were conducted based on data collected from an initial sample of preservice teachers.

The third phase, scale evaluation, involved testing the dimensionality of the retained models (one model per dimension) and their internal consistency on an independent sample using confirmatory factor analysis and McDonalds' omega.

2.2 Samples and sampling method

For the Exploratory Analysis (EA), 407 students enrolled in their second year of the 4-year integrated Master's in teaching programs from 6 French-speaking Belgian higher education institutions were invited (May 2025). Among them, 202 responded to the survey (49.6%). Only complete questionnaires were retained, resulting in 186 usable responses (attrition = 7.9%). 16 participants were excluded due to incomplete or invalid questionnaire responses: 9 did not complete any items, 3 only provided demographic information, and 4 answered only about 30% of the items. Given that all excluded cases presented more than 69% missing data at the item level, multiple imputations were not considered appropriate. Recent guidelines indicate that multiple imputations lead to significant variance shrinkage and compromised data reliability when applied to more than 70% of a single participant's data (Junaid et al., 2025). Most respondents were women ($n = 151$, 81%), which exceeds the demographic profile observed in French-speaking Belgian higher education institutions, where women represent approximately 69% of students enrolled in psychological and educational sciences programs (ARES, 2025). This overrepresentation of women in our sample should be kept in mind when interpreting the results. Respondents were mainly preservice elementary teachers ($n = 85$), and 40% ($n = 74$) reported prior study reorientation, which may have introduced some heterogeneity in research exposure within the sample. The sample size is consistent with methodological recommendations formulated by Guadagnoli and Velicer (1988). According to these authors, the effect of sample size on factor solution stability depends primarily on the strength of factor loadings. When these are high (≥0.60) and each factor is defined by at least four well-saturated items, the extracted solution can be considered robust, even with a modest sample size (>150).

For the confirmatory analysis (CA), 679 first-year students enrolled in the same academic programs were contacted (September 2025). A total of 557 responded (82%); the completed questionnaires yielded 523 usable responses (attrition rate = 6.1%). Most respondents were female ($n = 385$, 74%), which is also higher than the reference, but closer to it, and were predominantly enrolled in the lower secondary section ($n = 190$). Among them, 44% ($n = 231$) reported having already changed their academic track.

The mean socioeconomic index (PISA ESCS index, based on the highest occupational status of parents according to the ISCO-08 classification) was 3.09 (SD = 1.97) for the exploratory sample and 3.85 (SD = 2.52) for the confirmatory sample (PISA 2022 scale). It reflects the diversity of socioeconomic origins of students at these six schools, located in different geographic areas of Wallonia.

The sociodemographic characteristics of both samples are summarized in Table 1.

2.3 Measurement instrument

In the exploratory phase of the study conducted in May 2025, six instruments were selected from the psychometric literature based on their theoretical alignment with the constructs identified in the introduction. The selected instruments included the ATOSS (Brossard et al., 2005) and BISS (Dagnall et al., 2019) for attitudes and beliefs about science; the adapted Baromètre (Salvaing et al., 2025) and TPACI (Smith and Son, 2013) for trust in information sources and scientific institutions; the SESCI (Betz et al., 2003) for perceived research self-efficacy; and the P-TATER (Gonyea, 2013) for attitudes toward educational research and its integration into teacher training. An additional instrument, the IRS (Ståhl et al., 2016), was subsequently incorporated because of its theoretical relevance to rational thinking as an epistemic disposition. In accordance with recommendations in the psychometric literature, we adapted and translated existing instruments (Boateng et al., 2018; Worthington and Whittaker, 2006). These instruments are described below. It should be noted that most of these tools were originally designed for the general public or for specific cultural contexts, and not specifically for future teachers (except for Gonyea's tool, 2013). This discrepancy between the original target audience and our own also justifies the need for contextual adaptation that goes beyond a simple translation.

TABLE 1 Sociodemographic characteristics of the exploratory (sample A) and confirmatory (sample B) samples.

Characteristics	Category (%)	Sample A—Exploratory (N = 186)	Sample B—Confirmatory (N = 523)
Gender	Women (%)	81	74
Section	Kindergarten (%)	21	31
	Elementary (%)	46	32
	Lower secondary (%)	33	36
Socioeconomic status	Mean (SD)	3.09 (1.97)	3.85 (2.52)

The section refers to the level of education (kindergarten, elementary, or lower secondary) chosen by preservice teachers; the socioeconomic index is calculated according to PISA22 recommendations (i.e., based on the highest occupational status of parents on the international standard classification of occupation of 2008).

Based on the exploratory results and the need to refine the instrument, the confirmatory phase in September 2025 retained only the most conceptually robust and empirically coherent measures, namely the Belief in Science Scale (BISS) (Dagnall et al., 2019), the Science Subscale of the Expanded Skills Confidence Inventory (SESCI) (Betz et al., 2003), and the Preservice Teachers' Attitude Toward Educational Research (P-TATER) (Gonyea, 2013). In addition, the "Importance of Rationality" scale (IRS) (Ståhl et al., 2016), previously validated with high reliability, was incorporated due to its theoretical relevance to epistemic attitudes toward science and research among preservice teachers. Table 2 summarizes the data collection procedure.

Since the questionnaire measures respondents' attitudes, a Likert scale with 4 response formats ranging from "strongly disagree" to "strongly agree" was used. An even number of levels was proposed to avoid central tendency (Rust et al., 2014). The questionnaire was administered online using *LimeSurvey* software (version 6.13.0 + 250415).

TABLE 2 Overview of the data collection procedure across exploratory and confirmatory phases.

Scale	Exploratory (June 2025)	Confirmatory (September 2025)
#1	ATOSS	/
#2	BISS	BISS
#3	Baromètre	/
#4	TPACI	/
#5	SESCI	SESCI
#6	P-TATER	P-TATER*
#7	/	IRS

*A reduced version based on exploratory analyses conducted in June.

2.3.1 Attitude toward organized science scale (ATOSS)

The Attitude Toward Organized Science Scale (ATOSS) is designed to measure people's attitudes toward science. In this study, the version developed by Brossard et al. (2005) was used. The original ATOSS (National Science Board, 1996) consisted of four dichotomous items, offering only two response options ("agree" or "disagree"). Each item was scored as 0 or 1, and the total score ranged from 0 (anti-science) to 4 (pro-science). Since 28% of the responses in a previous pilot study were missing, probably because respondents would have preferred an intermediate "undecided" option, Brossard et al. (2005) created a modified version using a five-point response scale ("strongly agree" to "strongly disagree"). Despite its repeated use in previous research, this scale has relatively low internal reliability ($\alpha = 0.57$).

2.3.2 Belief in science scale (BISS)

BISS (Dagnall et al., 2019) includes 11 items that also measure respondents' attitudes toward science. The items take the form of statements questioning scientific authority. In other words, BISS assesses "the idea that science possesses unique and central value that provide a superior, exclusive guide to reality" (Dagnall et al., 2019, p.4). BISS presents high internal reliability ($\omega = 0.93$) in previous studies (Dagnall et al., 2019).

2.3.3 *Baromètre* la croix—verian—la poste on French people's trust in media

The *Baromètre* (Salvaing et al., 2025) examines individuals' relationship with the media across several dimensions, including interest in and engagement with current affairs, media habits and consumption, information processing, freedom of expression, the fight against disinformation, and the impact of artificial intelligence. For this study, the dimensions related to combating disinformation and the frequency of consumption of different sources were selected, and the items were adapted to the educational context. Reliability coefficients are not reported in the original study.

2.3.4 Trends in public attitudes about confidence in institutions (TPACI)

TPACI (Smith and Son, 2013) consists of 6 items that measure respondents' confidence in different institutions. This scale is based on the idea that science perception is influenced by confidence in scientific institutions. Reliability coefficients are not reported in the original study.

2.3.5 Science subscale of the expanded skills confidence inventory (SESCI)

SESCI (Betz et al., 2003) includes 12 items that assess respondents' confidence in their ability to understand popular science and to successfully complete science courses and scientific research. SESCI presents high internal reliability ($\omega = 0.90$).

2.3.6 Preservice teachers' attitude toward educational research (P-TATER)

P-TATER (Gonyea, 2013) consists of 36 items that measure participants' perception of the utility or the importance of educational research, as well as their perceived skills in this domain. P-TATER presents high reliability for both the attitude scale ($\alpha = .93$) and the perceived competence scale ($\alpha = 0.82$).

2.3.7 Importance of rationality scale (IRS)

IRS (Ståhl et al., 2016) assesses the degree to which individuals endorse rational thinking as a guiding principle in their everyday lives. It measures how strongly people value reasoning, logical coherence, and evidence-based judgment when forming opinions, evaluating information, and making decisions. IRS presents high internal reliability ($\alpha = 0.79–0.88$).

2.4 Statistical analysis

Before performing exploratory factor analysis (EFA), the suitability of the data for factor analysis was assessed. The Kaiser-Meyer-Olkin (KMO) and Bartlett's sphericity tests were used. A KMO ≥ 0.80 was considered good, while a KMO < 0.60 indicated unsuitable data (Kaiser, 1974). Then, to determine the number of factors to retain, complementary methods were used: parallel analysis (PA), Minimum Average Partial (MAP) method, and the Kaiser criterion (K1; eigenvalues greater than 1). For parallel analysis (PA), 1,000 iterations were used with a threshold set at the 95th percentile. Between 500 and 1,000 repetitions are generally recommended, but a higher number of iterations increases accuracy. The 95th percentile threshold provides a criterion for retaining only those factors that clearly exceed what would be expected by chance (Hayton et al., 2004). This multi-method approach is consistent with recommendations in the literature indicating that no single retention rule is optimal. Although K1 is one of the most used rules, research has shown that it is highly inaccurate (Hayton et al., 2004). In contrast, PA is consistently identified as the most accurate method across simulation studies, with MAP generally ranking as the second most accurate (Hayton et al., 2004). To complement these approaches, an Exploratory Graph Analysis (EGA) was conducted to estimate the dimensional structure of the scales using a Gaussian network model. EGA models items as nodes connected by partial correlations, where latent variables manifest themselves as highly interconnected clusters (Golino and Epskamp, 2017). The Louvain community detection algorithm was applied to identify groups of items corresponding to latent dimensions (Cosemans et al., 2022). The analysis was performed with the EGAnet package in R (Golino et al., 2020) on the polychoric correlation matrix ($n = 186$). The stability of the structure was assessed using Bootstrap EGA (bootEGA) with 500 resampled iterations, allowing us to estimate the stability of the number of dimensions, the assignment of items, and the Total Entropy Fit Index (TEFI) (Golino et al., 2020). When factor retention criteria converged, the consensus solution was retained directly. When criteria diverged, decisions were guided by the relative accuracy of each method as reported in simulation studies. PA is consistently identified as more accurate than K1 (Hayton et al., 2004). In parallel, EGA has shown strong performance in estimating the number of dimensions across a range of conditions (Golino et al., 2020). MAP was treated as a supplementary indicator given its tendency toward more conservative solutions. In cases of persistent ambiguity across these robust criteria, the theoretical framework served as a secondary consideration: the solution was retained only if the resulting factors could be interpreted considering the constructs being measured.

EFA was then performed using the lavaan package in R (version 4.5.0) (R Core Team, 2024). Given the ordinal nature of the data, the robust WLSMV (Weighted Least Squares Mean and Variance adjusted) estimator was used (Beauducel and Herzberg, 2006). A Geomin oblique rotation was applied to enable correlation between factors, which is expected for psychological constructs (Browne, 2001). The quality of the factor solutions was assessed by factor loadings (≥0.40).

During the analyses, it was also found that certain items in the BISS (1) and PTATER (3) did not have responses in all modalities of the Likert scale, which prevented the estimation of polychoric correlations. These items were therefore temporarily removed from the analyses based on the polychoric matrix. However, they were reintroduced into the EFA performed with lavaan (WLSMV), where they did not pose any estimation problems and were consistently integrated into the chosen factor structure.

Based on the suggested structures, confirmatory factor analyses were performed using the lavaan package (R). As with the exploratory analyses, the variables were specified as ordinal and the WLSMV estimator, recommended for this type of data, was used. The model fit was evaluated using standard indices [χ^2(df), CFI, TLI, RMSEA, SRMR] according to commonly accepted thresholds. For CFI and TLI, values ≥0.95 suggest an acceptable fit of the model to the data, and values ≥0.97 indicate a good fit. For RMSEA, values ≤0.08 suggest an acceptable fit, and values ≤0.05 indicate a good fit. For SRMR, values ≤0.10 suggest an acceptable fit and values ≤0.05 indicate a good fit (Nägel et al., 2023). The internal reliability of the scales was estimated using McDonald's omega coefficient (ω), as recommended by Béland et al. (2017) for a more robust estimate of reliability with ordinal data.

The results from cognitive laboratories, EFA and CFA are presented in the specific results sections.

3 Results

3.1 Item development

The translation process highlighted a few concepts that were difficult to translate into French, as well as the need to adapt certain items to the socio-cultural context of the French-speaking community of Belgium. For example, in the BISS, some items were explicitly based on a comparison between religion and science. While this opposition is central in contexts where religious affiliations are at the forefront of public debate, it appears less directly relevant in our context. Although religious school networks remain significant in the country and religious education is part of the school curriculum, Belgium ranks among the most secularized countries in the world, positioned in the final stages of the secular transition (Stolz et al., 2025). The expert panel therefore judged that framing scientific attitudes in opposition to religion was not relevant for the target population. Thus, the item "Science provides us with a better understanding of the universe than does religion" was reworded to emphasize the epistemic role of science without direct reference to religion. The new version of the item describes science as the "best tool" for understanding the universe. Similarly, an additional item was developed in response to concerns raised by the question inspired by Carl Sagan's book "The Demon-Haunted World" (1995) ("In a world haunted by demons, science is a candle in the darkness"), which presents science as a bulwark against superstition. The experts unanimously agreed that this metaphorical item, taken from the writings of a researcher unfamiliar to the target audience of the survey, could lead to confusion. They decided to write a new item parallel to the content of Carl Sagan's item (i.e., science as a "*guide*" to truth) and referring to contemporary issues of misinformation and neuromyths. The *Baromètre* has been significantly adapted to shift its focus from measuring the general public's trust in the media to focusing on specific information in education. Fifteen out of seventeen items were modified to change the wording, for example by reformulating questions about trust in the media into questions about trust in different sources of information related to education (social networks, teacher training, colleagues, education researchers, etc.). In line with this, all twelve items in the SESCI "science" subscale were adapted to explicitly refer to educational research tasks (e.g., understanding the results of an educational study, passing a course on educational research methodologies, planning an educational research project), to align the content with the skills expected of future teachers. For the TPACI, six institutions deemed most relevant to the field of education (university, government, media, medicine, scientific community, large companies) were selected from the initial list to further anchor the items in the context of the teaching profession. Finally, for the P-TATER, adaptations related to the context were made. For example, four items were added to better reflect the structure of studies in the Wallonia-Brussels Federation (e.g., "*A course on educational research is useful in initial teacher training programs starting at the bachelor's level*" or "*The master's degree in education must include courses on research methods*"). Some items were also reworded following review by experts who sometimes considered the vocabulary to be too specific (e.g., "*I am confident in my ability to understand the jargon of educational research*" became "*I am confident in my ability to understand the specific vocabulary of educational research*"). A total of fifteen items were reworded. In addition, five items from a non-validated but conceptually relevant version were reintegrated to better cover the dimensions of perceived usefulness, integration into training, and declared competencies (e.g., "*Teachers should improve their teaching practices based on recent educational research*").

Table 3 summarizes the adjustments (number and type) made to ensure semantic equivalence, conceptual clarity, and contextual relevance for the Belgian French-speaking teacher training context.

3.2 Scale development

3.2.1 Cognitive laboratories

The cognitive laboratories were recorded in audio format. The comments and feedback made by the interviewed students enabled the measurement instruments to be revised to improve the clarity of the items. For example, the word "tasks" from one of the Belief in Science Scale items (Dagnall et al., 2019) was misunderstood by most interviewed students and was therefore replaced by the term "problematic", which preserved the initial meaning while improving comprehension. Other similar changes were made. In addition, the order of items in the subscale "Attitudes of preservice teachers toward educational research" (P-TATER) (Gonyea, 2013) was adjusted, as some respondents experienced a sense of *déjà vu* (items related to the presence of research-related courses in their initial training were spread out more throughout the questionnaire). An item from the Attitude Toward Organized Science Scale (Brossard et al., 2005) ("science and technology are making our lives healthier, easier, and more comfortable") was also adapted. It was revised by keeping only references to science (i.e., removing the reference to technology) and further divided into two items: the first focusing solely on

TABLE 3 Summary of translation and adaptation procedures for each scale.

Scale	Number of modified items/ total number of items	Types of modifications
ATOSS	0/4	/
BISS	4/11	addition of an item, removal of reference to religion, and rewording of 2 items
Baromètre	15/17	adaptation to the educational context and adding specific sources of information and
TPACI	0/6	selection of 6 relevant institutions for education
SESCI	12/12	adaptation of items to educational research
P-TATER	24/42	rewording of 15 items, adding 4 specific items to the initial teacher training in Belgium and 5 items from the unvalidated version of the P-TATER
IRS	0/6	/

gains in ease and comfort, and the second on the idea of a healthier life. Student verbalization of thought indicated different responses depending on the attributes (i.e., gains in ease or healthier life) cited. Table 4 shows the total number of items per pre-tested tool and the modifications made thanks to cognitive laboratories.

With the aim of data saturation (Boateng et al., 2018) and testing the final version of the measurement instruments, 3 additional interviews with the concurrent thinking-aloud procedure were conducted. They confirmed the clarity of the modifications made to the tool.

3.2.2 Exploratory factor analyses

Three scales demonstrated clear and stable factorial structures, justifying their retention for confirmatory analyses.

The suitability of the BISS scale data for factor analysis was confirmed by factorability indices (KMO = 0.87; Bartlett's $\chi^2 = 624.63$, p < 0.001). The factor extraction analyses revealed a two-dimensional structure. While the MAP test indicated a one-dimensional solution, PA and K1 suggested the extraction of two factors. EGA also identified two distinct dimensions. The EGA bootstrap (500 iterations) confirmed that the most frequent solution had two factors (47% of replications). Nevertheless, several items showed low stability (items BISS_7, BISS_9, BISS_10, BISS_11: < 0.60), indicating they frequently changed dimensions across bootstrap replications, suggesting inconsistent factorial composition and a more fragile structure. The EFA shows that the two factors explain 52.7% of the total variance. The first factor (27.2% variance) includes 7 items, with loadings ranging from.41 to.94 (BISS_1, BISS_2, BISS_3, BISS_4, BISS_5, BISS_6, BISS_8). The second factor (25.5% variance) includes 4 items, with loadings ranging from.51 to.90 (BISS_7, BISS_9, BISS_10, BISS_11). One item from the second factor (BISS_7), added specifically when adapting the scale to the context, showed relatively modest saturation (0.50) compared to the other items in this factor, as well as low stability in the EGA bootstrap (<0.60). In accordance with the iterative refinement process recommended in EFA (Browne, 2001), and to maintain consistency with the original validated version of the BISS, this item was removed, and the EFA was re-estimated on the 10 original items. The post-deletion analysis confirms a robust factor solution (KMO = 0.863; Bartlett $\chi^2 = 716.29$, $p < 0.001$). PA and K1 maintained the suggestion of two factors, while MAP and EGA, supported by the EGA bootstrap (500 iterations), converged toward a more pronounced unidimensional solution (74% of replications). The one-factor EFA was tested and explains 45.9% of the variance, with acceptable standardized saturations (0.53–0.79) (see Table 5). This consolidated unidimensional solution, obtained after removing the cultural adaptation item, is retained for further analysis.

TABLE 4 Adjustments following cognitive laboratory pretesting.

Scale	Number total of items	Types of modification
ATOSS	5	splitting an item into 2
BISS	11	vocabulary of 1 item
Baromètre	17	/
TPACI	6	/
SESCI	12/12	rewording of 4 items
P-TATER	36	rewording of 6 items, vocabulary of 1 item and removal items from the unvalidated version of the P-TATER

The suitability of the SESCI scale data for factor analysis was also confirmed by factorability indices (KMO = 0.79; Bartlett's $\chi^2 = 1007.25$, $p < 0.001$). The factor extraction analyses diverged more than for the BISS. PA and K1 recommended the extraction of three factors, while the MAP test indicated a one-dimensional solution. In addition, the EGA identified a two-dimensional structure. The EGA bootstrap (500 iterations) confirmed that the most frequent solution had two factors (49.6% of replications). However, several items showed low stability (<0.60), suggesting a partially unstable structure. Given the divergence between criteria, the two-factor solution was retained following the predefined decision-making framework. EGA was prioritized over PA and K1 because the resulting two-factor structure was theoretically interpretable and more conceptually coherent than the alternative three-factor solution. The EFA is compatible with a two-factor solution, explaining 47.3% of the total variance. The first factor ("Intermediate Self-Efficacy", 27.0% of variance) comprises 7 items (SESCI_1, SESCI_2, SESCI_5, SESCI_7, SESCI_8, SESCI_10, SESCI_12) with loadings between 0.37 and 0.86. The second factor ("Advanced Self-Efficacy", 20.3% of variance) comprises 5 items (SESCI_3, SESCI_4, SESCI_6, SESCI_9, SESCI_11) with loadings between 0.50 and 0.90. All 12 items were retained (see Table 6).

Given the relatively high number of items in the PTATER (36 items) and the size of the available sample ($n = 186$), the participant/item ratio was insufficient to perform a comprehensive exploratory factor analysis with polychoric correlations, as confirmed by an unacceptable KMO index (0.273). In accordance with the recommendations of Little et al. (2013) regarding multidimensional scales, exploratory analyses were performed separately for each theoretically defined sub-dimension: a dimension relating to the attitudes toward educational research (original dimension, PTATER_1, 2, 4, 6, 8–10, 12, 14, 16, 17, 19, 20, 22–24, 27, 28, and 31), a dimension relating to the integration of educational research training into initial teacher training (additional dimension due to the addition of items to match the context during translation, PTATER_3, 5, 11, 13, 15, 18, 21, 25, and 26), and a dimension relating to teachers' perceived skills (original dimension, PTATER_7, 29, 30, 32–36).

Before conducting exploratory factor analyses for each of the three subscales, a polychoric correlation matrix was analyzed for all for all 36 PTATER items to identify cross-dimensional relationships or redundancies between theoretically distinct subscales. Examining the inter-item correlations made it possible to identify any significant redundancies or unexpected relationships between items belonging to different sub-dimensions. A preliminary examination of the polychoric correlation matrix revealed substantial item redundancy within the "attitudes toward research" dimension, with PTATER_23 exhibiting a very high correlation ($\rho = 0.76$) with PTATER_19.

TABLE 5 Exploratory factor analysis of the BISS scale (sample A, $n = 186$).

BISS	Items in French and their English translation	λ	h^2
BISS_1	La science est le meilleur outil dont nous disposons pour comprendre l'univers. Science is the best tool we have for understanding the universe.	**0.66**	**0.43**
BISS_2	Nous ne pouvons croire qu'en ce qui est scientifiquement démontrable. We can only rationally believe in what is scientifically provable.	**0.69**	**0.48**
BISS_3	La science nous dit tout ce qu'il y a à savoir sur ce qui constitue la réalité. Science tells us everything there is to know about what reality consists of.	**0.53**	**0.28**
BISS_4	Toutes les problématiques auxquelles les êtres humains sont confrontés peuvent être résolues par la science. All the tasks human beings face are soluble by science.	**0.66**	**0.43**
BISS_5	La méthode scientifique est la seule voie fiable vers la connaissance. The scientific method is the only reliable path to knowledge.	**0.68**	**0.47**
BISS_6	La seule forme véritable de connaissance que nous puissions avoir est la connaissance scientifique. The only real kind of knowledge we can have is scientific knowledge.	**0.75**	**0.56**
BISS_8	La science est l'élément le plus précieux de la culture humaine. Science is the most valuable part of human culture.	**0.60**	**0.35**
BISS_9	La science est le moyen le plus efficace pour atteindre la vérité. Science is the most efficient means of attaining truth.	**0.79**	**0.62**
BISS_10	Dans une société moderne, la science doit recevoir le plus grand respect. Scientists and science should be given more respect in modern society.	**0.66**	**0.43**
BISS_11	« Dans un monde hanté par les démons, la science est une bougie dans l'obscurité. » (Carl Sagan) "In a demon-haunted world, science is a candle in the dark." (Carl Sagan)	**0.73**	**0.53**

Extraction method: Principal Axis Factoring based on polychoric correlations. Rotation: Geomin oblique. Standardized loadings (λ) are presented. h^2 = communality.

This correlation can be explained by the overlap in the terms used in both items: the two items express the idea that educational research helps teachers improve their practice. PTATER_23 is simply a more detailed rephrasing of PTATER_19, without adding any additional conceptual content. PTATER_23 has therefore been deleted.

The initial exploratory factor analysis conducted on the 18 items theoretically associated with the dimension of "attitudes toward research" did not confirm the hypothesis of one-dimensionality. A middling KMO value was observed (.713), and Bartlett's χ^2 was significant. PA and K1 suggested the extraction of four factors, and MAP only one. EGA and EGA bootstrap showed that the three factors solution was the most frequent (54% of replications), but that a four factors solution also appeared in 35% of replications, indicating its plausibility. Initially, the 4 factors structure was tested. With this structure, an item had a loading greater than 1 (PTATER_27), which led to a verification of its correlation with the only item that also loaded on the fourth factor (PTATER_28), to rule out excessive collinearity. In the absence of redundancy between these two items ($\rho = .59$), these items were removed due to their unstable factorial behavior. Moreover, three items (PTATER_4, PTATER_10, PTATER_14) did not show satisfactory saturation (<.40) and were therefore removed. A new analysis was then performed, and the number of factors was questioned again. PA indicated three factors and MAP only one. K1 suggested two but the sharp drop in variance after the first factor also suggested the second factor provided little additional information and that a one dimension solution might sufficient. EGA and EGA bootstrap showed that the one factor solution was the most frequent (50% of replications). Given the persistent divergence between criteria, the unidimensional solution was retained. Although PA and K1 suggested additional factors, the EGA bootstrap most frequently identified a one-factor solution (50% of replications), and the additional factors provided limited conceptual interpretability and limited additional explanatory power. In addition, the most parsimonious structure was considered the most theoretically coherent representation of attitudes toward educational research. The unidimensional solution showed consistent and significant loadings for most items (.52 to.89) and an explained variance of 50%. The items were then selected based on their factor loadings, communalities, and conceptual consistency with the measured dimension. Items with loadings below.60 and high unique variance were considered for exclusion (PTATER_1, PTATER_8, PTATER_9), except for PTATER_31. Although it has a lower saturation, it has been retained due to its conceptual importance for the coverage of the construct, and its saturation remains above the minimum acceptable threshold (.40). The final EFA (10 items: PTATER_2, PTATER_6, PTATER_12, PTATER_16, PTATER_17, PTATER_19, PTATER_20, PTATER_22, PTATER_24, PTATER_31) shows acceptable saturations with a one-dimensional structure (0.53–0.89) and explains 56.5% of the total variance (see Table 7).

For the "integration in training subscale", the suitability of the data for factor analysis was directly confirmed by factorability indices (KMO = 0.87; Bartlett's $\chi^2 = 956.6$, $p < 0.001$). The methods for extracting the number of factors converged on a one-dimensional solution: PA, MAP, and K1 recommended extracting a single factor. EGA also identified a one-factor

TABLE 6 Exploratory factor analysis of the SESCI scale (sample A, $n = 186$).

SESCI	Items in French and their English translation	λ	h^2
Intermediate self-efficacy			
SESCI_1	Je me sens capable de comprendre les fondements scientifiques d'une recherche en éducation. I am confident in my ability to understand the scientific foundations of educational research.	**0.74**	**0.53**
SESCI_2	Je me sens capable de réussir un cours traitant des résultats de la recherche en éducation. I am confident in my ability to successfully complete a course on educational research findings.	**0.86**	**0.73**
SESCI_5	Je me sens capable de comprendre des graphiques présentés dans un article en sciences de l'éducation. I am confident in my ability to understand graphs presented in an article on educational sciences.	**0.51**	**0.34**
SESCI_7	Je me sens capable d'utiliser des connaissances scientifiques en éducation. I am confident in my ability to use scientific knowledge in education.	**0.74**	**0.54**
SESCI_8	Je me sens capable de me tenir informé(e) des dernières découvertes scientifiques en éducation. I am confident in my ability to stay informed about the latest scientific discoveries in education.	**0.37**	**0.24**
SESCI_10	Je me sens capable de réussir un cours sur les méthodologies de la recherche en éducation. I am confident in my ability to successfully complete a course on educational research methodologies.	**0.63**	**0.59**
SESCI_12	Je me sens capable de comprendre un entretien présenté dans un article en sciences de l'éducation. I am confident in my ability to understand an interview presented in an educational science article.	**0.55**	**0.36**
Advanced self-efficacy			
SESCI_3	Je me sens capable de rédiger un article scientifique en éducation. I am confident in my ability to write a scientific article on education.	**0.90**	**0.62**
SESCI_4	Je me sens capable de mener une étude sur les effets d'une méthode pédagogique dans ma classe. I am confident in my ability to conduct a study on the effects of a teaching method in my classroom.	**0.70**	**0.58**
SESCI_6	Je me sens capable de critiquer une étude scientifique en éducation. I am confident in my ability to critique a scientific study in education.	**0.53**	**0.47**
SESCI_9	Je me sens capable de planifier une démarche de recherche en éducation. I am confident in my ability to plan an educational research project.	**0.50**	**0.34**
SESCI_11	Je me sens capable de rédiger un mémoire de recherche. I am confident in my ability to write a research paper.	**0.58**	**0.35**

Extraction method: Principal Axis Factoring based on polychoric correlations. Rotation: Geomin oblique. Standardized loadings (λ) are presented. h^2 = communality.

structure, and EGA bootstrap (500 iterations) confirmed the stability. The EFA (9 items) shows acceptable saturations with a one-dimensional structure (0.56–0.81) and explains 53.3% of the total variance (see Table 7).

As for the subscale attitudes toward research, the initial exploratory factor analysis performed on the eight items theoretically associated with the subdimension "perceived competencies" also showed that the hypothesis of a unidimensional model was not fully confirmed. PA, K1, and EGA suggested two dimensions, while the MAP test indicated a single dimension. We therefore tested a two-factor EFA. However, the two-factor model did not provide a clear solution: one item (PTATER_7) did not load on either factor, and only one item (PTATER_36) remained in the second dimension. On this basis, these items were removed, and an EFA was redone on the remaining items. The analysis of the reduced solution (PTATER_29, PTATER_30, PTATER_32, PTATER_33, PTATER_34, PTATER_35) produced a one-dimensional model. The KMO value was satisfactory (0.845) and Bartlett's test remained significant ($\chi^2 = 412.23$, $p < 0.001$). PA and K1 still suggested two factors, but the MAP test and EGA indicated a one-dimensional solution. The EGA bootstrap showed that the most frequent solution had a single factor (86% of replications). On this basis, the one-factor solution was considered the most parsimonious and conceptually coherent representation of perceived competencies. The EFA was compatible with the one-factor structure, with acceptable standardized saturations (0.46–0.86) and the single factor explaining 46.9% of the total variance (see Table 7).

The other three scales showed insufficient psychometric properties, leading to their exclusion from confirmatory analyses: the ATOSS, the adapted Barometer, and the TPACI.

The ATOSS scale had a very low KMO (0.54), the adapted Barometer showed a moderate KMO (0.63), and the TPACI scale also had a low KMO (0.47), indicating inadequate sampling adequacy for factor analysis in each case. Although Bartlett's tests of sphericity were significant for all three scales (ATOSS: $\chi^2 = 85.70$, df = 10, $p < 0.001$; adapted Barometer: $\chi^2 = 725.55$, df = 136, $p < 0.001$; TPACI: $\chi^2 = 104.71$, df = 15, $p < 0.001$), the presence of correlations alone was insufficient to justify factor extraction. Given the low KMO values and the instability of their structures, none of these scales could yield reliable factor solutions and were excluded from further analyses.

TABLE 7 Exploratory factor analysis of the PTATER scale (sample A, $n = 186$).

PTATER	Items in French and their English translation	λ	h^2
Attitudes toward research (reduced)			
PTATER_2	Les enseignants peuvent acquérir de nouvelles connaissances grâce à la recherche en éducation. Teachers can gain new knowledge through educational research.	**0.76**	**0.58**
PTATER_6	La recherche en éducation peut aider les enseignants à répondre aux besoins de leurs élèves. Educational research can help teachers meet the needs of their students.	**0.69**	**0.48**
PTATER_12	Les enseignants devraient lire les recherches récentes en éducation, car elles leur permettent de continuer à se former. Teachers should read recent educational research because it helps them continue their professional development.	**0.89**	**0.79**
PTATER_16	Les élèves tirent profit du fait que leurs enseignants se tiennent au courant des recherches en éducation actuelles. Students benefit when their teachers keep up to date with current educational research.	**0.68**	**0.46**
PTATER_17	La recherche en éducation aide les enseignants à se tenir au courant des méthodes d'enseignement efficaces. Educational research helps teachers stay up to date on effective teaching methods.	**0.79**	**0.63**
PTATER_19	La recherche en éducation aide les enseignants à améliorer leur pratique. Educational research helps teachers improve their practice.	**0.81**	**0.65**
PTATER_20	La lecture de la recherche en éducation peut aider les enseignants à améliorer leur enseignement. Reading educational research can help teachers improve their teaching.	**0.81**	**0.66**
PTATER_22	Les enseignants devraient rester informés des nouvelles découvertes issues de la recherche en education. Teachers should stay informed about new findings from educational research.	**0.80**	**0.64**
PTATER_24	La recherche en éducation peut apporter des solutions aux problèmes rencontrés en classe. Educational research can provide solutions to problems encountered in the classroom.	**0.69**	**0.49**
PTATER_31	Je ne prévois pas d'appliquer les résultats de la recherche dans ma classe. I do not plan to apply research findings in my classroom.	**−0.53**	**0.28**
Integration in training			
PTATER_3	Un cours sur la recherche en éducation est utile dans les programmes de formation initiale des enseignants dès le bachelier. A course on educational research is useful in initial teacher training programs starting at the bachelor's level.	**0.67**	**0.45**
PTATER_5	Le master en enseignement doit inclure des cours relatifs aux méthodes de recherche. The master's degree in teaching must include courses on research methods.	**0.76**	**0.57**
PTATER_11	Un cours présentant les méthodes de recherche est utile dans les programmes de formation initiale des enseignants dès le bachelier. A course introducing research methods is useful in initial teacher training programs starting at the bachelor's level.	**0.81**	**0.66**
PTATER_13	La recherche en éducation est trop théorique pour être utile. Educational research is too theoretical to be useful.	**−0.56**	**0.32**
PTATER_15	Le master en enseignement doit inclure des cours relatifs aux résultats de la recherche en éducation. The master's degree in teaching must include courses on the results of educational research.	**0.72**	**0.51**
PTATER_18	Un cours présentant les résultats de la recherche en éducation devrait être inclus dans les programmes de formation initiale des enseignants dès le bachelier. A course introducing educational research findings should be included in initial teacher training programs starting at the bachelor's level.	**0.78**	**0.62**
PTATER_21	Un cours sur la recherche en éducation est utile dans différents cours suivis par les futurs enseignants. A course on educational research is useful in various courses taken by future teachers.	**0.74**	**0.55**
PTATER_25	Les cours de recherche en éducation peuvent permettre aux enseignants en formation d'acquérir des compétences précieuses. Courses on educational research can enable trainee teachers to acquire valuable skills.	**0.70**	**0.50**
PTATER_26	Le master en enseignement doit inclure des cours relatifs à la recherche en éducation. The master's degree in teaching should include courses related to educational research.	**0.79**	**0.62**
Perceived competencies (reduced)			
PTATER_29	J'ai confiance en ma capacité à comprendre le vocabulaire spécifique de la recherche en éducation. I am confident in my ability to understand the specific vocabulary used in educational research.	**0.46**	**0.21**
PTATER_30	J'ai beaucoup d'expérience dans l'application des résultats de la recherche dans mon enseignement. I have a lot of experience applying research findings in my teaching.	**0.50**	**0.25**
PTATER_32		**0.81**	**0.65**

(*Continued*)

TABLE 7 Continued

PTATER	Items in French and their English translation	λ	h^2
	J'ai confiance en ma capacité à utiliser les résultats de recherches menées en classe pour modifier mon enseignement. I am confident in my ability to use the results of classroom research to modify my teaching.		
PTATER_33	J'ai confiance en ma capacité à appliquer les théories pédagogiques dans ma classe. I am confident in my ability to apply educational theories in my classroom.	**0.56**	**0.32**
PTATER_34	Je peux appliquer avec succès les résultats de la recherche que je mets en lien avec mon enseignement. I can successfully apply research findings that I relate to my teaching.	**0.80**	**0.65**
PTATER_35	J'ai confiance en ma capacité à appliquer les résultats de recherches menées en classe avec mes propres élèves. I am confident in my ability to apply the results of classroom research with my own students.	**0.86**	**0.74**

Extraction method: Principal Axis Factoring based on polychoric correlations. Rotation: Geomin oblique. Standardized loadings (λ) are presented. h^2 = communality.

TABLE 8 Exploratory factor analysis of the IRS scale (sample B, *n* = 523).

IRS	Items in French and their English translation	λ	h^2
IRS_1	Il m'est personnellement important de douter face aux affirmations non prouvées. It is important to me personally to be skeptical about claims that are not backed up by evidence.	**0.42**	**0.17**
IRS_2	Il m'est personnellement important de rester rationnel(le) et de garder mon sang-froid même lors de débats conflictuels. It is important to me personally to remain rational and levelheaded even in heated arguments.	**0.46**	**0.21**
IRS_3	Il m'est personnellement important de remettre en question les croyances traditionnelles en utilisant la logique et les preuves. It is important to me personally to examine traditionally held beliefs using logic and evidence.	**0.56**	**0.31**
IRS_4	Il m'est personnellement important de pouvoir justifier mes croyances en utilisant des preuves et des arguments rationnels. It is important to me personally that I can justify my beliefs using rational arguments and evidence.	**0.63**	**0.40**
IRS_5	Il m'est personnellement important d'avoir un regard critique sur les croyances auxquelles je tiens le plus. It is important to me personally to critically examine my long-held beliefs.	**0.74**	**0.54**
IRS_6	Il m'est personnellement important d'être quelqu'un de rationnel. It is important to me personally to be a rational person.	**0.56**	**0.32**

Extraction method: Principal Axis Factoring based on polychoric correlations. Rotation: Geomin oblique. Standardized loadings (λ) are presented. h^2 = communality.

As the IRS scale was added in June, it was not included in the initial exploratory phase conducted on Sample A. Exploratory factor analyses were therefore performed on Sample B, the sample used for the confirmatory analyses of the other scales. Consequently, the IRS did not undergo a formal confirmatory validation phase using independent samples. IRS should therefore be considered a preliminary instrument that requires further validation studies. The suitability of the data was confirmed by the factorability indices (KMO = 0.743 and Bartlett's = 214.50, $p < 0.001$). The number of factors to be retained differed depending on the index used. Pa indicated 3 factors, K1 suggested 2, and MAP determined a one-dimensional structure. EGA also indicated a unidimensional structure, the stability of which was verified by EGA bootstrapping (60% of replications). EFA is compatible with a one-factor structure with acceptable saturations (.42 to .74), despite a modest explained variance (32.5%) (see Table 8).

Table 9 presents a synthesis of the exploratory factor analyses conducted on these first four translated scales, including the factorability indices [KMO and Bartlett χ^2 (df)], the number of factors extracted with parallel analysis (PA), Minimum Average Partial method (MAP), the Kaiser criterion (K1) and the Exploratory Graph Analysis (EGA), factor loadings range and the explained variance.

3.2.3 Confirmatory factor analyses

Following exploratory factor analyses, only scales with a theoretically interpretable factor structure were retained for confirmatory factor analyses. CFA was thus conducted for the BISS, SESCI, and the PTATER scale.

For the BISS scale (refined version), a unidimensional model was tested in CFA, in accordance with the results of EFA. The model demonstrated acceptable fit [$\chi^2(35) = 213.652$, $p < 0.001$; $\chi^2/df = 6.10$; CFI = 0.904; TLI = 0.877; RMSEA = 0.099; SRMR = 0.068]. However, robust indices indicate a more moderate fit ($CFI_{rob} = 0.854$; $TLI_{rob} = 0.812$; $RMSEA_{rob} = 0.107$; SRMR = 0.068). The standardized factor loadings were all significant (0.48–0.71). Furthermore, the internal consistency of the French version of the BISS is adequate, with a total McDonald's omega coefficient of 0.83, suggesting that the items provide a reliable overall score of belief in science (see Figure 1).

For the SESCI scale, a two-factor model was tested based on exploratory analyses. The model demonstrated acceptable fit [$\chi^2(53) = 300.892$, $p < 0.001$; $\chi^2/df = 5.67$; CFI = 0.933;

TABLE 9 Summary of exploratory factor analyses for the translated scales.

Scale	KMO	Bartlett χ^2 (df)	PA	MAP	K1	EGA	Loading range	Explained variance (%)
BISS (reduced)	0.863	716.29 (36), $p < .001$	2	1	2	1	0.53–0.79	45.9%
SESCI	0.787	1007.25 (66), $p < .001$	3	1	3	2	0.37–0.90	47.3%
P-TATER								
Attitudes toward research (reduced)	0.733	1159.16 (36), $p < .001$	3	1	2	1	0.53–0.89	56.5%
Integration in training	0.867	956.60 (36), $p < .001$	1	1	1	1	0.56–0.81	53.3%
Perceived competencies (reduced)	0.845	417.23 (15), $p < .001$	2	1	2	1	0.46–0.86	46.9%
IRS (sample B)	0.743	214.50 (15), $p < 0.001$	3	1	2	1	0.42–0.74	32.5%

Loading range = minimum and maximum factor loadings observed.

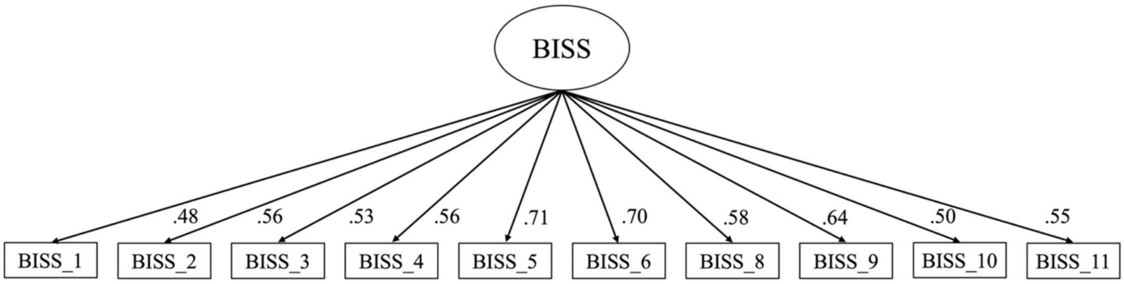

FIGURE 1
Path diagram of the confirmatory factor model of the refined BISS scale (standardized loadings, sample B, $n = 523$).

TLI = 0.916; RMSEA = 0.095; SRMR = 0.059]. However, robust indices indicated a more moderate fit ($CFI_{rob} = .868$; $TLI_{rob} = 0.835$; $RMSEA_{rob} = 0.112$; SRMR = 0.059). The standardized factor loadings were all significant (0.47–0.73 for the first factor; 0.62–0.77 for the second factor), providing initial support for the psychometric property of the two dimensions. However, the high correlation between factors (r = 0.88, or approximately 77% common variance) indicates that the two dimensions are strongly related and could be considered facets of an overall construct. To test this hypothesis, a one-dimensional model was also estimated. The one-factor model showed comparable fit, but slightly lower ($\chi^2(54) = 350.431$, $p < 0.001$; $\chi^2/df = 6.49$; $CFI_{rob} = 0.846$, $TLI_{rob} = 0.812$, $RMSEA_{rob} = 0.120$, SRMR = 0.064). A χ^2 difference test revealed that the two-factor model significantly better fitted the data than the one-factor model ($\Delta\chi^2 = 40.76$, $\Delta df = 1$, $p < 0.001$). Considering these results and theoretical considerations, the two-factor model was retained, while recognizing that the two dimensions ("Intermediate Self-Efficacy" and "Advanced Self-Efficacy") reflect closely related aspects of the same construct. In terms of reliability, the total McDonalds omega coefficient of the SESCI is high ($\omega = 0.90$), indicating good internal consistency of the overall scale (see Figure 2).

For the PTATER scale, a three-factor model was tested based on exploratory analyses. The model demonstrated acceptable fit [$\chi^2(272) = 1061.235$, $p < 0.001$; $\chi^2/df = 3.90$; CFI = 0.947; TLI = 0.942; RMSEA = 0.075; SRMR = 0.063]. However, robust indices indicate a more modest fit ($CFI_{rob} = 0.845$; $TLI_{rob} = 0.829$; $RMSEA_{rob} = 0.092$; SRMR = 0.063). Most standardized factor loadings are significant and show acceptable to satisfactory values (0.20–0.81 for the first factor; 0.33–0.80 for the second factor; 0.13–0.75 for the third factor). However, three items show particularly weak loadings: one on the first factor (PTATER_31,.20), one on the second factor (PTATER_13,.33) and one on the third factor (PTATER_30,.13). These items were removed, and the model was re-estimated with the remaining 22 items. Removing these problematic items improved the model fit. The readjusted model (9 items for factor 1, 8 items for factor 2, 5 items for factor 3) shows an improved overall fit according to standard indices [$\chi^2(206) = 690.898$, $p < 0.001$; $\chi^2/df = 3.35$; CFI = 0.965; TLI = 0.961; RMSEA = 0.067; SRMR = 0.051]. The robust indices also improved moderately ($CFI_{rob} = 0.871$; $TLI_{rob} = 0.855$; $RMSEA_{rob} = 0.094$; SRMR = 0.051). All standardized factor loadings in the refined model are now significant and show acceptable values (0.53–0.81 for factor 1; 0.72–0.80 for factor 2; 0.56–0.75 for factor 3). Nevertheless, the three factors show strong intercorrelations ($r_{12} = 0.93$, $r_{13} = 0.69$, $r_{23} = 0.69$), with the correlation between factors 1 and 2 being particularly high (86% shared variance). This pattern of intercorrelations is consistent with the presence of a higher-order general factor, which justifies the use of a second-order model in which a single latent factor (PTATERMODEL) accounts for the shared variance among the three first-order factors. This higher-order structure also aligns with the theoretical assumption that attitudes toward educational research, integration of research in training, and perceived competence all reflect a broader disposition toward educational research. The reduced version of the PTATER also exhibits very high internal consistency, with a total McDonald's omega coefficient of 0.96 (see Figure 3).

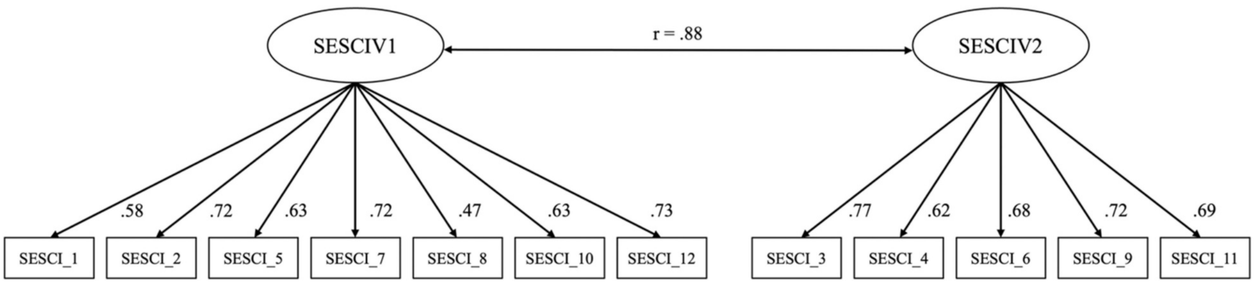

FIGURE 2
Path diagram of the confirmatory factor model of the SESCI (standardized loadings, sample B, *n* = 523).

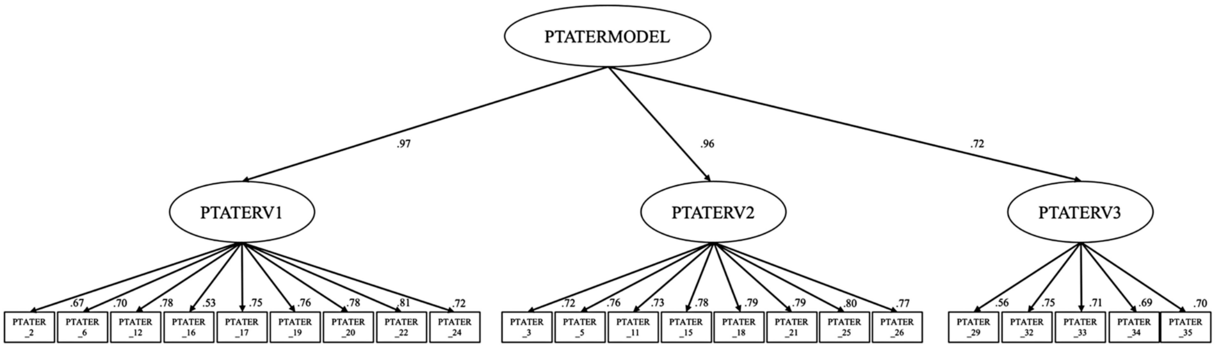

FIGURE 3
Path diagram of the confirmatory factor model of the refined PTATER (standardized loadings, sample B, *n* = 523).

4 Discussion

The objective of this study was to translate and validate several measurement instruments designed to assess preservice teachers' attitudes toward science and educational research in the French-speaking community of Belgium. By adopting a rigorous three-phase methodological approach (item development, scale development, and evaluation) based on the recommendations of Boateng and colleagues (2018), this research provides preliminary evidence for three translated instruments with promising psychometric properties: the Belief in Science Scale (BISS), the Science Subscale of the Expanded Skills Confidence Inventory (SESCI), and the Preservice Teachers' Attitude Toward Educational Research (P-TATER).

For the BISS, the unidimensional structure was supported by initial confirmatory evidence, consistent with the work of Dagnall et al. (2019). Although the reliability observed in this study ($\omega = 0.83$) is slightly lower than that reported in the original version (0.93), it remains adequate according to standard criteria (Béland et al., 2017).

For SESCI, the two-factor model (Factor 1, "Intermediate Self-efficacy" and Factor 2, "Advanced Self-Efficacy") was retained ($\omega = 0.90$), although the correlation between these factors is high ($r = 0.88$). This strong association can be interpreted considering Bloom's revised taxonomy (Anderson and Krathwohl, 2001), which distinguishes between different levels of cognitive processes. The items saturating the first factor mainly refer to intermediate-level skills, corresponding to the processes of comprehension and application [understanding the scientific foundations of educational research (SESCI_1), staying informed about recent discoveries (SESCI_8), or successfully completing a course on research methodologies (SESCI_10)]. Conversely, items on the second factor involve higher-level cognitive processes, closer to the categories of evaluating and creating [e.g., critiquing a scientific study (SESCI_6), planning a research project (SESCI_9), or writing a research paper (SESCI_11)]. Thus, this analysis suggests that the two factors correspond to hierarchical levels of confidence in scientific skills.

The P-TATER has the most complex structure. After removing items with low saturation and readjusting the model, a three-dimensional structure with 22 items was retained, offering the best fit indices among tested models and adequate reliability ($\omega = 0.96$). Nevertheless, the high correlations between the factors, particularly between the first two ($r = 0.93$), pose an interpretative challenge. An alternative two-factor model, obtained by merging these two dimensions, was tested. Although its fit indices were very close to those of the three-factor model, they were consistently slightly lower. Thus, the three-factor model was chosen because it could be explained theoretically. This structure is consistent with the theoretical framework according to which teachers' attitudes toward research are not an isolated construct but are influenced by perceived competencies (Lysenko et al., 2014). From this perspective, the high correlations observed between the three factors, particularly between attitudes toward research and the place of research in training, suggest a close and consistent relationship between these dimensions. It should also be noted that the item-reduction process applied to the P-TATER, which led from 36 to 22 items across the exploratory and confirmatory phases, constitutes an empirical refinement based on the characteristics of the present samples. The resulting structure should therefore be interpreted as a data-driven approximation rather than a definitive solution and requires future cross-validation on independent samples.

Another consideration concerns the scoring strategy for the SESCI and the P-TATER. The high inter-factor correlations (SESCI: $r = 0.88$; P-TATER: $r = 0.69$–0.93) observed in both scales suggest the possible presence of a dominant general factor underlying the subscale structure. The presence of this general factor supports the use of a composite total score. However, future users should select their scoring strategy based on their specific research objectives. When the goal is to examine specific dimensions of the construct, subscale scores may be preferable. Conversely, when an overall index is sufficient, a total score may offer greater parsimony.

Overall, these three instruments show adequate to good internal consistency, as evidenced by McDonald's omega coefficients (ω between 0.83 and 0.96). These results are broadly consistent with those reported in the original studies (Betz et al., 2003; Dagnall et al., 2019; Gonyea, 2013) and provide preliminary evidence for the relevance of these tools for assessing representations and attitudes toward science and research in the specific context of preservice teacher education. They begin to address the need identified in this context, where few validated tools were previously available for this specific population.

However, a few nuances can be highlighted. To begin with, one common limit observed for the three selected instruments concerns the systematic discrepancy between conventional and robust adjustment indices. While conventional indices indicate satisfactory to good fits (CFI = 0.966–0.993; TLI = 0.956–0.993), robust indices reveal more modest fits ($CFI_{rob} = 0.854$–0.871; $TLI_{rob} = 0.812$–0.855), below the conventional threshold of 0.95 (Hu and Bentler, 1999). The ratio χ^2/df (3.35–6.49) also confirms an imperfect but acceptable fit given the complexity of the models. This difference can be explained by the ordinal nature of the data with the 4-point Likert scale. Rhemtulla et al. (2012) show that this kind of data do not meet the continuity assumption of classical maximum likelihood methods, generating biases in the indices. Xia and Yang (2019) confirm that WLSMV, adapted to ordinal data, systematically produces lower CFI/TLI values, reflecting an appropriate correction for non-normality. Li (2016) also adds that WLSMV gives more conservative indices with ordinal data, particularly for moderate samples. Thus, these results justify reporting both types of indices, with a preference for robust indices for the final interpretation.

Another limitation lies in the relatively modest percentages of explained variance: 45.9% for the BISS (reduced), 47.3% for the SESCI, 56.5%, 53.3%, and 46.9% for the three subscales of the P-TATER, and 32.5% for the IRS. These values, particularly for the IRS, may raise concerns. However, as Hooper (2012) points out, there is no strict normative threshold for this criterion in EFA. I The interpretation of percentages of explained variance must take context into account. In psychology more broadly, large-scale reviews suggest that explained variances around 40% are common rather than exceptional (Smedslund, 2022). It supports considering values in the 40%–60% range as acceptable for complex attitudinal constructs in educational sciences. Our results for the BISS (45.9%), SESCI (47.3%), and P-TATER subscales (46.9%–56.5%) fall within this range. Nevertheless, the IRS (32.5%) captures a relatively modest proportion of the construct "importance of rationality" and should be interpreted as a complementary indicator to other measures of epistemic attitudes such as the BISS. Furthermore, the IRS occupies a distinct position in the validation process. Unlike the BISS, SESCI, and P-TATER, which followed a full exploratory-then-confirmatory sequence on independent samples, the IRS was incorporated at a later stage and has only been examined through exploratory analysis. No independent confirmatory validation is therefore available. IRS should be considered as a preliminary instrument that requires further validation studies.

However, three instruments did not demonstrate sufficient psychometric properties during exploratory analyses: ATOSS (KMO = 0.54), the adapted *Baromètre* (KMO = 0.63), and TPACI (KMO = 0.47). These sampling adequacy indices, all below the minimum threshold of 0.60 recommended by Kaiser (1974), indicate that the correlation matrices do not present usable factorial structures. Although Bartlett's sphericity tests are significant for all three scales, which attests to the existence of correlations between items, this necessary condition is insufficient to justify factor extraction. Several hypotheses explain these validation failures. First, the limited number of items in certain scales (4 for the ATOSS, 6 for the TPACI) restricts their ability to form stable factors. It's particularly true in the context of cross-cultural adaptation, where certain items may lose their discriminant power due to translation or cultural differences. With so few items, even the removal of one or two poorly performing items after adaptation leaves factors below the recommended minimum of three items (Worthington and Whittaker, 2006), making the emergence of a stable factor structure statistically unlikely. Secondly, the ATOSS has known psychometric weaknesses even in its original version, with Brossard et al. (2005) reporting poor reliability ($\alpha = 0.57$), which suggests problematic internal consistency of the construct itself. Thirdly, although the Barometer was initially selected because it covered concepts theoretically relevant to epistemic attitudes in education—namely, information processing and trust in the media—no reliability coefficients were reported in the original study, leaving its psychometric properties undocumented prior to this adaptation. The extensively modified version (15 out of 17 items) did not yield a coherent factor structure. This reflects a broader challenge in the cross-cultural validation of scales. When an instrument has no documented psychometric properties and requires substantial contextual adaptation, the risk of compromising both conceptual coherence and content validity is increased (Boateng et al., 2018). Finally, regarding the TPACI, its measurement of trust in various institutions (scientific, political, media) is particularly sensitive to context. Recent work underlines that institutional confidence is highly reactive to major events such as health crises, scientific controversies, and waves of misinformation or disinformation, which can rapidly reshape levels and patterns of trust (Tihon and Glowacz, 2024; Vosoughi et al., 2018; World Health

TABLE 10 Synthetic overview of the psychometric properties gathered for all translated scales.

Scale	Initial items	Exploratory (June 2025)	Confirmatory (September 2025)	Final items	ω	Conclusion
ATOSS	5	Administered	/	/	/	Insufficient factorial structure
BISS	11	EFA	CFA	10	0.83	Preliminary confirmatory properties
Baromètre	17	Administered	/	/	/	Insufficient factorial structure
TPACI	6	Administered	/	/	/	Insufficient factorial structure
SESCI	12	EFA	CFA	12	0.90	Preliminary confirmatory properties
P-TATER	36	EFA	CFA (reduced)	22	0.96	Preliminary confirmatory properties — item structure requires cross-validation
IRS	6	/	EFA	6	/	Exploratory only

*The conclusion reflects the stage of psychometric properties. 'Administered' indicates that the scale was included in the exploratory phase but did not proceed to factor analysis due to insufficient sampling adequacy. 'Preliminary confirmatory properties indicates that the scale completed both exploratory and confirmatory phases on independent samples; further replication is nonetheless needed before the structure can be considered definitive. 'Exploratory only' indicates that the scale was examined solely through exploratory factor analysis on the confirmatory sample, without independent confirmatory validation.

Organization 1926). In this perspective, Boateng et al. (2018) emphasize that scales measuring institutional attitudes require thorough contextual validation during cross-cultural adaptations, as differences between the American and Belgian contexts may alter the factor structure. The TPACI would therefore require complete reconceptualization in this context, particularly regarding the choice of institutional referents.

Table 10 provides a synthetic overview of the psychometric properties gathered for all translated scales across the study.

Some study limitations are worth discussing. The size of the exploratory sample ($N = 186$), although consistent with Guadagnoli and Velicer (1988) recommendations for high-loading EFA, remains moderate. Certain authors recommend at least 10 subjects per item or 100 per factor (Queiroga, 2024), particularly concerning factors with few items despite loadings >0.60. Additionally, the composition of the samples may partly explain the observed response patterns. While the gender distribution of the confirmatory sample (74%) is closer to that of the reference population, the exploratory sample shows a more pronounced overrepresentation of women (81% compared to approximately 69% of students in teacher education programs at French-speaking higher education institutions in Belgium; ARES, 2025). Furthermore, the two samples also differed in year of study (second-year vs. first-year students) and in programs distribution, with a predominance of students in initial training for elementary school teaching in the exploratory phase and students in initial training for lower secondary school teaching in the confirmatory phase. Given that attitudes toward science and educational research vary by gender and disciplinary specialization (Brossard et al., 2005), these differences may have contributed to some instability in the factor structures between exploratory and confirmatory phase. Replication using a representative sample of preservice teachers is therefore recommended in order to ensure that the structures obtained here can be considered stable. Finally, as with any self-reported research, social desirability bias may affect responses, with students potentially overestimating their favorable attitudes toward science. This bias may have been reinforced by the administration conditions, as the questionnaire was completed by students enrolled in courses taught by the first and last authors of the article. This context may have made the students less inclined to express negative attitudes toward science or educational research. A further limitation concerns construct equivalence. Several instruments were substantially modified beyond linguistic translation. While these adaptations were necessary to ensure contextual relevance, they may also have altered certain psychometric properties of the original scales. Linguistic equivalence and contextual relevance were systematically addressed through the translation and expert review process, but construct equivalence remains to be empirically tested. Future studies should examine measurement invariance across the original and adapted versions, where feasible, to determine the extent to which results obtained with the French-language versions can be compared to those reported in the source studies.

Despite these limitations, the three promising instruments are useful tools for assessing future teachers' attitudes toward science and research. These measures respond to a growing need in contexts where training "through and by" research is encouraged internationally (Aspfors and Eklund, 2017; Munthe and Rogne, 2015). Their availability facilitates the evaluation of training programs and the identification of students requiring specific support. For example, the BISS would identify students who express skepticism about the preeminence of science. Meanwhile, the SESCI would highlight those who doubt their own scientific abilities. As for the P-TATER, it would help identify attitudes that are more unfavorable toward educational research. Future research could assess temporal stability via test–retest, examine predictive links between attitudes (BISS/SESCI/P-TATER) and actual use of research during internships, validate the IRS by CFA on an independent sample, explore effects related to gender and socioeconomic status, and test factorial invariance across gender, teacher training programs, and French-speaking contexts.

5 Conclusion

This study translated various instruments designed to assess preservice teachers' attitudes toward science and educational research in the Belgian French-speaking context. Following a rigorous three-phase validation framework (Boateng et al., 2018), it provides French versions of three of these tools: the BISS, the SESCI, and the P-TATER. These scales show promising factorial structures, adequate internal consistency, and theoretically coherent interpretations. Together, these tools help fill a methodological gap in French-speaking research on teacher education, where few validated measures were previously available for this population (Gonyea, 2013).

These instruments offer promising opportunities for empirical monitoring of preservice teachers' epistemic dispositions toward science and educational research. Given that such attitudes have been identified as potential predictors of research use in practice (Dagenais et al., 2010; Lysenko et al., 2014), their measurement constitutes a step toward evaluating and strengthening research-based teacher education programs. More specifically, the BISS may provide an indication of general beliefs about science as a reliable source of knowledge, the SESCI may reflect students' confidence in their ability to engage with educational research tasks, and the P-TATER may capture attitudes toward the relevance of educational research for teaching practice and its integration into initial training.

At the same time, these findings remain preliminary, which explains why the study highlights several challenges for future work, particularly about the validation of short scales, the interpretation of robust fit indices compared to conventional indices with ordinal data, and the relatively modest explained variance for certain constructs, such as the IRS. Further research should replicate these results in other contexts to test the invariance of measures across subgroups and to examine the temporal stability and predictive validity of the instruments in relation to actual research use during internships and early career stages. Further work is also needed to confirm and refine the structure of the IRS using independent samples and confirmatory analyses. Taken together, these lines of inquiry will help consolidate a robust set of tools for studying teachers' epistemic dispositions and support the development of a research-based teaching profession.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the studies involving humans because Research in the field of education does not require ethical approval at our institution. 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.

Author contributions

EG-V: Visualization, Project administration, Validation, Data curation, Formal analysis, Resources, Methodology, Conceptualization, Writing – original draft, Investigation. RD: Writing – review & editing. AD: Writing – review & editing, Supervision. DD: Methodology, Writing – review & editing, Writing – original draft, Supervision, Validation, Formal analysis.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

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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.2026.1863674/full#supplementary-material

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