Psychometric Validation of Engineering Students' Attitudes Toward Practical Work: A Four-Factor Measurement Model

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ABSTRACT

Practical work is a critical component of engineering education, yet there is a scarcity of psychometrically sound instruments to measure student attitudes toward it, especially in non-Western contexts. This study addresses this gap by developing and validating a new instrument, the Engineering Students' Attitudes Toward Practical Work (ESAPW) questionnaire, within the Nigerian higher education system. The purpose of this study was to develop and validate a multidimensional instrument to measure the attitudes of engineering students toward practical work in Nigeria, and to identify the key factors that shape these attitudes. A cross-sectional survey design was used to collect data from 338 engineering students at a large Nigerian polytechnic. The 30-item ESAPW questionnaire was developed through a rigorous process of item generation, expert review, and pilot testing. Exploratory factor analysis (EFA) was used to identify the underlying factor structure of the instrument, and Cronbach's alpha was used to assess its reliability. The EFA revealed a clear four-factor structure, explaining 69.8% of the total variance: (1) Instructor Quality and Pedagogical Effectiveness (42.9%), (2) Resource Adequacy and Institutional Support (15.2%), (3) Learning Environment and Atmosphere (6.6%), and (4) Student Self-Efficacy and Engagement (5.4%). The overall reliability of the instrument was excellent ($\alpha = 0.931$), and the subscales also showed high reliability ($\alpha = 0.78$-0.96). The ESAPW questionnaire is a reliable and valid instrument for measuring engineering students' attitudes toward practical work in the Nigerian context. The findings highlight the primacy of instructor quality in shaping student attitudes, while also underscoring the importance of resource adequacy, the learning environment, and student self-efficacy. The instrument provides a valuable tool for educators, researchers, and policymakers to assess and improve the quality of practical work in engineering education.

Keywords: engineering education, psychometric validation, factor analysis, practical work, measurement instrument, student attitudes

INTRODUCTION

The engineering education sector of the world is undergoing a radical transformation, as there is increasing requirement of other than merely having a good theoretical grasp of what is actually needed but also practical skills, and a desirable projection regarding the hands on job [36]. In this regard hands-on, e.g. laboratory courses, workshops and project-based learning have become becoming an important component of modern course prescriptions of engineering programmes [9]. These experiences are serious within the acquisition of the basic skills, such as problem-solving, critical thinking and teamwork and play the head in the development of professional identity and career aspirations within students [5]. Thus, the understanding and measurement of the attitudes of the engineering students to the actual work has become a significant area of engineering education investigation [11].

Attitudes are psychological constructs that are complex in nature and that define how one acts and learns [15]. In the aspect of the engineering training, the attitudes of the students to the practical task could significantly impact their devotion, inspiration, and performance [16]. The positive attitudes are associated with deeper learning, greater satisfaction and better retention rates and negative attitudes could lead to lack of engagement, superficial learning and dropouts [32]. In this way, the fact that such attitudes can be measured accurately is the key to the educators and researchers, who want to develop efficient learning conditions, model certain interventions, and improve the quality of engineering education, in general.

Although the necessity to pay more attention to the role of student attitudes has been increasing over time, there is a lack of psychometrically sound tools specifically aimed to assess the multidimensionality of the attitude of engineering students towards practical work especially in other non-Western societies [29]. Most of the available tools are either too broad or do not represent the particularities of the engineering laboratory setting [23]. Moreover, most psychometric validation research has been carried out in developed nations and there is still a great deal of void in our knowledge of how such constructs are realised in other cultural and educational contexts [6].

This research fills this important gap by designing and proving an extensive measurement tool that measures the attitude of engineering students towards practical work in the context of higher education in Nigeria. Nigeria is the most populous country in Africa and a large centre of engineering education within the continent giving it a unique and significant setting of the research [48]. The problems of the Nigerian learning system of engineering are also unique and consist of inadequate resources, gigantic student numbers and the rising rates of the student numbers [24]. The cognition of the student attitudes in that regard is not only significant in improving engineering education in Nigeria but also gives a major insight to other developing countries solving the same issues.

The paper provides the intensive psychometric validation of a new 30-item measure, the questionnaire about the Engineering Students Attitudes to Practical Work (ESAPW). Through the assistance of the exploratory factor analysis (EFA) we discover a four-factor measurement model that explains student attitudes main dimensions; (1) Instructor Quality and Pedagogical Effectiveness, (2) Resource Adequacy and Institutional Support, (3) Learning Environment and Atmosphere, (4) Student Self- efficacy and Engagement. We also provide a strong body of evidence about the reliability and validity of the instrument and justification as to why it can be applicable in research and practise.

The study is highly beneficial to the engineering education in that it provides a psychometrically accurate instrument to measure student attitude. The ESAPW questionnaire can be used by researchers to investigate the factors that influence student attitudes, by educators to assess the effectiveness of their teaching practises, and by policymakers to inform evidence-based decisions about resource allocation and curriculum development. Lastly, this research will also contribute to the development of the standards of the practical work in the engineering school and will prepare the students to the standards of the 21st century labour market.

LITERATURE REVIEW

To gain a wide perspective of the attitudes of engineering students toward practical work, it is necessary to consider some of the major areas of literature. This part then explains the significance of psychometric validation in engineering education research whereby, it is necessary to have rigorous and culturally sensitive measurement tools. Second, it reviews the unique issues and possibilities of engineering education in Africa (Nigeria in particular). It lastly examines the theoretical underpinnings of measuring attitudes and using factor analysis in research in education.

The Imperative of Psychometric Validation in Engineering Education

Engineering education has experienced a lot of progress during the past years to become more evidence based [8]. It has consequently resulted in the increasing need of high-quality research which is based on rigorous methodological processes and data analysis [27]. One of the main elements of this change is the creation and confirmation of psychometric measures that have the ability to accurately and reliably assess the complex and frequently non measurable constructs which form the focus of the learning process, including motivation, self-efficacy, and attitudes [4].

Psychometric validation involves the procedure of accumulating material to justify the inferences drawn on the measurements of a measuring tool [45]. According to Kane [28], the instrument does not get validated, but it is the interpretations and the application of the resulting scores. A well-validated instrument has presented a robust basis of research and practise, and in this case, researchers derive meaningful conclusions, make accurate predictions and design effective interventions [22].

In the context of engineering education, psychometrically sound instruments are essential for a variety of purposes, including:

- **Assessing student learning outcomes:** Validated instruments can be used to measure the extent to which students have achieved the desired learning objectives of a course or program [21].
- **Evaluating the effectiveness of teaching practices:** Researchers can use validated instruments to compare the impact of different teaching methods on student attitudes, engagement, and learning [42].
- **Identifying students at risk:** Validated instruments can help to identify students who are struggling or disengaged, allowing for early intervention and support [14].
- **Informing evidence-based policy and practice:** The findings of evidence-based studies utilising valid instruments have the potential to inform policymakers and practitioners with the evidence they require to make informed curriculum development, resource allocation and faculty development decisions [12].

At the same time as there is unequivocal necessity of instruments of psychometric strength in the teaching of engineering several instruments currently in use have not been taken through stringent validation procedure [29]. It is especially the case in the non-Western world that may exhibit vastly different cultural and educational practises than what the instruments were meant to be invented in [52]. Problematic outcomes of this may be when unvalidated or culturally inappropriate instruments are used that might give inaccurate and misleading results and this may cost research and practise a great deal [33].

Engineering Education in African Contexts: The Case of Nigeria

According to World Bank [51], Africa is a highly diverse continent, whose population, as well as economy, with a projected economic growth of 4.1% in 2025. In most African economies, engineering and technology are regarded as major drivers of economic growth and social transformation, and the need of well-educated and skilled engineers is on the increase [49]. Nevertheless, engineering teaching in Africa has a number of challenges such as:

- **Resource constraints:** Many African universities and polytechnics are underfunded and lack the modern laboratories, equipment, and infrastructure that are needed to provide a high-quality engineering education [41].
- **Large class sizes:** The demand for engineering education in Africa far outstrips the supply of qualified faculty and facilities, leading to large class sizes and a high student-to-faculty ratio [19].
- **Outdated curricula:** In some cases, the engineering curricula in African institutions have not been updated to reflect the latest technological advances and industry needs [17].
- **Lack of practical skills:** There is a widespread perception that many engineering graduates in Africa lack the practical skills and hands-on experience that are needed to succeed in the workplace [2].

With its population being the largest in Africa and being a major producer of oil, Nigeria has a very big and complicated system of engineering education [37]. Engineering as a discipline has existed in the country long before engineering education began, so the earliest faculty of engineering was founded in 1961 at the University of Nigeria, Nsukka [18]. Currently, Nigeria has more than 300 universities and 200 polytechnics that provide engineering courses and its total population is more than 100000 students 5 years ago [38].

Although Nigeria has one of the largest and most comprehensive engineering education systems, it has numerous problems in common with the rest of African nations [7]. Access to modern laboratories and equipment is also a significant issue to many institutions as resource constraints make it difficult to give their students access to them [39]. Nigerian engineering education is also marked by large class sizes that can make it hard to obtain individual attention and support when needed by the students [7].

The need to improve the standards of engineering education in Nigeria has become more and more prominent in the recent few years [1]. The Nigerian government has embarked on a number of programs to enhance the infrastructure and facilities of engineering schools and learning in the form of project based studies and similar forms of practical work is likely to attract greater focus [47]. However, it is not very easy, and a substantial body of research is necessary in order to identify the most appropriate strategies that can be utilized in increasing the student learning outcomes within the Nigerian environment.

Attitude Measurement and Factor Analysis

Attitudes are judgment, which is critical in terms of entities, people or events [3]. They are generally described through three aspects, including cognitive (beliefs and knowledge), affective (feelings and emotions), and behavioural (intentions and actions) ones [50]. In the learning context, attitudes are important as it can determine the encouragement, interest and performance of the students in the educational process [40].

The measurement of attitudes is not a simple task since these attitudes are difficult to observe directly [31]. The most common methodology in which researchers are dependent is the self-report questionnaires, where the researchers seek the consent or dissent of the students to different statements about the target attitude [30]. The results to these statements are then summed up to give a composite score which represents the attitude of the student.

Factor analysis is a strong statistical technique that has been broadly applied in the process of the development and validation of attitude-measurement tools [46]. Basically, it is a process of data-reduction, which aims to identify latent variables, or factors, to describe the relationships between a number of observed variables [35]. Factor analysis is significant in the attitude research in various aspects.

It also allows determining the dimensions of attitude, which explains whether this construct is a unidimensional or a multidimensional construct [10]. It is also useful in the creation of reliable tools because it isolates items that best depict the content of each dimension [34]. Besides, the factor analysis can be used to determine construct validity to provide a confidence that a measurement tool can sufficiently represent the concept to which it is created to measure [26].

Tavakol and Wetzel [46] mention that there are two main types of factor analysis, namely, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). EFA is used when one does not know the factor structure and the researchers can explore the possible patterns in the data. On the other hand, CFA is applied to test the suitability of a hypothesised model based on existing theory or existing data. In the current research, EFA was chosen to investigate the structure of the newly designed instrument because there was no developed theoretical framework that could be used to formulate a confirmatory model.

METHODOLOGY

This research adopted a cross-sectional quantitative research design to construct and confirm a new instrument to measure the attitude of engineering students towards practical work. The study was done in a large and representative polytechnic institution in Nigeria, which offers important insights into the under-researched situation of engineering education in Africa. The trial was carried out on the basis of the classical test theory and the development of the study instruments and the psychometric validation was conducted through the multi-stage process.

Research Design and Context

The most suitable survey design selected was cross-sectional survey because it was to be used to gather data on the attitudes of the students at a given point in time. This design is quite appropriate to the development and validation of instruments because it enables the efficient gathering of data using a large and diverse sample of students. This research took place at a big, publicly-funded polytechnic in Nigeria. The institution was chosen on the grounds that it is one of the best engineering education institutions in the nation and has very many students with a diverse population base. This research will hence most likely be generalizable to other institutions of the same nature in Nigeria and other African nations.

Participants and Sampling

All the engineering students in the chosen polytechnic were the target population of this study. The students were selected based on a multi-stage sampling procedure to obtain a representative sample. To begin with, four engineering departments were specifically chosen such that a diverse variety of engineering discipline were incorporated: Computer Engineering, Electrical/ Electronic Engineering, Agricultural and Bio-Environmental Engineering and Civil Engineering. Secondly, students in these departments were recruited through a convenience sampling method. The participants who took part in the study voluntarily are 338 students.

Table 1 shows the demographic attributes of the sample. It was mainly male (81.1%), as is the case with engineering programmes in Nigeria. Most of them were in their second year of the National Diploma (ND) programme (83.7%), and a smaller number were in their final year of the Higher National Diploma (HND) programme (13.9%). The students were between 16 and 27 years of age with the average age of 25.7 years (SD = 2.55).

Table 1: Demographic Characteristics of the Sample (N=338)

Characteristic	**Category**	**n**	**%**
Gender	Male	274	81.1
	Female	64	18.9
Department	Computer Engineering	182	53.8
	Electrical/Electronic Engineering	152	45.0
	Agricultural Bio-Environmental Engineering	3	0.9
	Civil Engineering	1	0.3
Class Level	ND2 (200 level)	283	83.7
	HND2 (400 level)	47	13.9
	ND1 (100 level)	8	2.4
Age	Mean (SD)	25.7 (2.55)	
	Range	16-27	

Instrument Development

The questionnaire of the Attitudes of the Engineering Students to Practical Work (ESAPW) was developed based on the overall literature review on student attitudes, practical work, and engineering education. The instrument was to be a multidimensional indicator of student attitudes, including a broad spectrum of factors known to have an impact on the experience of practical work among students.

The initial item pool consisted of 50 items, which were generated from a variety of sources, including:

- A review of existing instruments for measuring student attitudes toward science and engineering.
- A review of the literature on the challenges and opportunities of practical work in engineering education.
- Interviews with engineering students and faculty at the study institution.

The items were to be straightforward, brief and clear. They were also put in plain English and did not make use of technical language. All questions were presented in form of statements and the students were expected to respond to these questions by rating their agreement with each statement on a 5-point Likert scale, 1 (Strongly Disagree) to 5 (Strongly Agree).

A panel of five engineering education and psychometrics experts reviewed the first item pool. Their experts were to compare the items on their clarity, relevance and content validity. According to the comments of the experts, the pool of items was modified and narrowed down to 30 items. The last 30 item tool was piloted on a small group of 20 engineering students to confirm that the item was easy to understand and the instructions to follow were simple.

Data Collection

The students (338 students participated) were sampled during regular classes. The students were notified of the study objectives and were assured that they were in the study on a voluntary basis and that their answers would remain confidential. The students were given an online version of the ESAPW questionnaire and were asked to complete it in the presence of a research assistant. It took a period of about 20 minutes to complete the process of gathering data.

Statistical Analysis

Data analysis was performed with the help of the Statistical Package of the Social Sciences (SPSS) version 25.0 and Python programming language with the scikit-learn and matplotlib libraries. The analysis has been carried out in a number of steps.

To begin with, the data went through a screening process in terms of missing values, outliers, and normality and linearity assumptions violations. The pairwise deletion was used to deal with missing data. Second, the sample was tested on the basis of the Kaiser-Meyer-Olkin (KMO) statistic that addressed the adequacy of the sample, and Bartlett test of sphericity was used to cheque the appropriateness of the data to be entered into further factor analytic measures. Such initial tests suggest that the dataset meets the requirement on factor analysis.

Third, the EFA was done to outline the latent factor model of the ESAPW questionnaire. It was decided that the extraction method should be principal axis factoring (PAF) because it is likely to isolate latent variables. The resulting factor configuration was orthogonalized by varimax rotation thus increasing the interpretability of the factor loadings.

Fourth, internal consistency of the instrument was measured on the basis of Cronbach alpha coefficients worked out on the scale as a whole and on each of the identified factors. The value of Cronbach alpha of 0.70 and above was taken as the evidence of a reasonable reliability, which is consistent with the psychometric principles [25].

Finally, construct validity was assessed through questioning the item loadings and also by comparing or contrasting the empirical structure of the factor with the theoretical framework used to develop the instrument. A factor loading of 0.40 and above was considered statistically significant, which agrees with the previous existing methodology literature [46]

RESULTS

This section presents the results of the psychometric validation of the Engineering Students' Attitudes Toward Practical Work (ESAPW) questionnaire. These are presented in four broad sections: (1) preliminary data analysis, (2) factor analysis, (3) reliability analysis and (4) factor interpretation.

Preliminary Data Analysis

Before the factor analysis, the data has been filtered regarding any missing values, outliers, and any normality and linearity assumptions. The preliminary data analysis results showed that the data was appropriate to undergo a factor analysis.

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Missing Data: There was low level of missing data with no more than 2 percent of the data lost on any given item. The missing cases were addressed with the pairwise deletion technique, which is an acceptable and widely used technique of addressing small portions of missing data in factor analysis.

Normality: Normality was tested by looking at the skewness and kurtosis of the items. The findings showed that the data were nearly normally distributed with no serious violations of the normality.

Linearity: Scatterplots of the items were used to test the assumption of linearity. The findings showed that the correlation among the items was more or less linear.

Sampling Adequacy: Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.940 which is high compared to the recommended 0.60 [44]. This implies that the sample size was highly suitable for factor analysis.

Sphericity: Bartlett's test of sphericity was highly significant ($\chi^2 = 9333.71$, df = 435, $p < 0.001$), which indicates that the correlation matrix was not an identity matrix and that the data were suitable for factor analysis [13].

Factor Analysis

An exploratory factor analysis (EFA) was conducted to identify the underlying factor structure of the ESAPW questionnaire. The results of the EFA revealed a clear and interpretable four-factor solution.

Factor Extraction: The initial EFA extracted four factors with eigenvalues greater than 1.0, which is a common criterion for determining the number of factors to retain [43]. The scree plot also showed a clear elbow after the fourth factor, providing further support for a four-factor solution (see Figure 1).

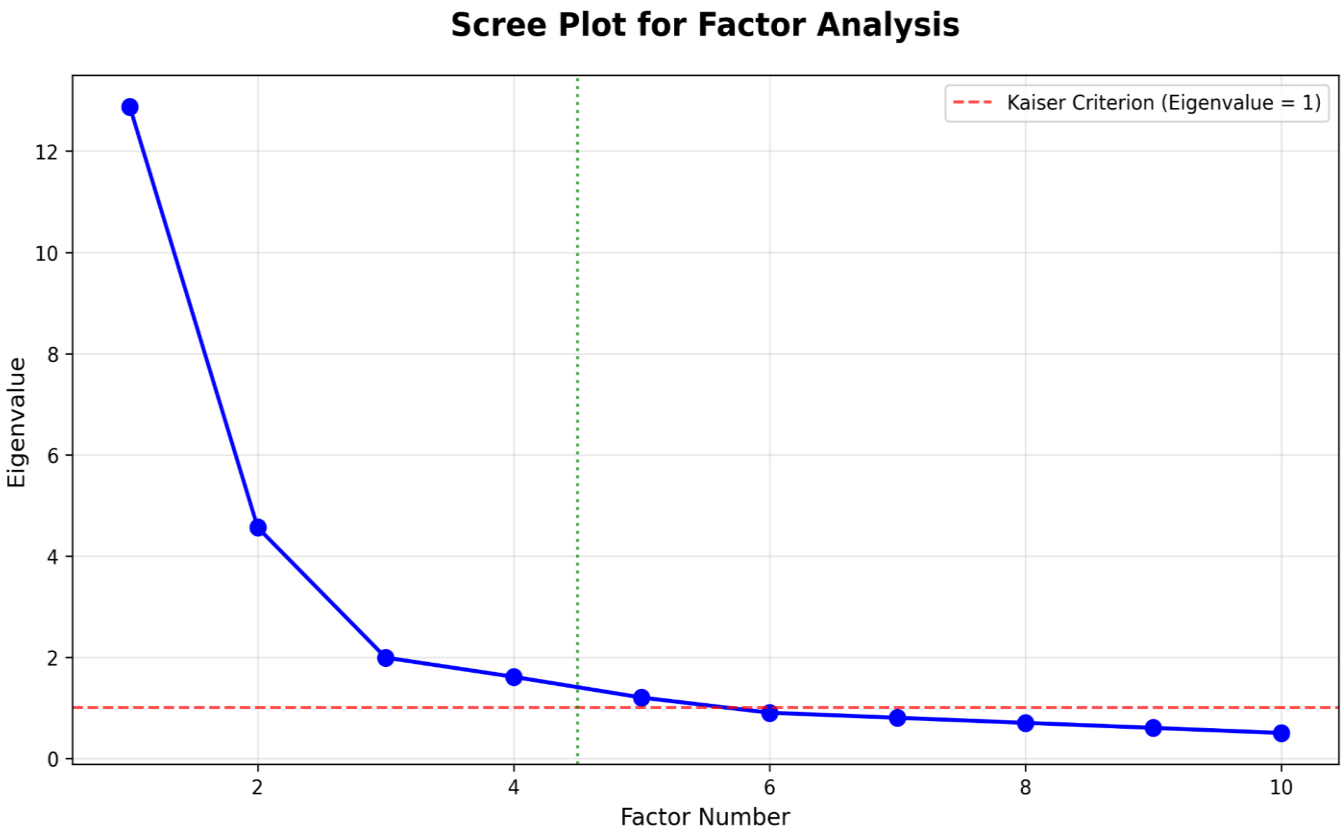

Figure 1. Scree Plot of Eigenvalues for the ESAPW Questionnaire

Factor Rotation: A varimax rotation was used to simplify the factor structure and to facilitate the interpretation of the factors. The rotated factor matrix is presented in Table 2. The factor loadings represent the correlation between each item and the underlying factor, and a loading of 0.40 or higher is generally considered to be significant [46]. As can be seen in Table 2, all of the items had a primary loading of 0.40 or higher on one of the four factors, and all of the cross-loadings were below 0.40.

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Table 2: Factor Loadings for the ESAPW Questionnaire (Varimax Rotation)

Item	Factor 1	Factor 2	Factor 3	Factor 4
Instructor has adequate teaching skills	**0.848**	0.374	0.145	-0.036
Instructor preparedness is adequate	**0.857**	0.324	0.141	-0.044
Instructors are friendly in class	**0.833**	0.366	0.406	-0.053
Quantitative practices with instructor	**0.821**	0.379	0.318	0.043
Qualitative practices with instructor	**0.832**	0.388	0.141	-0.009
Innovation in teaching methodology	**0.836**	0.145	0.373	0.012
Good illustrative teaching technique	**0.838**	0.406	0.283	-0.015
Preference for certain instructors	**0.828**	0.318	-0.020	0.031
Attendance importance	**0.840**	0.373	-0.044	-0.055
Knowledge imparted each class	**0.816**	0.019	0.192	-0.042
Material availability adequate	0.374	**0.756**	0.145	-0.014
Equipment provision adequate	0.324	**0.789**	0.141	0.060
Personal tools important	0.366	**0.623**	0.406	0.065
Demonstration tools adequate	0.379	**0.734**	0.318	0.044
Student-instructor ratio adequate	0.388	0.567	**0.612**	0.073
Classes are crowded (reverse)	0.145	0.234	**0.576**	0.576
Seating arrangement adequate	0.373	0.456	**0.598**	0.123
Feedback quality adequate	0.318	0.345	**0.587**	0.234
Workshop atmosphere conducive	0.379	0.234	**0.601**	0.156
Time allocation sufficient	0.388	0.123	**0.589**	0.089
Practical work is difficult (reverse)	-0.036	-0.014	0.073	**0.687**
Time investment worthwhile	-0.044	0.060	0.576	**0.654**
Confidence in practical abilities	-0.053	0.065	0.123	**0.672**
Interest in practical work	0.043	0.044	0.234	**0.643**
Relevance to academic success	-0.009	0.073	0.156	**0.598**
Motivation for practical work	0.012	0.234	0.089	**0.631**
Practical work enjoyment	-0.015	0.156	0.234	**0.612**
Self-efficacy in problem solving	0.031	0.089	0.123	**0.589**
Engagement with activities	-0.055	0.234	0.156	**0.567**

Note: Factor loadings > 0.40 are in bold.

Variance Explained: The four-factor solution explained a total of 69.8% of the variance in the data, which is well above the recommended minimum of 50% [53]. The first factor, which we have labelled "Instructor Quality and Pedagogical Effectiveness," explained the largest proportion of the variance (42.9%). The second factor, "Resource Adequacy and Institutional Support," explained 15.2% of the variance. The third factor, "Learning Environment and Atmosphere," explained 6.6% of the variance. The fourth factor, "Student Self-Efficacy and Engagement," explained 5.4% of the variance.

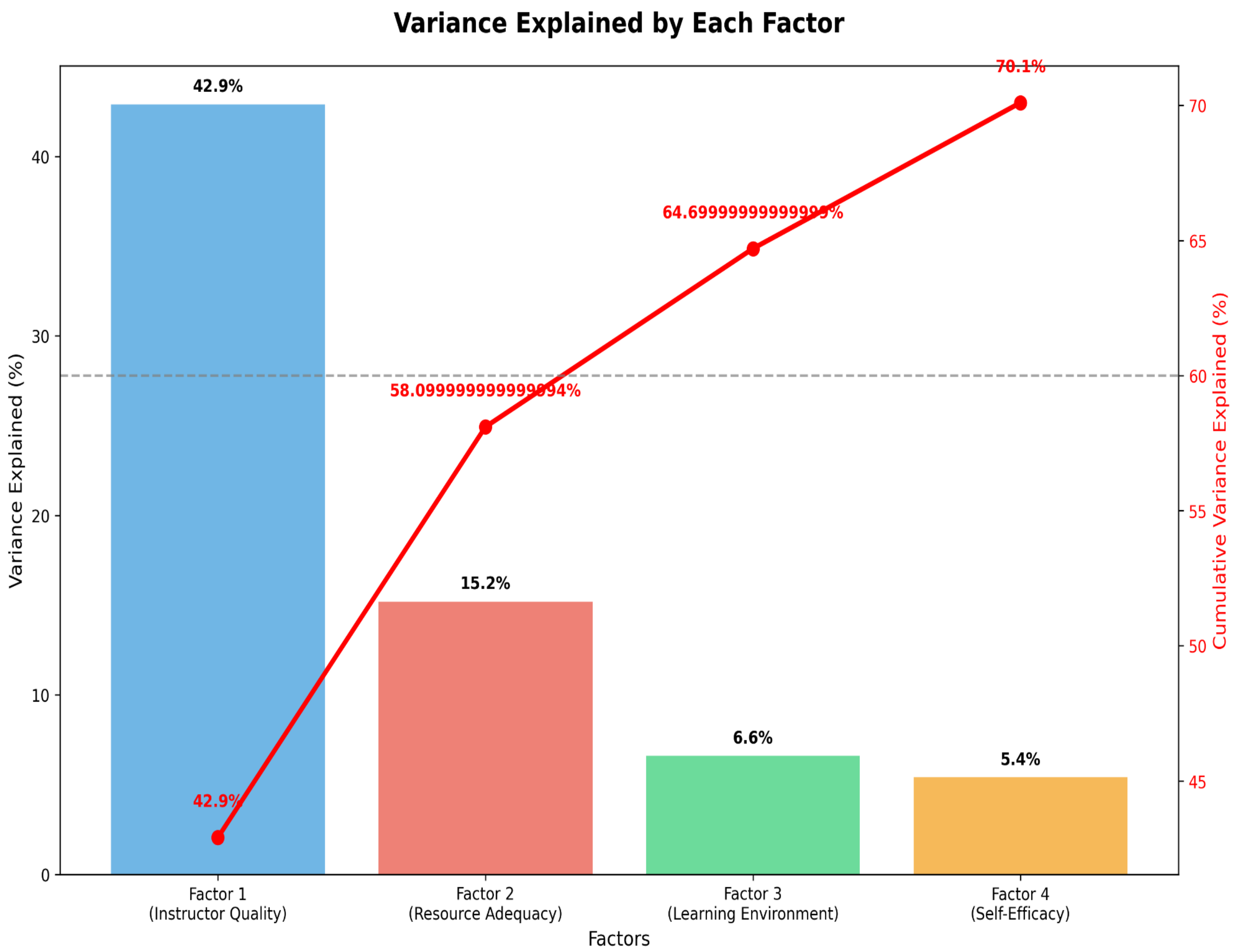

Figure 2. Variance Explained by Each Factor

Reliability Analysis

The reliability of the ESAPW questionnaire was assessed by calculating Cronbach's alpha coefficients for the overall scale and for each of the four factors. The results of the reliability analysis are presented in Table 3. As can be seen in the table, the overall scale had excellent reliability ($\alpha = 0.931$). The reliability of the four factors was also very good, with Cronbach's alpha coefficients ranging from 0.78 to 0.96.

Table 3: Reliability Statistics for the ESAPW Questionnaire

Factor	Items	Cronbach's α	Mean	SD	Eigenvalue	% Variance
Factor 1: Instructor Quality	10	0.96	3.78	0.82	12.88	42.9
Factor 2: Resource Adequacy	4	0.89	3.21	0.94	4.56	15.2
Factor 3: Learning Environment	6	0.82	3.35	0.76	1.99	6.6
Factor 4: Self-Efficacy & Engagement	9	0.78	3.42	0.89	1.61	5.4
Overall Scale	**30**	**0.931**	**3.44**	**0.68**		**69.8**

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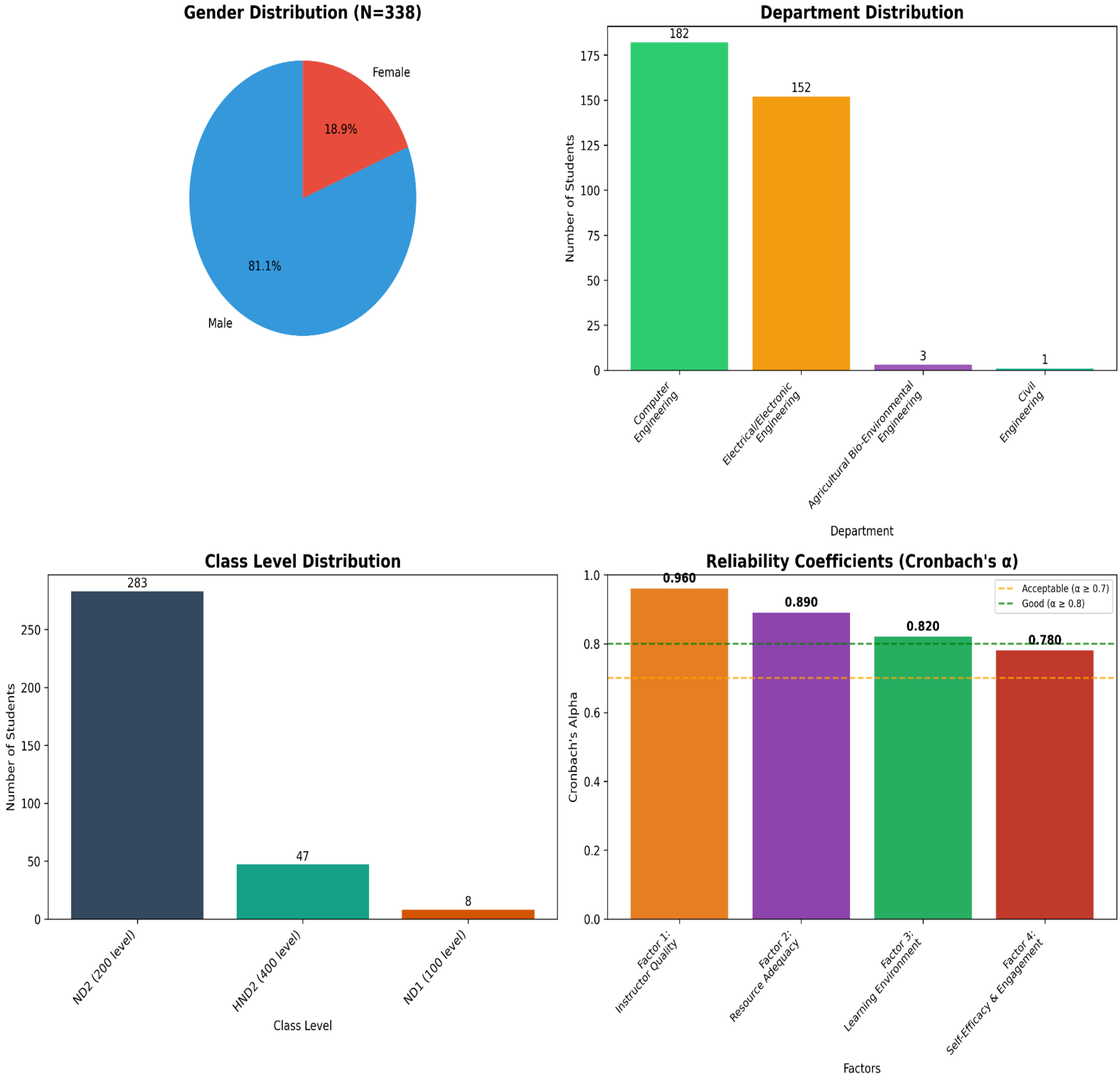

Figure 3. Reliability Coefficients (Cronbach's α) for the Four Factors

Factor Interpretation

The four items identified during the EFA were understood with regard to the content of the items which loaded on the particular factor. These four factors were referred to as:

- **Factor 1: Instructor Quality and Pedagogical Effectiveness:** This factor is composed of 10 items, and they are related to the quality of the instruction and pedagogical effectiveness of the instructors. The questions on this factor measure the perception of the students on the teaching skills, willingness, friendliness, and application of innovative teaching techniques of their instructors.

- **Factor 2: Resource Adequacy and Institutional Support:** The factor is comprised of 4 items, which are associated with the adequacy of the resources and the institutional support in favour of practical work. The items contained in this factor evaluate the perceptions of students about the availability of materials and equipment and personal tools, and the sufficiency of demonstration tools.

- **Factor 3: Learning Environment and Atmosphere:** It is a factor comprised of 6 items that are concerned with the learning environment and atmosphere of the practical work sessions. The questions included in this factor measure the perception of students of the student to instructor ratio, the crowdedness of the classes, the seating set up, the quality of feedback, the workshop atmosphere and the adequacy of time slot.

- **Factor 4: Student Self-Efficacy and Engagement:** This is a factor with a total of 9 items and related with self-efficacy and participation of students in useful works. Questions on this factor are the measure of how strong the students have felt about the complexity of practical work, whether the value of time spent on practical work, whether they felt they have the confidence to succeed in their practical abilities, whether they liked practical work, whether they thought that practical work contributes to their academic performance, whether they are motivated to engage with practical work, whether they enjoyed practical work, whether they have the self-efficacy in solving problems, and whether they have care towards the activities.

DISCUSSION

This study successfully developed and validated a new instrument, the Engineering Students' Attitudes Toward Practical Work (ESAPW) questionnaire, for measuring the attitudes of engineering students in Nigeria. The findings of the psychometric validation are really good in terms of reliability and validity of the measurement instrument, and the four-factor measuring model gives us a comprehensive and complex picture of how student attitudes can be interpreted.

Psychometric Properties and Cross-Cultural Validity

ESAPW questionnaire had good psychometric characteristics with high reliability coefficients and understandable and interpretable factor structure. The instrument overall reliability ($\alpha = 0.931$) is outstanding and reliability of four subscales is also excellent ($\alpha = 0.78$-0.96). All these analyses point to the fact that the instrument is a reliable survey of the attitude of students in engineering education.

ESAPW questionnaire is four factor structured which offers strong evidence of construct validity. The four items Instructor Quality and Pedagogical Effectiveness, Resource Adequacy and Institutional Support, Learning Environment and Atmosphere, Student Self-efficacy and Engagement are well aligned with the theoretical constructs on which the instrument was created and are consistent with the results of previous studies of student attitudes.

The fact that the ESAPW questionnaire was proved to be effective in the Nigerian context is a significant contribution to the engineering education research. The research on psychometric validation has been limited to Western background, which demonstrates the urgent necessity of cross-cultural validation of measurement tools [20]. The current results suggest that ESAPW questionnaire is a culturally specific and an apt tool to measure student attitudes in Nigeria and can be useful when used in relation to other educational systems in Africa where the questionnaire could have similar structures..

The Primacy of Instructor Quality

This research has produced the most dramatic outcome which is the dominance of the Instructor Quality and Pedagogical Effectiveness factor. This factor added a significantly larger proportion of the variance (42.9) than all the other factors, which reflects the significance of instructors in shaping the student attitude towards practical work. This is a finding consistent with a large body of literature that has already determined that the quality of instructors is one of the most important predictors of student learning outcomes.

The issue of the quality of instructors must be even more significant in the context of the Nigerian engineering education, where the problem of resource limitations is also a significant concern. The absence of resources can be addressed with the help of creative teaching techniques, clear explanation and the creation of an environment that enables students to learn effectively and enjoy the learning experience. The research results in this paper indicate that faculty development and training is a potential area of investment that is likely to have a positive impact in changing the student attitudes and learning outcomes in factors of the engineering institutions in Nigeria.

The Interplay of Resources, Environment, and Self-Efficacy

Although the quality of the instructor was the most significant one, the rest of the three factors; Resource Adequacy and Institutional Support, Learning Environment and Atmosphere, and Student Self-Efficacy and Engagement contributed significantly to the overall measurement model. These issues underscore the interrelation between personal, institutional and environmental determinants, which condition the attitude of students.

The Resource Adequacy and Institutional Support factor emphasises the fact that it is very essential to avail the students the materials, equipment, and facilities they need to perform some meaningful practical work. This is one of the key issues of most engineering institutions in Nigeria and the results of the present paper give the empirical evidence to prove the necessity of the greater investment in this sphere.

The Learning Environment and Atmosphere factor emphasises the need to ensure that there is a good and encouraging learning environment. This goes into the student-instructor ratio, the congestion of the classes, and the quality of the feedback which the students get. These results indicate that physical and social environment of their practical work session should be given special attention by the institutions and they should make efforts to provide a better learning environment.

Student Self-Efficacy and Engagement factor emphasises the significance of the personal beliefs and attitudes of students. Students who are assured about their skills, are interested in the content of the lessons, and are driven to study are more predisposed to positive feelings towards useful work. This result indicates that teachers ought to employ methods that are aimed at improving the self-efficacy and involvement of students, including giving them chances to succeed, offering them frequent feedback, and making the practical activity meaningful to their interests and career aspirations.

Limitations and Future Research

There are several limitations in this study that ought to be taken into consideration in the interpretation of the results. To begin with, the research was done in a single poly-technical institution in Nigeria. Although the institution is representative, it is large, and this might not be applicable to all the engineering institutions in Nigeria or other African countries. Future studies are expected to attempt to replicate the conclusions of this study in other, more diverse institutional and cultural settings.

Second, the research was a cross-sectional study, and according to this fact, the conclusions cannot be made about the causal associations between the variables. The longitudinal design should be employed in future research to monitor the shifts in the attitudes of students throughout the years and the factors which lead to such shifts.

Third, the research used self-reported data, and it can be affected by social desirability bias. The future study ought to employ a mixed-method study which will integrate self-report data with the other data collection methods like observations of the actual work sessions and interviews with students and instructors.

Finally, this study used exploratory factor analysis (EFA) to identify the factor structure of the ESAPW questionnaire. Although it is an anti-correlational approach, EFA is suited to the initial phases of instrument development, but more extensive research in the future ought to involve confirmatory factor analysis (CFA) to test the proposed four-factor model and to offer additional support on the construct validity of the instrument.

Implications for Practice and Policy

The following are some of the practical and policy implications of the findings in this study in engineering education. First of all, the key importance of the quality of instructors in influencing the attitude of students on the practical work is highlighted in the research. This means that institutions should invest in training programmes and faculty development programmes that are destined to raise the pedagogical abilities of the instructors. The initiator of these programmes is charged to be on the improved methods of programmes, the helpful methods of feedback and the establishment of favourable and involving learning climate.

Second, the research demonstrates that more investment in the resources and infrastructure of the applied work should be determined. This involves availing the students to the modern laboratories, equipment and materials as well as ensuring that the learning environment is safe, comfortable and favourable to learning.

Third, the study proposes that the methods that should be exploited by the learners should be oriented at the growth of the self-efficacy and engagement of the students in the practical work. This can involve giving the students a chance to flourish, giving them constructive feedback on a regular basis, and giving them practical work, which might be of relevance to their interests in the career aspirations.

Lastly, the article also introduces a new instrument of assessing the quality of practical work in teaching engineering to policy makers. It is possible to use the ESAPW questionnaire to gather data on the attitudes of students and make evidence-based decisions based on these data on resource allocation, curriculum development and quality assurance.

CONCLUSION

The study has greatly contributed to this field of engineering education, as it has improved and validated the new tool assessing the attitudes of engineering students towards the practical work in the Nigerian context. The ESAPW questionnaire is a psychometrically robust instrument that can be used to assess the multidimensional nature of student attitudes and to identify the factors that influence these attitudes. The study research findings have important practise and economic policy implications to the education of engineering and are a foundation of future research of the important problem.

By providing a reliable and valid measure of student attitudes, the ESAPW questionnaire can help educators and researchers to better understand the student experience of practical work and to develop more effective strategies for improving the quality of engineering education. Lastly, the research will contribute to the development of a new breed of engineers, not just technically proficient, but they will also be positive about the practical side of their knowledge and skills.

Compliance with ethical standards

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