AJSTME, Volume. 12, Issue 1. 119-125, January, 2026. https://www.ajstme.com.ng
ISSN: 2251-0141 (Print), 2971-6233 (Online)

Development and Construct Validation of the Psychomotor Skills Assessment in Physics (PSAP)

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Abstract

This study developed and established construct-related evidence for the Psychomotor Skills Assessment in Physics (PSAP), a performance-based instrument designed to assess senior secondary school students' psychomotor skills during Physics practical work. The study formed part of a broader instrumentation investigation conducted in South-East Nigeria with 384 Senior Secondary School III students selected through multistage sampling. An initial pool of 84 items was generated from the Physics curriculum, related literature, and Harrow's psychomotor taxonomy. Following expert screening and construct validation procedures, 34 items were removed and 50 items were retained across five subscales: Basic Fundamental Movement, Perceptual Ability, Physical Ability, Skilled Movement, and Non-Discursive Communication. Corrected item–total correlation, factor analysis, and Cronbach's alpha were used to answer the research questions. The findings showed that item–total correlations ranged from .51 to .87 with a grand pooled correlation of .67, indicating adequate item homogeneity. Factor loadings ranged from .518 to .896, supporting a clear five-factor structure. Internal consistency coefficients were .74, .83, .86, .89, and .72 for the five subscales respectively, while the overall instrument yielded an alpha of .80. The study concludes that PSAP is a psychometrically sound instrument with acceptable to high internal consistency and strong construct-related evidence for the assessment of students' psychomotor skills in Physics practical activities.

Keywords: construct validation, factor structure, internal consistency, item–total correlation, psychomotor skills, Physics practical

Introduction

Practical work is a fundamental component of Physics education because it gives students the opportunity to translate theoretical concepts into observable action through the handling of apparatus, measurement, observation, and experimental procedure. Physics practical activities require learners not only to know scientific principles, but also to demonstrate competence in performing tasks accurately, safely, and systematically. This is consistent with the long-standing view that effective science learning is not complete until learners can connect conceptual understanding with direct experimentation and manipulation of materials. Deacon and Hajek (2019) and Prades and Espinar (2020) emphasized that practical work helps students verify principles, correct misconceptions, and link theory with real-life scientific activity. For this reason, assessment in Physics should extend beyond the cognitive domain to include the psychomotor domain, which captures learners' practical and manipulative abilities.

The psychomotor domain occupies a central place in science learning because it concerns the development of coordinated movement, manual skill, control, accuracy, and technical performance. In the context of education, psychomotor learning involves the physical execution of tasks that reflect the learner's ability to translate knowledge into purposeful action. Hamid and Baharom (2020) and Baharom et al. (2021) noted that psychomotor skills are usually developed in laboratory and workshop settings where students interact directly with tools, materials, and equipment.

In Physics, such interaction is especially important because many school-based practical activities require learners to set up apparatus, align instruments, measure physical quantities, record data, and adjust procedures with precision. Thus, psychomotor competence is not peripheral to Physics education; it is one of the conditions for meaningful engagement with the subject.

The importance of psychomotor assessment is also supported by the goals of science education in Nigeria. The National Policy on Education emphasizes the acquisition of appropriate skills, scientific attitudes, and competencies necessary for technological development and productive living (Federal Republic of Nigeria, 2013, 2014). Similarly, the Nigerian Educational Research and Development Council Physics curriculum stresses the acquisition of relevant scientific skills and attitudes as preparation for technological application and further study (NERDC, 2012). These policy and curriculum provisions imply that learners should not only know Physics concepts but should also be able to perform practical tasks that demonstrate procedural competence. Yet, school assessment practices often focus more on theoretical knowledge than on the direct evaluation of psychomotor skills.

Psychomotor assessment involves the evaluation of students' ability to apply knowledge through coordinated physical action and task performance. In educational practice, this includes such behaviours as handling equipment correctly, setting up apparatus, taking measurements, observing carefully, and carrying out procedures in the proper sequence. Hidayah (2017) explained that psychomotor assessment requires direct observation of learners as they prepare materials, arrange equipment, carry out procedures, and interpret outcomes. Similarly, Begam and Tholappan (2018) noted that psychomotor assessment becomes more meaningful when students are observed while performing actual practical tasks rather than when they are assessed only through written responses. In the same vein, Salim et al. (2022) argued that practical skill assessment in laboratory settings should be based on observable performance behaviours because such behaviours reveal whether students have genuinely acquired manipulative competence.

In Physics education, the need for psychomotor assessment is especially important because many practical competencies cannot be validly inferred from written reports alone. Students may provide correct theoretical explanations or well-written laboratory records without demonstrating actual skill in apparatus manipulation or experimental execution. Chabalengula et al. (2009) emphasized that direct observation during laboratory work provides a more authentic basis for assessing students' science process skills than written products alone. Abraham, Reiss, and Sharpe (2013) also argued that the assessment of practical work in science should reflect what students do in the laboratory, not merely what they later write about it. This makes performance-based instruments particularly relevant for evaluating students' practical competence in Physics.

A useful theoretical basis for understanding psychomotor performance comes from psychomotor taxonomies such as those of Simpson (1972), Dave (1975), and Harrow (1972). Among these, Harrow's taxonomy is especially relevant because it describes psychomotor learning as progressing from basic movement to more refined and complex forms of skilled performance. The taxonomy includes such levels as basic fundamental movement, perceptual abilities, physical abilities, skilled movements, and non-discursive communication. These categories are closely related to the demands of Physics practical work, where students must coordinate hand and eye movements, manipulate apparatus, exercise control and balance, and demonstrate increasing fluency in experimental procedures. By organizing assessment around these dimensions, an instrument such as PSAP can provide a more comprehensive evaluation of students' practical capabilities.

However, the usefulness of any assessment instrument depends not only on its content and structure but also on the strength of its psychometric properties. Among these properties, reliability is central. Reliability refers to the degree to which an instrument produces consistent and dependable results under appropriate conditions (Nworgu, 2015; Heale & Twycross, 2015). A reliable instrument reduces measurement error and increases confidence that observed scores reflect actual differences in students' performance rather than inconsistencies in the instrument or scoring process. In the context of psychomotor assessment, reliability is particularly critical because scores are often derived from observation and professional judgment, which may introduce rater variability if the instrument is not carefully developed and standardized.

Reliability evidence can be examined from different but complementary perspectives. One important form is inter-rater reliability, which refers to the degree of agreement among different raters who assess the same performance. This is especially important for performance-based and observational instruments where scores may be influenced by the subjective judgment of assessors. When raters interpret criteria differently, the usefulness of the instrument is weakened. Onunkwo (2002) and Nworgu (2015) both emphasized that scorer reliability is necessary for instruments involving observational ratings, checklists, and essay-type judgments. In the present context, a psychomotor assessment instrument in Physics must show that different raters can apply it consistently to the same student performance.

A second important form of reliability is stability, often estimated through a test–retest approach. Stability refers to the extent to which an instrument yields consistent scores across time when administered under comparable conditions. De Souza et al. (2017) explained that an instrument is dependable when repeated measurement produces sufficiently similar results. In psychomotor assessment, evidence of stability is important because it shows that the instrument is not producing erratic scores from one administration to another. This is particularly relevant where the assessment is intended for classroom use, research, or monitoring of student progress.

A third source of reliability evidence is the inter-correlation pattern among items and subscales. Inter-correlation analysis provides information about the internal relatedness of the instrument's dimensions and the extent to which items function together in a coherent way. When items correlate too weakly, the instrument may lack unity; when they correlate too highly, item redundancy may be indicated. Therefore, examining the inter-correlation matrix of PSAP and its subscales helps determine whether the instrument reflects a coherent but non-duplicative structure. This type of evidence is important in multidimensional observational instruments, especially those designed around theoretically distinct but related aspects of psychomotor performance.

Empirical studies reviewed in the main work also support the need for reliability-focused investigation of psychomotor instruments. Yusuf and Afolabi (2018), for example, developed an instrument for assessing students' laboratory skills in Physics and reported a high reliability coefficient, indicating that structured observation can yield dependable data in school science settings. Eze and Agwagah (2017) developed and validated a test for measuring Physics laboratory manipulative skills and demonstrated that psychomotor performance in Physics can be assessed through carefully designed practical instruments. Nahadi, Firman, and Yulina (2016) developed a performance assessment instrument for assessing senior secondary students' psychomotor competence and reported acceptable evidence of validity. Although their study was situated in Chemistry, it reinforces the broader point that performance-based psychomotor assessment can be systematically developed and tested.

Further empirical support comes from technical and vocational education studies reviewed in the thesis. Asukwo et al. (2019) developed and validated a psychomotor skills assessment guide in electronics work and reported acceptable internal consistency, inter-rater reliability, and correlation over time. Hassan, Musa, and Usman (2020) similarly developed an instrument for assessing students' practical skills in electronics works and obtained reliability coefficients that supported classroom use. Hassan, Deba, and Saulawa (2022) also reported that a standardized instrument for assessing practical skills in carpentry and joinery showed strong reliability. Mbaga, Yusuf, and Asukwo (2024) extended this pattern by developing a psychomotor skill assessment tool for electrical installation and maintenance works and reporting high reliability and acceptable inter-rater agreement. Although these studies were conducted outside Physics, they provide important empirical support for the broader argument that psychomotor assessment instruments can and should be supported by multiple forms of reliability evidence.

Despite these contributions, there remains a gap in the area of senior secondary school Physics. Much of the existing research in Physics education has focused on cognitive achievement, interest, attitude, conceptual understanding, or the effects of instructional strategies, while relatively less attention has been devoted to the systematic assessment of students' psychomotor performance using standardized instruments. Where practical work is assessed, teachers often rely on informal observation or written reports rather than structured performance rating. This gap is especially important in a subject like Physics, where the ability to carry out practical procedures is central to meaningful learning and to preparation for higher study and technological application.

It was in response to this need that the Psychomotor Skills Assessment in Physics (PSAP) was developed. The PSAP is a structured observational rating scale designed to assess students' psychomotor skills in Physics practical work across five subscales: Basic Fundamental Movement, Perceptual Ability, Physical Ability, Skilled Movement, and Non-Discursive Communication. Since the instrument is intended for direct classroom and laboratory use, it is necessary to establish whether it produces dependable results across raters, across time, and across its internal dimensions.

This study therefore investigated the reliability evidence for PSAP by examining its inter-rater reliability, stability indices, and inter-correlation matrix. Establishing these reliability properties is essential for supporting the use of PSAP as a dependable instrument for assessing students' psychomotor performance in Physics practical activities.

Research Questions

1. What are the item–total correlations of Psychomotor Skills Assessment in Physics and its subscales?
2. What is the factor structure of Psychomotor Skills Assessment in Physics and its subscales?
3. What are the internal consistency indices of Psychomotor Skills Assessment in Physics and its subscales?

Methodology

The study adopted an instrumentation research design because the broader investigation was concerned with the development, testing, and validation of an assessment instrument for use in Physics practical education. The study was carried out in South-East Nigeria. Three states—Abia, Enugu, and Imo—were selected from the five states in the zone in order to maintain feasibility while preserving regional representativeness. The population comprised all Senior Secondary School III Physics students in the selected states. A sample of 384 students was drawn using multistage sampling. Three states were selected, followed by the selection of six local government areas, 12 schools, and 32 Physics students from each sampled school. The choice of the three states and 12 schools were guided by considerations of manageability, accessibility, and resource constraints, without compromising the generalizability of the findings.

The instrument used for the study was the Psychomotor Skills Assessment in Physics (PSAP), a researcher-constructed observational rating scale used alongside a structured Physics practical activity. The initial version of PSAP contained 84 items generated from the senior secondary Physics curriculum, relevant literature on psychomotor assessment, and Harrow's psychomotor taxonomy. The items were designed to measure five psychomotor domains: Basic Fundamental Movement, Perceptual Ability, Physical Ability, Skilled Movement, and Non-Discursive Communication. The initial instrument was face-validated by experts in Physics Education and Measurement and Evaluation. Based on expert comments, some items were reworded, reorganized, or removed before the construct-validation stage. Thereafter, the instrument was subjected to factor analysis. As a result of the factor-analytic procedure, 34 items were removed because of low loadings, cross-loadings, or redundancy, leaving 50 retained items distributed equally across the five subscales. Corrected item–total correlation statistics were used to answer the first research question. Factor analysis was used to answer the second research question, while Cronbach's alpha was used to determine the internal consistency indices of the instrument and its subscales.

Results

Research Question 1: What are the item–total correlations of PSAP and its subscales?

Table 1. Summary of item–total correlations of PSAP and its subscales

Subscale	Items	Item–total correlation range	Pooled correlation
Basic Fundamental Movement	10	.58–.84	.66
Perceptual Ability	10	.51–.78	.69
Physical Ability	10	.56–.78	.66
Skilled Movement	10	.61–.87	.75
Non-Discursive Communication	10	.52–.76	.60
Overall PSAP	50	.51–.87	.67

Table 1 shows that all PSAP subscales demonstrated adequate item homogeneity. Item–total correlations ranged from .51 to .87 across the full instrument, with a grand pooled correlation of .67. At the subscale level, pooled correlations ranged from .60 to .75, indicating that the retained items were meaningfully related to their respective dimensions and to the total scale.

Research Question 2: What is the factor structure of PSAP and its subscales?

Table 2. Factor loading ranges for PSAP and its subscales

Subscale / factor	Items retained	Factor loading range	Interpretation
Basic Fundamental Movement	10	.603–.862	Strong to very strong
Perceptual Ability	10	.518–.887	Strong to very strong
Physical Ability	10	.625–.876	Strong to very strong
Skilled Movement	10	.627–.893	Strong to very strong
Non-Discursive Communication	10	.540–.896	Strong to very strong
Overall retained items	50	.518–.896	Strong to very strong

Table 2 indicates a clear five-factor solution corresponding to the theorized subscales of the instrument. Across all retained items, factor loadings ranged from .518 to .896. These loading values show that the items related strongly or very strongly to their intended latent dimensions, thereby supporting the construct structure of PSAP.

Research Question 3: What are the internal consistency indices of PSAP and its subscales?

Table 3. Internal consistency indices of PSAP and its subscales

Subscale	Items	Cronbach's alpha	Interpretation
Basic Fundamental Movement	10	.74	High reliability
Perceptual Ability	10	.83	Very high reliability
Physical Ability	10	.86	Very high reliability
Skilled Movement	10	.89	Very high reliability
Non-Discursive Communication	10	.72	High reliability
Overall PSAP	50	.80	Very high reliability

Table 3 shows that the internal consistency coefficients for the five subscales ranged from .72 to .89, while the overall instrument yielded an alpha coefficient of .80. These values indicate that PSAP has acceptable to very high internal consistency and that the retained items function together as a dependable measure of psychomotor skills in Physics.

Discussion

The first finding of the study showed that the retained PSAP items demonstrated adequate item homogeneity, with overall item–total correlations ranging from .51 to .87 and a grand pooled correlation of .67. These values indicate that the retained items were sufficiently related to the total instrument and that each item contributed meaningfully to the construct being measured. This supports the decision to retain the 50 items after the earlier screening and elimination of weak or redundant items. The result is consistent with Opara and Magnus-Arewa (2017), who reported satisfactory item relationships in their development and validation of a mathematics achievement test, thereby reinforcing the importance of item–total correlation as an indicator of item quality during instrument development.

The second finding revealed a clear five-factor structure for PSAP, corresponding to Basic Fundamental Movement, Perceptual Ability, Physical Ability, Skilled Movement, and Non-Discursive Communication. Factor loadings ranged from .518 to .896, which indicates that the retained items had strong to very strong relationships with their respective factors. This result provides empirical support for the multidimensional structure of the instrument and suggests that the five retained domains are defensible components of psychomotor assessment in Physics.

The finding agrees with Nahadi, Firman, and Yulina (2016), whose performance assessment instrument also demonstrated strong factor-related evidence in the assessment of psychomotor competence. It also aligns with Adesoji and Ibraheem (2022), who reported that their competency-based physics assessment instrument showed a clear factor structure across multiple practical domains.

The third finding showed that PSAP had acceptable to very high internal consistency. The overall alpha coefficient of .80 indicates that the total instrument functions as a dependable measure, while the subscale coefficients of .72 to .89 show that each dimension of the instrument is internally coherent. This means that the retained items within each subscale work together to assess a common domain without becoming overly repetitive. The result is in agreement with Adesoji and Ibraheem (2022), who also reported a high reliability coefficient for a competency-based physics practical assessment instrument.

Overall, the item–total correlation evidence, the factor structure, and the internal consistency findings suggest that PSAP possesses adequate construct-related evidence for use in Physics practical assessment. It is therefore more than a face-valid checklist of laboratory actions; it is an empirically refined observational instrument whose retained items relate meaningfully to the total score, cluster into theoretically interpretable dimensions, and demonstrate acceptable internal consistency.

Conclusion

This study developed and established construct-related evidence for the Psychomotor Skills Assessment in Physics (PSAP). The findings showed that the retained items demonstrated acceptable item–total correlations, the instrument exhibited a clear five-factor structure consistent with the theorized psychomotor domains, and the internal consistency coefficients for the total scale and subscales were acceptable to very high. On the basis of these findings, PSAP can be regarded as a psychometrically sound instrument for assessing students' psychomotor skills in Physics practical activities.

Recommendations

1. Since the retained items demonstrated acceptable item–total correlations, the 50-item PSAP should be used in its present form for practical Physics assessment rather than being reduced further without new empirical evidence.
2. Since factor analysis supported five distinct but related dimensions, teachers and assessment developers should organize practical assessment in Physics around these domains—Basic Fundamental Movement, Perceptual Ability, Physical Ability, Skilled Movement, and Non-Discursive Communication.
3. Since the instrument demonstrated acceptable to very high internal consistency, PSAP should be adopted for classroom-based practical assessment and future studies should extend its validation to other samples and school contexts.

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