Development and Validation of an Instrument Assessing Physics Teachers' Beliefs, Competence, and Attitudes in Smartphone-Based Physics Experiments

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Abstract

Much scientific research in physics education has been dedicated to using smartphone sensors in physics experiments. However, a dependable and valid instrument for evaluating physics teachers' beliefs, skills, knowledge, and perspectives regarding physics experiments that employ smartphone technology has been lacking. This research aims to develop a robust survey instrument that accurately measures these various dimensions of physics teachers' engagement with smartphone-based experiments. The instrument development utilized the Technology Acceptance Model (TAM) and the Technological Pedagogical Content Knowledge (TPACK frameworks. Initially, 72 developed statements were developed and were divided into four sections. The instrument was subjected to initial expert review and was cut down to 63 items. Then, the instrument was sent for a pilot study in a high school with six science teachers (N = 6), and their comments were used to revise the instrument. The final administration was conducted in Catbalogan City Division and Samar Division with 87 teachers (N = 87) as total participants. The data gathered was used to subject the instrument to content validity, internal consistency, and construct validity analyses. During the content validity, 20 statements were deemed appropriate by the five-panel experts, 26 were omitted, and 17 were revised. The questionnaire shows strong internal consistency and reliability with an average Cronbach's Alpha of 0.951 across all sections. There were three factors derived from the EFA. Knowledge and competence statements were highly correlated under Factor 1 with high eigenvalue. These two statements were merged. The study has produced 34 valid and reliable statements to assess physics teachers' beliefs, competence, and attitudes toward smartphone-based physics experiments.

Keywords

Smartphone learning, teacher's competence, exploratory factor analysis, content validity index

1. Introduction

Incorporating smartphone technology into education is not just a trend; it's a potential game-changer. It provides new ways to improve teaching and learning experiences. In physics education, using smartphones for experiments offers a flexible and easy way to conduct hands-on activities, promote interactive learning, and improve conceptual comprehension. This approach especially benefits teachers looking to incorporate modern, technology-based techniques. However, the effective use of smartphone-based physics experiments relies on teachers' attitudes, expertise, and confidence in using these technologies, which can significantly impact the quality of physics education.

Studies on smartphone-based physics experiments are mostly related to the use of smartphone

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sensors for physics experiments, for example, the review by Sirisathitkul and Sirisathitkul [1]. Some literature also focused on determining the effect of smartphone-related physics experiments on the student's conceptual understanding and critical thinking skills, for instance, the studies of Colt et al. [2] and Kaps et al. [3]. The research of Lahme et al. [4] shed new light on the understudied physics teachers' beliefs, competence, knowledge, and attitudes toward smartphone-based physics experiments. They found that lab instructors generally had a favorable outlook on utilizing digital technologies in physics laboratory classes, mainly because of their ability to conduct experiments and enhance students' skills, motivation, and relevance. While developing digital competencies was considered less crucial than traditional learning goals, the ability to collect and analyze data using digital tools was identified as an essential skill for students to attain. On top of this, Seifert [5] revealed that college instructors were amazed by the capabilities of technology. They viewed augmented reality in smartphones as mesmerizing and recognized its potential, but they felt that additional training was necessary before they could use it effectively. They were pragmatic and utilized the workshop to strategize projects across different subjects that could leverage the benefits of mobile technologies.

Studies on physics teachers' beliefs, competence, knowledge, and attitudes toward smartphone-based physics experiments are scarce. Understanding the factors influencing teachers' adoption and effective use of smartphone-based experiments is necessary. The lack of comprehensive tools for systematically measuring these multidimensional aspects is a gap that needs to be filled. Considering the growing incorporation of digital resources in the educational realm, it is crucial to comprehend educators' viewpoints and skills to facilitate the successful implementation and use of these tools. A reliable and valid tool to capture these variables is essential. The study of Lahme et al. [4] did not use a standardized instrument, and Seifert's [5] instrument was focused on the level of interest and the perception of self-efficacy. A valid and reliable instrument could offer a systematic and dependable approach to evaluating physics teachers' beliefs, competence, knowledge, and attitudes toward smartphone-based physics experiments, providing valuable information that can guide the development of professional training initiatives and policy-making. The current study aims to bridge this gap by developing and validating a survey instrument to assess physics teachers' beliefs, knowledge, competence, and attitudes toward smartphone-based physics experiments.

An instrument that measures physics teachers' beliefs, competence, knowledge, and attitudes toward smartphone-based physics experiments is crucial for providing customized support and training for teachers. It helps identify areas where teachers excel and where they need more assistance, allowing educational leaders to create tailored professional development programs. The study of Posnanski [6] used the analysis of teachers' beliefs and self-efficacy as a basis for creating a continuing professional development program (CPD). According to Ahmed [7], academic institutions that have a deeper grasp of how students decide to adopt and utilize a particular technology and the reasons behind the acceptance and use of mobile learning will be better equipped to implement effective and original technology solutions. This approach improves physics education by enhancing teachers' skills and knowledge and addressing any barriers to using smartphone-based experiments effectively.

Additionally, a standardized tool on physics teachers' beliefs, competence, knowledge, and attitudes toward smartphone-based physics experiments adds to the extensive research on integrating educational technology. Ahmed [7] argued that more comprehensive and systematic data on mobile learning is needed to capture the full potential of smartphone-based experiments. Hence, this present undertaking is a novel task that ventures into the in-service physics teachers' beliefs, competence, knowledge, and attitudes toward smartphone-based physics experiments. This survey's dependable and valid data can help identify patterns, connections, and effects of smartphone-based experiments on educational outcomes. This information can guide future research and advancements in educational technology, promoting ongoing enhancements and adjustments to teaching methods to address the changing needs of modern classrooms.

This research aims to develop a robust survey tool that accurately measures the various dimensions of physics teachers' engagement with smartphone-based experiments. The study evaluated the survey's internal consistency, construct validity, and reliability. This study seeks to provide a valuable resource for researchers and educators looking to enhance physics education through innovative technological integration by ensuring that the survey instrument is valid and reliable. The research questions are: What is the reliability of the physics teachers' beliefs, competence, knowledge, and attitudes toward smartphone-based physics experiment instruments based on Cronbach's alpha's point estimate? What is the content validity index of this instrument? How many factors can this instrument measure based on the exploratory factor analysis?

2. Methodology

2.1 Instrument Development

The formulation of the instrument on physics teachers' beliefs, competence, knowledge, and attitudes toward smartphone-based physics experiments was informed by both the Technology Acceptance Model (TAM) and the TPACK framework (Technological Pedagogical Content Knowledge), thereby ensuring that robust theoretical principles underpinned the questionnaire. The TAM is a commonly utilized framework for comprehending user adoption and utilization of technology. Moslehpour et al. [8] explained that it encompasses fundamental constructs such as perceived usefulness (PU) and perceived ease of use (PEOU), which impact users' perspectives toward technology and their inclination to use it. The TPACK framework underscores the amalgamation of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) for the proficient use of technology in teaching [9].

Moreover, the teachers' beliefs included their overall attitudes towards smartphone-based physics experiments, indicating their inclination and preparedness to incorporate them into their teaching. This concept was founded on the TAM, highlighting the significance of attitudes in shaping technology adoption.

Table 1
TAM and TPACK constructs and the sample questionnaire item derived from them

Construct	Questionnaire Statement
Perceived Usefulness	I find smartphone-based experiments to be an innovative approach to teaching physics.
Perceived Ease of Use	Using smartphones for experiments saves preparation time compared to traditional methods.
Technological Knowledge	I am knowledgeable in ensuring the accuracy of data collected using smartphone sensors.
Pedagogical Knowledge	I am competent in managing classroom dynamics during smartphone-based experiments.
Content Knowledge	I am knowledgeable in the data analysis techniques using smartphone-collected data.
Technological Pedagogical Content Knowledge	I am knowledgeable about safety and ethical considerations in using smartphones for physics experiments.

Competence was broadly defined to encompass various forms of knowledge, including technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), and the integrated knowledge represented by TPACK. Technological knowledge refers to teachers' expertise in smartphone-based physics experiments, while pedagogical knowledge pertains to their comprehension of effective teaching methods. Content knowledge involves their understanding of physics concepts, essential for crafting and executing relevant experiments. The TPACK construct addresses the convergence of these knowledge domains, illustrating teachers' capacity to seamlessly integrate technology into their teaching to improve student learning outcomes.

Knowledge was categorized into two main areas: subject-specific and technological domains, acknowledging teachers' need to be knowledgeable in both the content they teach and the technological tools they utilize. This dual emphasis ensures teachers can proficiently utilize smartphone technology to enhance their physics instruction. Attitudes stemming from the TAM were assessed through perceived usefulness (PU) and perceived ease of use (PEOU). PU reflects teachers' perspectives on the benefits of smartphone-based experiments for improving teaching and learning. At the same time, PEOU evaluates their perceptions of the ease of implementing these experiments in their classrooms. Together, these elements offered a comprehensive framework for comprehending the various facets of physics teachers' involvement with smartphone-based experiments, guiding the development of a reliable and comprehensive survey instrument.

Table 1 is an example of a questionnaire statement and its corresponding construct. Initially, 72 statements were made. The survey statements were matched with corresponding theoretical constructs based on the definitions in the Technology Acceptance Model (TAM) and the Technological Pedagogical Content Knowledge (TPACK) framework. Each construct was matched with a questionnaire statement that represented its core concept. Table 1 methodically aligns each survey item with its corresponding construct, ensuring comprehensive coverage of teachers' beliefs, competence, knowledge, and attitudes toward smartphone-based physics experiments.

Table 2

Frequency of Survey Items by Construct

Constructs	Frequency of Statements
Perceived Usefulness	13
Perceived Ease of Use	5
Technological Knowledge	5
Pedagogical Knowledge	2
Content Knowledge	1
Technological Pedagogical Content Knowledge	8
Total	34

The total number of items in Table 2 is the final number of statements per construct after the validity and reliability measures. Table 2 illustrates how the questionnaire items are distributed across different constructs, revealing the focus on various aspects of teachers' involvement with smartphone-based physics experiments. The construct with the highest number of items is PU, with 16 items. This emphasis is justified by the critical need to understand teachers' perceptions of the effectiveness and benefits of using smartphones in physics education. Teachers' beliefs about the usefulness of this technology are crucial for its acceptance and integration into teaching practices, hence the larger number of items aimed at capturing these beliefs.

PEOU and TK contain five items. PEOU is important because the easier it is for teachers to use smartphone-based experiments, the more likely they are to adopt and consistently use them. Similarly, Technological Knowledge is vital because teachers need to be skilled in using smartphone technologies and applications to implement these experiments effectively. TPACK comprises eight items, reflecting the significance of integrated knowledge for effectively combining technology, pedagogy, and content. TPACK is a comprehensive construct that captures the intersection of different knowledge areas, crucial for successful technology integration in teaching.

PK and CK have fewer items, 2 and 1, respectively. While these constructs are important, they represent more general and foundational aspects of teaching that may not require as many specific items in a survey focusing on smartphone-based experiments. PK involves general teaching strategies, and CK involves subject-specific knowledge; both are critical but might be less dynamic in integrating new technology than PU and TPACK.

Overall, 34 items remained after the validation and reliability analysis: 10 in Section 1 (beliefs), 9 in Section 2 (competence), eight statements in Section 3 (knowledge), and 10 in Section 4 (attitude). Table 5 shows this together with Cronbach's alpha for each section. However, in the final section, knowledge and competence were merged.

2.2 Participants and Data Collection Procedure

When the 72 items were assembled, they were sent to three-panel experts. These experts have experience formulating and validating questionnaires. Upon initial review, the items were trimmed down to 63.

The revised instrument was then sent to a five-panel expert for further review (N = 5). The five-panel expert comprises an educational technologist, a physics education expert, a psychometrician, a high school physics teacher, and an educational researcher. The educational technologist is skilled in integrating technology into teaching and offers valuable insights into the practical application and relevance of PU and PEOU-related items. The physics education expert with a strong background in subject matter and innovative teaching methods. The psychometrician or survey methodologist has a proven track record in developing and validating educational assessments, which was invaluable for assessing the overall structure and wording of the items. Furthermore, a high school physics teacher who regularly uses technology in their classroom can provide practical, real-world insights. Lastly, an educational researcher specializing in teacher professional development and continuous professional development programs can offer a comprehensive perspective. This time, their marks and remarks on the questionnaire were used to validate the content validity. The content validity index was used to determine the instrument's content validity. A more detailed discussion of this content validity is in the analysis section.

After the content validation, the items were piloted in a high school in Catbalogan City Division, Philippines. Six science teachers participated (N = 6). They had at least two years of experience teaching physics. These teachers provided comments at the end of the questionnaire. Most suggested adding the phrase "I am" to the knowledge and competence statements to clarify the items.

The final administration occurred in the Catbalogan City Division and Samar Division. Eighty-seven teachers (N = 87) participated in this final administration and were chosen using a convenience sampling technique. This strategy entails selecting participants based on their availability and ease of access. When distributing the instrument to online teachers, the researcher targeted those who are readily available or have voluntarily agreed to participate instead of randomly selecting from the entire pool of physics teachers. The challenge for this study is to locate the teachers. Friends, colleagues, and acquaintances help the researcher find science teachers via online platforms.

The instrument was encoded into a Google form and sent to the teachers via Facebook Messenger. The first part of the instrument asked the participants to read and agree with the instructions, confidentiality and voluntary clauses, an informed consent form, and a data security form. Once they clicked "Yes, proceed," they agreed to join the study voluntarily.

2.3 Data Analysis

The validity and reliability of the instrument, called physics teachers' beliefs, competence, knowledge, and attitudes toward smartphone-based physics experiments, were assessed through several methods. Content validity was measured through the content validity index (CVI), and construct validity was evaluated through exploratory factor analysis (EFA). Meanwhile, the instrument's reliability was determined using Cronbach's alpha to measure internal consistency.

CVI was employed to ascertain content validity. CVI is a tool used to evaluate the relevance of items in a questionnaire or test. According to Jeldres et al. [10], CVI assesses how well the items on an instrument represent the construct being studied based on the experts' evaluation. It quantitatively evaluates content validity, guaranteeing that the instrument effectively covers the intended content domain. A group of experts assesses the relevance of each item using a 4-point scale. A higher CVI score indicates strong content validity, suggesting that the items effectively capture the intended construct. The tool utilized was modified from Waltz and Bussel [11]. It comprises four categories: relevance, clarity, simplicity, and ambiguity. The expert assigned a rating ranging from 1 to 4 for each category. The expert's ratings for the relevance section were 1 for not relevant and 4 for highly suitable.

The researcher calculated the mean rating for each criterion to establish an item's CVI based on relevance, clarity, simplicity, and ambiguity. This involved summing up the ratings provided by all ten experts and then dividing by the total number of experts. The overall CVI was then derived from the average of these four sections.

Another method to ensure the study's instrument validity is the EFA. Exploratory Factor Analysis is utilized in validating instruments to reveal the fundamental structure of data by identifying the hidden factors that elucidate the correlations among observed variables [12]. It aids in enhancing the instrument's precision by determining which items are related, thus confirming the construct and improving the instrument's trustworthiness and validity.

EFA provides valuable insights into the construct being measured, helping researchers refine their measurement tools, develop theories, and guide future research efforts. The EFA and Cronbach's Alpha analyses were performed using the JASP open-source software, while the descriptive statistics, such as mean and standard deviation, were obtained from Microsoft Excel.

3. Results and Discussion

3.1 Content Validity

When evaluating the questionnaire's CVI with input from five experts, the researcher employed a methodical approach to ensure the questionnaire effectively covered the intended content domain. The researcher computed each item's CVI. The CVI is derived from the proportion of experts who provide a rating of 3 or 4 for the item. For instance, if all five experts rate an item as 3 or 4, the CVI for that item would be 1.0, demonstrating unanimous agreement on its relevance. Conversely, if only four out of five experts rate it as 3 or 4, the CVI would be 0.8. This approach ensures that each item receives an individual assessment for its relevance from the expert panel.

Table 3
Distribution of Questionnaire Item Ratings by Experts

Score	relevant	clarity	simplicity	Ambiguity
1.00-1.99	10	11	9	15
2.00-2.99	9	8	15	10
3.00-3.99	35	34	32	29
4.00	9	10	7	9

Table 3 illustrates how the five experts rated the questionnaire items based on four criteria: relevance, clarity, simplicity, and ambiguity. Most items received score ratings between 3.00 and 3.99 for relevance, clarity, and simplicity, indicating generally positive but not perfect scores. However, a notable number of items scored low for ambiguity (1.00-1.99), highlighting potential issues with clarity or confusion. Additionally, items scoring between 2.00 and 2.99 for simplicity suggest areas that could benefit from further simplification to improve overall comprehension and effectiveness.

Haron et al. [13] devised a strategy to analyze the CVI value. According to them, an item is deemed appropriate if its CVI is higher than 0.79. If its CVI value falls between 0.70 and 0.79, it requires revision. Items with a CVI less than 0.70 should be omitted.

Table 4
Sample CVI and Interpretation for Questionnaire Items under Relevant and Ambiguity Sections

Item No.	Relevant	CVI	Interpretation	Ambiguity	CVI	Interpretation
1	4	0.80	Appropriate	4	0.80	Appropriate
2	5	1.00	Appropriate	4	0.80	Appropriate
3	4	0.80	Appropriate	4	0.80	Appropriate
3	3	0.60	Omited	4	0.80	Appropriate
4	5	1.00	Appropriate	5	1.00	Appropriate
5	4	0.80	Appropriate	5	1.00	Appropriate

Table 4 presents each questionnaire item's CVI and expert interpretation based on relevance and ambiguity. Each item's relevance and ambiguity were rated on a scale from 1 to 5, and the CVI values were calculated accordingly. Most items have a high CVI (0.80 or 1.00), indicating that experts generally agree on the appropriateness and clarity of these items. However, one item (item 3) has a lower CVI of 0.60 for relevance, suggesting that it may not be suitable and was omitted. The consistently high CVI scores for ambiguity demonstrate that the items are generally clear and not confusing to the experts. Of the 63 items during the final administration, 26 were omitted, and 17 were revised. Only 37 items were subjected to the internal consistency analysis and EFA.

3.2 Reliability of the Instrument

Table 5 shows the number of statements and Cronbach's Alpha values for different parts of the questionnaire that assess physics teachers' beliefs, competence, knowledge, and attitudes. The Cronbach's Alpha values for each part reflect how consistent the items are within that section. The beliefs, competence, and knowledge sections exhibit very high Cronbach's Alpha values (0.956, 0.981, and 0.976, respectively), indicating excellent reliability. Although the attitudes section has a Cronbach's Alpha of 0.892, which is slightly lower than the other section, it still shows good reliability. The average Cronbach's Alpha across all sections is 0.951, demonstrating strong internal consistency and reliability for the questionnaire.

Table 5
The number of statements per section and its corresponding Cronbach's alpha value.

Section	Number of Statements	Cronbach's Alpha
Beliefs	10	0.956
Competence	9	0.981
Knowledge	8	0.976
Attitudes	10	0.892
Average	--	0.951

The alpha values in Table 6 represent the internal consistency measure for each statement of the 37-item questionnaire. BS means Belief Section, CS means Competence Section, KS means Knowledge Section and AS means Attitude Section. All 37 statements were found to have a Cronbach's Alpha value of higher than 0.900, which means the items have very high reliability.

Table 6
The Cronbach's Alpha of Each Statement with its corresponding mean and standard deviation

Item	If item dropped Cronbach's α	mean	sd
BS1	0.962	3.989	1.084
BS2	0.962	4.23	1.344
BS3	0.962	4.057	1.124
BS4	0.961	3.402	1.205
BS5	0.962	3.713	1.200
BS6	0.962	4.023	1.067
BS7	0.961	3.713	1.056
BS8	0.961	3.92	0.955
BS9	0.962	3.885	1.115
BS10	0.961	3.874	1.076
CS1	0.960	2.966	1.176
CS2	0.960	3.023	1.248
CS3	0.960	2.736	1.243
CS4	0.960	3.207	1.365
CS5	0.960	3.172	1.259
CS6	0.960	3.138	1.313
CS7	0.960	3.138	1.313
CS8	0.960	3.195	1.256
CS9	0.960	3.00	1.258
KS1	0.960	2.678	1.316
KS2	0.960	2.69	1.194
KS3	0.960	2.598	1.205
KS4	0.961	2.977	1.303
KS5	0.960	2.713	1.229
KS6	0.960	3.149	1.136
KS7	0.961	3.08	1.193
KS8	0.960	3.138	1.122
AS1	0.961	3.782	0.945
AS2	0.962	4.23	0.742
AS3	0.961	3.644	0.952
AS4	0.961	4.057	0.812
AS5	0.961	4.103	0.836
AS6	0.962	4.103	0.748
AS7	0.962	3.218	0.982
AS8	0.963	4.184	0.755
AS9	0.961	4.011	0.739
AS10	0.962	4.46	0.712

3.3 Construct Validity

Two assumptions should be cleared before an EFA is conducted. These are the Kaiser–Meyer–Olkin

(KMO) and Bartlett sphericity tests. The KMO test should yield a Measure of Sampling Adequacy (MSA) value greater than 0.500, and the Bartlett sphericity tests should have an alpha value less than 0.05 test significance level [15]. The EFA analysis of this present questionnaire yielded an MSA of 0.770 (MSA = 0.770), above the threshold of 0.500 set by Almeida et al. [15]. The Bartlett sphericity test found the p-value less than 0.001 ($p = <0.001$) lower than the significance test level of 0.05. Since all assumptions have been met, the EFA analysis must proceed.

Table 6

Eigenvalues and Explained Variance for Unrotated and Rotated Solutions in Factor Analysis

Factor	Eigenvalues	Unrotated Solution		Rotated Solution	
		Sum Sq Loadings	Proportion Variance	Sum Sq Loadings	Proportion Variance
1	16.244	16.027	0.433	13.211	0.357
2	7.882	7.263	0.206	7.166	0.194
3	2.978	2.684	0.073	5.957	0.61

The data from Table 6 shows the variance explained by factors in a factor analysis before and after rotation. This rotation process simplifies and clarifies the factor structure, making it easier to interpret the underlying constructs measured by the factors by distributing the variance more evenly across them. The eigenvalues indicate each factor's variance, with higher values representing a larger contribution. In the unrotated solution, Factor 1 has an eigenvalue of 16.027, explaining 43.3% of the variance, while Factor 2 and Factor 3 have eigenvalues of 7.263 (20.6% variance explained) and 2.684 (7.3% variance explained), respectively. Post-rotation, the eigenvalue for Factor 1 decreases to 13.211, explaining 35.7% of the variance, signifying a redistribution of the explained variance. Factor 2 experiences minimal change, with its eigenvalue decreasing slightly to 7.166 (19.4% variance explained). Conversely, Factor 3 demonstrates a notable increase in its eigenvalue to 5.957 (6.1% variance explained).

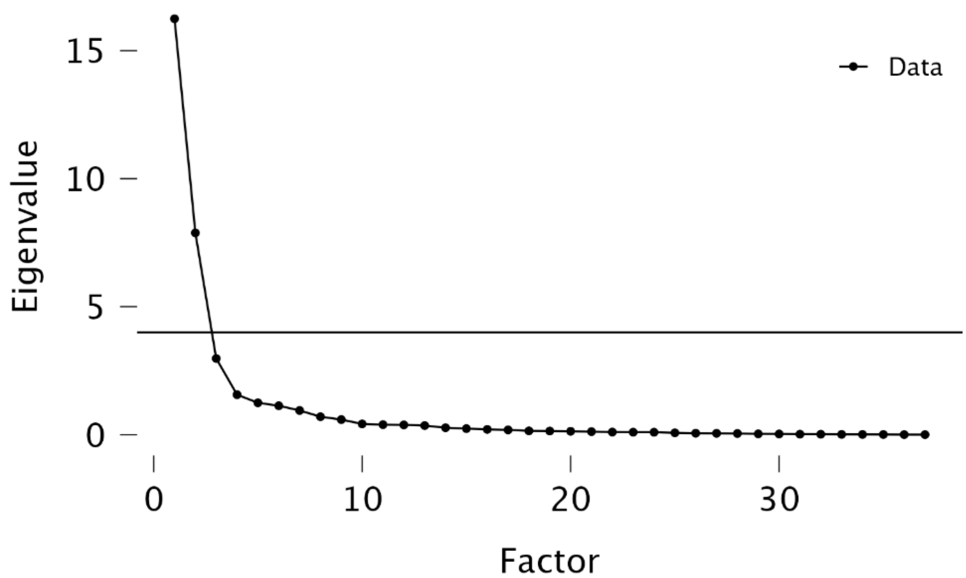

Figure 1. The scree plot shows the three factors measured in the analysis. The picture was captured using JASP software.

The scree plot in Figure 1 affirms the three factors identified in the exploratory factor non-rotation and rotation analysis. Therefore, the analysis can only measure three factors, with Factor 1 being the strongest. Factor 1 has an eigenvalue of 16.027, explaining 43.3% of the variance.

Table 7
The 37 statements and their respective factor loadings and uniqueness

Statements	Factor 1	Factor 2	Factor 3	Uniqueness
KS5	0.988			0.156
KS7	0.981			0.175
KS4	0.978			0.197
KS3	0.947			0.13
CS8	0.944			0.175
KS8	0.934			0.212
KS6	0.928			0.214
CS7	0.909			0.188
KS1	0.906			0.166
KS2	0.892			0.188
CS9	0.85			0.113
CS5	0.817			0.131
CS3	0.787			0.203
CS4	0.734			0.121
CS1	0.719			0.177
CS6	0.712			0.148
CS2	0.688			0.138
BS3		0.933		0.146
BS5		0.92		0.241
BS9		0.86		0.200
BS1		0.852		0.268
BS4		0.8		0.294
BS6		0.746		0.346
BS8		0.735		0.278
BS7		0.731		0.314
BS10		0.677		0.386
BS2		0.668		0.391
AS2			0.873	0.354
AS5			0.841	0.129
AS9			0.723	0.394
AS4			0.699	0.198
AS3			0.659	0.415
AS10			0.653	0.611
AS1			0.612	0.391
AS6				0.719
AS7				0.801
AS8				0.959

The factor loading used in this study is 0.60 since the number of participants is 87. This process is based on Hair et al. [16]. The data in Table 7 displays the factor loadings and uniqueness values for different statements in factor analysis. The statements primarily load onto one of three distinct factors, illustrating the main dimension they represent. For instance, items KS5 to CS2 are mostly associated with Factor 1, with strong loadings (e.g., KS5 with a loading of 0.988) and low uniqueness values, indicating their strong representation of Factor 1. BS3 to BS2 mostly load onto Factor 2, demonstrating significant loadings (e.g., BS3 with a loading of 0.933) and moderate uniqueness values, suggesting a good fit for Factor 2. Likewise, items AS2 to AS1 load onto Factor 3 with high loadings (e.g., AS2 with a loading of 0.873), while AS6 to AS8 exhibit high uniqueness values, implying they might not align well with any of the three factors. The statements AS6, AS7, and AS8 were omitted.

Notice that only three factors were recognized by the EFA, and four questionnaire sections exist. The statements coming from knowledge and competence merge into one factor only. This merging only means that competence and knowledge are highly correlated. The close relationship between the assessment items for these two attributes may indicate that participants see competence and knowledge as closely linked or that the measurement items are conceptually alike. According to Taniredja and Abduh [17], competencies encompass a complex blend of knowledge, skills, understanding, values, and affective attitudes demonstrated through actions in specific situations. Bekere and Tekerel [18] found that knowledge is part of competence, attitude, awareness, and skills. However, this study found that attitude is another factor. Therefore, in the final instrument, both statements of knowledge and competencies were merged. The final number of statements in the questionnaire is 34.

More samples are needed to affirm the instrument’s reliability and construct validity. This is a limitation of this research. It may be necessary to conduct additional analysis, such as confirmatory factor analysis (CFA) or qualitative assessment, to gain a more comprehensive understanding of the framework of your tool and enhance its measurement characteristics.

The main implication of this valid and reliable instrument is that it can now be used for a continuing professional development CPD) program. Effective professional development programs can benefit from thoroughly assessing physics teachers' beliefs, competence, and attitudes toward smartphone-based physics experiments. By pinpointing areas where teachers may lack confidence or harbor negative attitudes, the program could customize its content to address these gaps and bolster teachers' skills and confidence in utilizing smartphone technology in their teaching. Additionally, Krabenick and Noda [19] argued that grasping teachers' beliefs can aid in aligning the program with their values and teaching philosophies, promoting greater engagement and applicability. Ultimately, targeted professional development initiatives can lead to enhanced instructional methods and more advanced, technology-integrated physics education [20].

4. Conclusion

The development and validation of a new instrument specifically targeting the use of smartphones in physics teaching may offer original evaluation criteria for future research. Such instruments could cover general pedagogical excellence and specialized indicators of effective smartphone use. Smartphones provide opportunities for conducting experiments using built-in sensors (accelerometers, gyroscopes, etc.). Assessing teachers' ability and willingness to use such features could become a new area of pedagogical research, emphasizing the importance of digital literacy in physics teaching. This may offer new approaches to studying how teachers perceive smartphones in education and their impact on the effectiveness of physics teaching an may include an assessment of the barriers and motivations that affect integrating such methods into the learning process. The considered approach with smartphones may consist of new dimensions of professional evaluation of the skills related explicitly to using digital tools in physics teaching.

Much empirical research in physics education has focused on using smartphone sensors in physics experiments. This phenomenon suggests the increasing importance of smartphone sensors in classroom physics experiments. Despite this emergence, a reliable and valid tool to examine physics teachers' beliefs, competence, knowledge, and attitudes toward smartphone-based physics experiments has not been found. This gap is the focus of this research. The first step was to create the questionnaire using the TAM and TPACK theories. The instrument was subjected to initial expert review, pilot study, and final administration.

The data from the final administration was collected for content validity, construct validity, and internal consistency. The CVI is derived from the proportion of experts who provide a rating of 3 or 4 for the item. Most items have a high CVI (0.80 or 1.00), indicating that experts generally agree on their appropriateness and clarity. Of the 63 items during the final administration, 26 were omitted, and 17 were revised. Only 37 items were subjected to the internal consistency analysis and EFA.

The alpha values represent the internal consistency measure for each statement of the 37-item questionnaire. All 37 statements were found to have a Cronbach’s Alpha value of higher than 0.900, which means the items are very reliable. The average Cronbach’s Alpha across all sections is 0.951, demonstrating strong internal consistency and reliability for the questionnaire.

However, three statements under the attitude section were omitted because their factor loading is below the threshold value of 0.600. It was concluded that knowledge and competence correlated as they merged into factors with very high eigenvalue. This only means that they have similar concepts, and according to the literature, knowledge is part of competence. On the other hand, attitude did not correlate with competence, as cited by many in the literature. As a result, attitude was independent of competence. Finally, the study developed 34 valid and reliable statements that can measure physics teachers’ beliefs, competence, and attitudes toward smartphone-based physics experiments.

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Declaration of Generative AI

While preparing this research article, the authors used Grammarly to enhance the paragraphs' grammar, spelling. Figure 1 is captured using the JASP software. The authors reviewed the improved content and take full responsibility for the publications’ content.

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