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Survey Design to Assess Indian Secondary Science Teachers' Inquiry-Based Pedagogical Confidence and Assessment Practices

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Abstract

The National Curriculum Framework (NCF) for School Education 2023 has set a transformative agenda for Indian education, emphasising the need for a competency-based education which fosters critical 21st-century skills [1]. Central to this transformation is assessment as learning and for learning with frameworks that evaluate abilities and competencies rather than rote learning [2]. In science education, the emphasis is on a pedagogical approach where assessment is viewed as an integral part of teaching with individualised feedback timely provided to support learners in developing a research mindset and scientific inquiry skills [3]. In response to this priority, a survey assessing secondary science teachers' pedagogical confidence, assessment practices, and instructional approaches related to scientific inquiry was designed and validated. The findings would then be used to create an assessment framework and training materials to support teachers; pedagogic practice in the teaching of scientific inquiry. This paper presents the justification, design and validation of this survey. Drawing on literature on inquiry-based science education and teacher self-efficacy, Likert-scale style questions were included that reflect key scientific inquiry skills such as hypothesis formulation, experimental design, data interpretation, and assessment strategies. To validate and further develop the survey, responses from 1,418 secondary science teachers in India were collected and factor analysis revealed five interpretable factors related to the teaching of inquiry skills: teaching confidence (measurement and manipulative skills, in particular), assessment competence, pedagogical knowledge and training and support awareness. Scale reliability was found to be high with a Cronbach's alpha internal consistency coefficient of 0.96.

Keywords: *Self-efficacy scale, Assessment competence, Pedagogical confidence, Scientific inquiry skills,*

1. Introduction

The NCF 2023 [1] and CBSE Science Curriculum 2025–26 [3] call for a shift toward inquiry-driven, competency-based science education, emphasising a more realistic approach to science education in India [4]. Core concepts and scientific inquiry skills like questioning, experimentation, and reasoning are the main focus over rote learning and factual recall. To support this, assessment must change from a focus on testing recall of knowledge to that of scientific competencies and be conducted *as* learning and *for* learning. In this vein, assessment becomes part of a process that supports learning and progression, requiring teachers to possess both the pedagogical knowledge and the assessment literacy necessary for an effective inquiry-based instruction.

Research [5] [6], however, highlights persistent gaps in teachers' confidence and competence in assessing and teaching scientific inquiry skills. This underscores the need for a diagnostic form of assessment that can identify teachers' strengths, and training needs to inform the design of professional development that equips teachers with the necessary skills, knowledge and confidence. The survey instrument presented in this paper was developed to fulfil this purpose by capturing multiple dimensions of teacher confidence in inquiry-based science teaching and assessment so that an assessment framework and training program aligned with the NCF 2023 vision [1] and CBSE science curriculum [3] could be developed.

2. Study Context and Rationale

The National Curriculum Framework for School Education (NCF) 2023 [1] has set a transformative agenda for school education in India, emphasising the need for a competency-based curriculum that shifts away from rote learning towards the development of skills such as problem-solving, critical thinking and creativity. This shift requires a redefining of learning as competence-based to become a process of developing skills rather than factual recall. In other words, the new framework calls for a move from content-heavy instruction to a competency-based, inquiry-driven pedagogy. For science education, this means moving beyond teaching from the textbook to experiential, discovery-oriented, and project-based activities where students actively engage in inquiries requiring them to design and undertake investigations and communicate findings. Such pedagogy is not only more effective in developing scientific understanding, but, as per the NCF vision [1], is also more engaging and makes learning more meaningful for learners.

As stated in the science learning framework [3], science maintains its focus on its core content whilst promoting the development of students' abilities and competencies in scientific inquiry. It can be argued that [4] the vast and rapidly expanding nature of scientific knowledge makes it neither realistic nor pedagogically sound to include all science content in the school curriculum. Instead, the framework advocates for focusing teaching on essential disciplinary concepts whilst creating space for the development of scientific inquiry competencies. The ability to devise questions and hypotheses, design experiments and make observations and derive evidence-based arguments through data collection and analysis should be both age-appropriate and relevant to students' everyday lives [3].

The realisation of the NCF vision requires a pedagogical transformation, complemented by a redefinition of assessment practices [1]. Assessment needs to move away from testing factual recall towards an evaluation of a scientific mindset and the development of scientific inquiring skills [2]. In this context, assessment is envisioned both *as* learning and *for* learning fostering student growth and readiness for progression. To implement this vision effectively, teachers must be equipped with both the pedagogical strategies and the assessment literacy and framework required to facilitate and improve inquiry-based learning and teaching.

Current research [5] on assessing scientific inquiry skills in a meaningful way, highlights persistent gaps in teachers' competence while many teachers continue to rely on traditional methods in teaching these skills and promoting a research mindset [6]. The use of traditional approaches is also the result of teachers' limited self-efficacy and conceptual understanding of scientific inquiry methods [6]. Such deficiencies can hinder reform, more generally, and the realisation of the NCF vision. Therefore, in alignment with data-driven practices informing the design of support and development systems, an instrument on teachers' confidence, pedagogical knowledge, and assessment practices related to scientific inquiry, is a necessary first step. Research also highlights this [7] noting that well-designed instruments are essential not only to identify gaps in pedagogical and assessment practice but also to design responsive training. The survey instrument presented in this paper was developed precisely for this purpose: to serve as a diagnostic tool of teachers' self-efficacy in assessing scientific inquiry skills, whilst capturing related pedagogical dimensions to support a training needs analysis for subsequent professional development.

2.1 Background to the study

The importance of beliefs in one's action, and more specifically on teacher practice, is well documented in the literature [7] [8]. This importance makes the concept of self-efficacy critical in understanding and assessing inquiry-based teaching. Self-efficacy, first coined by Bandura, refers to self-judgment of one's ability to perform a certain task. In Bandura's words [9]:

> People with high assurance in their capabilities in given domains approach difficult tasks as challenges to be mastered rather than as threats to be avoided. Such an efficacious outlook fosters intrinsic interest and deep engrossment in activities. These people set themselves challenging goals and maintain strong commitment to them . . . In contrast, people who have a low sense of efficacy in given domains shy away from difficult tasks, have low aspirations and weak commitment to the goals they choose to pursue. When faced with difficult tasks, they swell on their personal deficiencies…, rather than concentrate on how to perform successfully (p.11).

In teaching, self-efficacy is understood as the extent to which a particular form of teaching can be enacted effectively as per the teacher's belief [10]. This belief is particularly relevant in the context of scientific inquiry teaching, where teachers need to both facilitate student-led investigations and assess learning in ways that reflect the complexity of scientific inquiry [11]. Indeed, research has indicated that teachers' interpretations of the challenges associated with inquiry teaching is key for the effectiveness of such a pedagogy [12]. Teachers with high self-efficacy should therefore be more successful in dealing with the challenges associated with science inquiry-based teaching because of the amount of perseverance a teacher exhibits and the amount of effort a teacher invests when working towards achieving an objective [9].

Self-efficacy is defined in this study as teachers' perceived competence in their pedagogical approach for both the development of scientific inquiry skills and knowledge as well as the extent to which they can enhance and support learning using not just different types of assessments but the correct assessment for the context – i.e., assessment of learning and, as per the emphasis in the Indian CBSE curriculum, for and as learning [3]. In the designing of the survey instrument, teacher perceived competences are measured as context-specific dispositions for scientific inquiry teaching and assessment. These include the ability to teach and assess inquiry processes such as hypothesis formation, experimental design, and data interpretation. The instrument was designed to capture these dispositions for the design of targeted professional development that would foster teachers' self-efficacy. This is essential for sustainable change in the context of educational reform and the implementation of inquiry-based science education [13].

2..2 Science Teachers' Self-Efficacy Beliefs Measurement

There is a range of instruments that have been developed to measure teacher self-efficacy in science teaching, and these have been utilised in research. However, these are often limited in scope and, in some cases, context specific which limits their wider application. One of the most widely used and recognised is the Science Teaching Efficacy Beliefs Instrument [14] designed to measure science teachers' beliefs regarding their general ability to teach science effectively. Despite its wide use, the instrument is limited as it focuses on science teaching more generally rather than capturing teachers' self-efficacy for teaching science inquiry skills—a core dimension of science education emphasised in the CBSE framework [3]. The teaching of scientific inquiry skills requires not only knowledge of science content and general pedagogical awareness but also competence in facilitating student-led inquiry activities and assessing inquiry processes and skills. By addressing this specific aspect of perceived competence, a more complete picture of teacher self-efficacy for implementing inquiry-driven pedagogy and assessment would be achieved as outlined in NCF [1].

The Teaching Science as Inquiry 69-item scale [15] is one of the earliest attempts to directly measure teacher self-efficacy of inquiry-based science teaching. The instrument has been widely used but its focus is primarily on the procedural aspects of scientific inquiry teaching (e.g., devising scientific questions and hypotheses, presenting explanations, etc.) neglecting other important aspects, such as practical work, data collection and analysis and critical thinking [16].There have also been more recent efforts, such as the Inquiry-Based Science Teaching Efficacy Scale (IBSTES) [17], a 29 Likert-scale instrument offering a more nuanced view of teacher self-perceived competence for both procedural scientific inquiry skills and the nature of science, critical thinking and collaboration skills. However, IBSTES was developed in the Turkish context and for the assessment of primary teachers' efficacy, which may not fully reflect the pedagogical and curricular realities of Indian secondary science classrooms. Importantly, while the IBSTES captures the efficacy in teaching science inquiry skills, it does not explicitly address teachers' perceived competence in assessing these in the classroom - assessment *for* and *as* learning practices that are critical components of inquiry competencies and in aligning classroom practices with the NCF's vision [1].

3. Instrumentation

Building on previous studies on science teacher self-efficacy in teaching science and scientific inquiry [12][13][15], the instrument developed in this study addresses gaps in the existing scales by offering a diagnostic tool tailored to the Indian secondary education and NCF vision. The instrument integrates pedagogical knowledge of inquiry-based science teaching and confidence in facilitating the development of science inquiry skills in the science classroom as well as self-perceived competence in assessing the development of these inquiry skills. The instrument includes closed-choice scaled items that require teachers to reflect on their self-perceived confidence but unlike other instruments

that rely solely on general pedagogical knowledge [15] [17], the instrument in this study also included closed-choice items on teachers' assessment practices and their confidence to promote subject-specific assessment literacy in practical work and inquiry skills development. Open-ended items where teachers were asked to provide examples of their practices and reflect on challenges they experience when teaching and assessing science inquiry skills were also included. By embedding these constructs into the survey design, the instrument not only supports a training needs analysis but also aligns with the broader goals of the NCF 2023 and CBSE curriculum, which emphasise inquiry as both a method and a learning outcome.
The questionnaire was designed using Jisc and comprised four main sections: (1) teacher demographics, (2) pedagogical approaches to scientific inquiry, (3) confidence in teaching and assessing scientific inquiry skills, and (4) assessment practices and professional development needs. To measure teachers' confidence, items of IBSTES were adapted to reflect the context of scientific inquiry; a necessary approach in order align the scale with pedagogy for science inquiry skills and the specific self-perceived competencies required for teaching these skills. Questions relating to the assessment of scientific inquiry in secondary science classrooms were added to facilitate the development of an assessment framework for scientific inquiry skills and training secondary science teachers in India. Respondents rated their confidence using a five-point Likert-type scale (1 = Strongly Disagree to 5 = Strongly Agree) -e.g., 'I am confident to teach students how to formulate scientific questions', 'I am confident in designing practical activities to assess students' interpretation skills', and 'I am confident in providing constructive feedback on students' scientific inquiry competency during practical work'.

3.1 Administration of the Instrument and Participants

The survey was administered online to a sample of 1418 secondary science teachers from schools under the Central Board of Secondary Education (CBSE), a national-level board of school education in India, managed by the Government of India. Ethical approval was obtained from the institutional review board at the University of Lincoln. Before consenting to the research all participating teachers were provided with information on the purpose and procedures of the study, with reassurance that their responses would be collected anonymously, kept confidential and used solely for research purposes.

Demographic		Percentage
Age	25–44 years	36.30%
	25–34 years	33.81%
	45–54 years	21.28%
	55 years and above	5.27%
	Under 25 Years	3.35%
Gender	Female	73.54%
	Male	25.68%
	Prefer not to say	0.50%
	Non-binary	0.29%
Experience	6–10 years	23.02%
	11–15 years	22.31%
	2–5 years	20.03%
	More than 20 years	15.97%
	16–20 years	13.26%
	Less than 2 years	5.42%
School Type	Private School (CBSE)	93.95%
	Government School (State)	2.07%
	Government Aided Schools	0.85%
	Other	3.13%

Table 1. Age, gender, teaching experience, and type of school of survey respondents.

As Table 1 shows, the majority of respondents were female teachers (73.5%) -typical in the education sector- and participants were mostly (70%) between 25 and 44 years old. In terms of teaching experience, most respondents had between 6 and 15 years of experience (45%), while 16% reported more than 20 years. Regarding school type, an overwhelming majority (94%) taught in private CBSE schools. This demographic profile reflects the target population for the training program and highlights the dominance of experienced female teachers in private school educators in the sample.

3.1 Dimensionality and reliability testing of the instrument

Principal Component Analysis (PCA) and Factor Analysis (FA) are commonly used to examine dimensionality, but PCA was deemed more appropriate, as the instrument was developed by adapting items from existing surveys and combining these with items specific to the purpose of the instrument - i.e., development of an assessment framework and training teachers on its implementation rather than FA that would have been more suitable for alignment with a theoretical framework. PCA reduced complexity in the instrument by combining linearly correlated items into a smaller set of uncorrelated components that addressed the maximum variance in the data set. In other words, PCA was performed to refine the instrument through identification of patterns and groupings among items that fulfilled the practical survey objectives rather than testing assumptions about underlying theoretical concepts [18].
PCA was carried out on the 1418 responses collected and any missing values were imputed using the median value for that item. Reliability calculations using Cronbach's α were also performed to assess internal consistency [19]

4. Data Analysis and Findings

The scree plot from the PCA revealed five main components. Each point represents a principal component and its explained variance ratio. The first point explains approx. 60% of the variance with a gradual flattening at point four and five, suggesting that beyond these first five components, additional components suggest that there is no variance in the data set. This is also summarised in Table 2 with examples from survey items for each component provided.

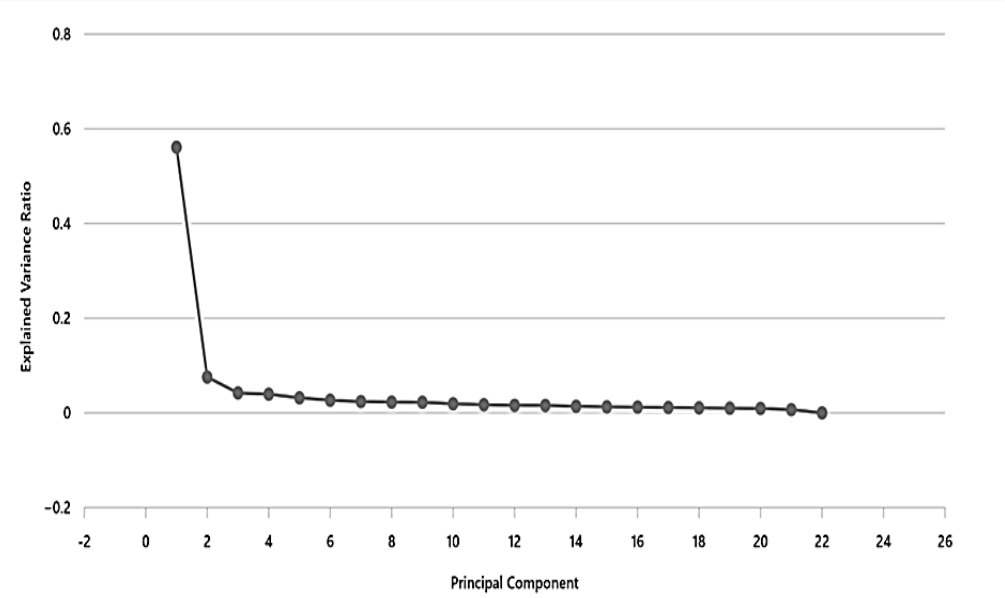

Fig.1. Scree Plot from Principal Component Analysis

Component	Variance Explained (%)	Examples of Top Items for Perceived Competence
PC1	56.11	Assess understanding of inquiry method; Assess identifying a problem; Assess ability to reflect/evaluate findings; Assess interpretation skills
PC2	7.56	Teach observation skills; Teach recording observations; Teach precise measurements; Teach accurate measurements Teach measurement errors
PC3	4.22	Teach executing practical work independently; Teach designing practical work;
PC4	3.94	Teach safe use of lab equipment; Teach identifying a problem
PC5	3.18	Teach hypothesis formulation; Teach dependent/independent variables; Teach data interpretation; Teach accurate measurements

Table 2. Summary of the first five components with examples of the top survey items

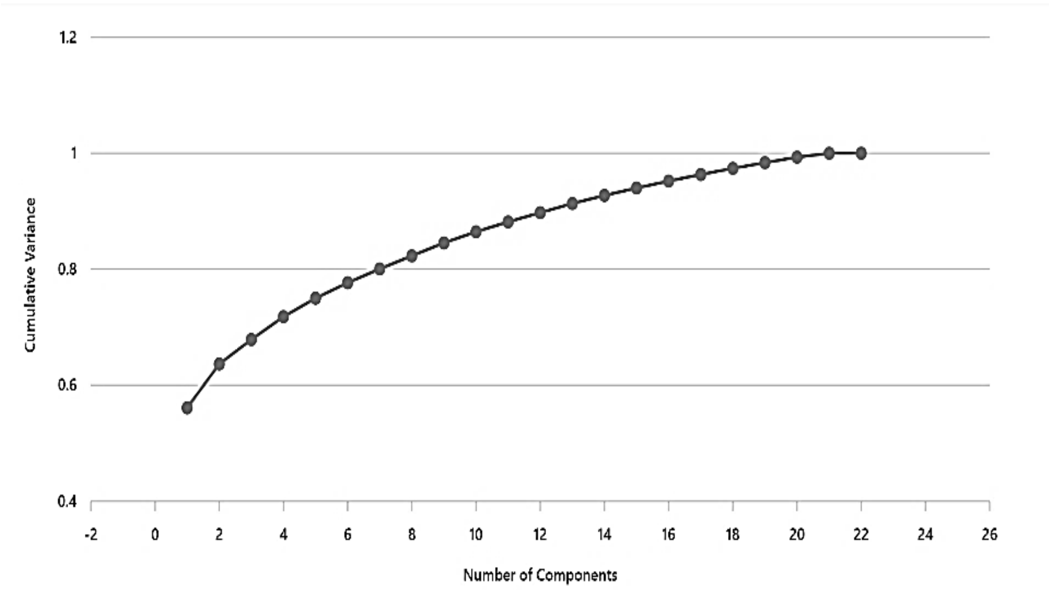

Fig. 2. Cumulative variance explained by principal components

Figure 2 shows how much total variance is explained as components are added with all components accounting for 74.99%. Reliability analysis (Table 3) demonstrated excellent internal consistency for the overall scale (Cronbach's α = 0.962) and strong reliability for each component with Cronbach's α ranging from 0.841 to 0.903, exceeding the commonly accepted thresholds for educational research [20].

Component	Cronbach's α
PC1	0.903
PC2	0.880
PC3	0.849
PC4	0.841
PC5	0.874
Scale -overall	0.962

Table 3. Cronbach's α for each component and the overall survey scale reliability.

5. Discussion

Although the analysis indicates multidimensionality, there is one dominant component which represents 56.11 of the variances and is related to assessment of scientific inquiry skills. The remaining components represented the teaching of different skills such as observation and measurement skills for PC2, practical work design and independence for PC3, laboratory safety and hypothesis formulation for PC4, and variable identification and measurement accuracy for the fifth component.
The analysis confirms that while the instrument is not strictly unidimensional, it is structured around one dominant component -i.e., teachers' self-efficacy in assessing scientific inquiry skills - which was the primary focus in its design. This focus was intentional, as the instrument was primarily developed to evaluate perceived competence for the assessment of scientific inquiry learning and skills development. This, in turn, is used to inform the design of training for the assessment of scientific inquiry skills and the development of an assessment framework for use in Indian secondary science education classrooms. Additional components, like perceived competence in teaching observation, measurement, and hypothesis formulation were also retained for a holistic coverage of multiple related competencies that underpin successful assessment practices. The reason for this being that teachers cannot meaningfully assess inquiry skills without first being competent to teach and scaffold them. By retaining all five components, this provides an overview of teacher perceived competence and ensures that the training needs analysis and professional development address both assessment competence and the pedagogical foundations necessary for scientific inquiry skills teaching.

5.1 Implications

The instrument presented in this paper is one of only a few designed specifically to measure secondary science teachers' confidence and practices in both the teaching and assessment of scientific inquiry skills. It offers a valuable resource in identifying gaps in pedagogical and assessment confidence and in developing professional development programs to support teachers in building this confidence in implementing an inquiry-driven, competency-based science curriculum. It reflects, however, an interpretation of what scientific inquiry entails and what assessment *for* and *as* learning is, guided by the NCF 2023 vision and the Indian CBSE context as well as the professional development and training needs analysis it was designed to serve. It is therefore specific to this context and aim and the interpretation of scientific inquiry and assessment are not exhaustive suggesting there is a need to further deploy, test and validate the instrument on this basis. This is essential to advance the shared understanding of scientific inquiry and the measurement of teacher and assessment confidence across diverse educational contexts.

REFERENCES

[1] National Steering Committee for National Curriculum Framework, "National Curriculum Framework for School Education 2023", n.d.
https://www.education.gov.in/sites/upload_files/mhrd/files/infocus_slider/NCF-School-Education-Pre-Draft.pdf
[2] Alphaplus, "A suggested assessment framework for CBSE science, mathematics and English for Classes 6 to 10", 2021, January
https://cbseacademic.nic.in/web_material/Manuals/AssessmentFramework.pdf
[3] Central Board of Secondary Education (CBSE), "Learning Framework", n.d. Retrieved October 22, 2025, from https://cbseacademic.nic.in/cbe/documents/Learning_Standards_Science.pdf
[4] Abrahams, I., Potterton, B., Fotou, N., & Constantinou, M, "Scientific literacy: Who needs it in a 'Black Box' technological society?", In Conference Proceedings. New Perspectives in Science Education, 2019.
[5] Zhu, Y., Chi, S., & Wang, Z., "Chemistry Teachers' Knowledge in Assessing Scientific Inquiry Competence", Journal of Baltic Science Education, 2025, *24*(4), 774-793.
[6] Aydeniz, M., Bilican, K., & Senler, B., "Development of the inquiry-based science teaching efficacy scale for primary teachers", Science & Education, 2021, 30(1), 103-120.
[7] LI, Gang; MA, Yan. "Exploring the influencing factors of teacher beliefs and their impact on teacher behaviors", BMC Psychology, 2025, 13(1), 1-12.

[8] Wallace, C. W., & Kang, N., “An investigation of experienced secondary science teachers’ beliefs about inquiry: An examination of competing belief sets”, Journal of Research in Science Teaching, 2024, 41, 936–960.
[9] Bandura, A., “Self-efficacy”. In V. S. Ramachaudran (Ed.), Encyclopedia of human behavior, New York, Academic Press, 1994, 71-81.
[10] Lazarides, R.., & Warner, L., "Teacher Self-Efficacy", Oxford Research Encyclopedia of Education, 2020, Oxford University Press.
[11] Chichekian, T., & Shore, B. M., “Preservice and practicing teachers’ self-efficacy for inquiry-based instruction”, Cogent Education, 2016, *3*(1), 291-318.
[12] Chichekian, T., Shore, B., M., “Preservice and practicing teachers’ self-efficacy for inquiry-based instruction”, Cogent Education, 2016, 3(1), 2016, 1-19.
[13]. Lee, O., Hart, J.E., Cuevas, P., & Enders, C., “Professional development in inquiry-based science for elementary teachers of diverse student groups”, Journal of Research in Science Teaching, 41(10), 2004, 1021-1043.
[14] Riggs, I. M., & Enochs, L. G., “Toward the development of an elementary teacher’s science teaching efficacy belief instrument”, Science Education, 1990, 74(6), 625–637.
[15] Smolleck, L., D., Zembal-Saul, C., & Yoder, E.P., “The development and validation of an instrument to measure preservice teachers' self-efficacy in regard to the teaching of science as inquiry”, Journal of Science Teacher Education, 2006, 17(2), 137-163.
[16] Toma, R.B., Yánez-Pérez, I., & Meneses-Villagrá, J.Á., “Measuring self-efficacy beliefs in teaching inquiry-based Science and the nature of scientific inquiry, Science & Education, 2025, 34, 3347–3363.
[17] Aydeniz, M., Bilican, K. & Senler, B., “Development of the inquiry-based science teaching efficacy scale for primary teachers”, Science & Education, 2021, 30, 103–120.
[18] Abdi, H., & Williams, H., J., "Principal component analysis." Wiley Interdisciplinary Reviews: Computational Statistics, 2010, 2(4), 433-459.
[19] Field, A., “Discovering statistics using IBM SPSS statistics”. Sage publications, 2024.
[20] Tavakol, M., & Reg, D., "Making sense of Cronbach's alpha", International Journal of Medical Education, 2011, 2, 53-55.