



Variable Conceptualisation and Measurement in Environmental Research

Beulah I. Ofem¹, Akaawase Alexander Mchi^{2*}



¹Department of Urban and Regional Planning, University of Uyo, Uyo, Nigeria

²Department of Urban and Regional Planning, Delta State University of Science and Technology, Ozoro, Nigeria

*Corresponding Author: akaawasemchi@gmail.com

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ABSTRACT

This paper discusses the importance of variable conceptualisation and measurement in environmental research. The paper explains how wrong application of concepts can mislead the researcher when conducting research, and the resultant effects on each stage of the environmental research process. The paper is motivated by the problems behind many research students pursuing their masters or doctoral degree programmes face, especially with change in dissertations or theses titles and methods to match the contents of their reports. In this paper, the authors demystify the challenges encountered by unskilful researchers and students when trying to make their readers have a clear understanding of their research reports (dissertations or theses). Therefore, the paper may serve as a guide in planning and conducting environmental research by university degree students and early career researchers.

Keywords: Conceptualisation, Operationalisation, Level of Measurements.

1 Introduction

The antecedence of research recorded that search for knowledge is always based on reliable data and the methods used in data capturing. The data capture process starts with variable conceptualisation and measurements. For this reason, the research process has been structured into three phases; the conceptual, the empirical, and the interpretative (Jain *et al.*, 2013; Mason, 2009). Simkus & Frothingham (2022) explained that scientific discourse makes use of different strategies in order to convince, and the scientific community believe in the traditional phases of research consisting of three fundamental stages like conceptual, empirical and interpretative. The interest of this paper is in the conceptual phase of the research process that regulates the type of questions to be addressed by the study, and how to find answers to those questions using variables as tools of research procedure.

Evidence has shown that many research students pursuing their masters (or doctoral) degree programmes are faced with problems of change in dissertations or theses titles and change of methods to match the contents of their reports. Sometimes, the students are asked to collect fresh field data and prepare new reports that will be in harmony with their research titles with a view to ensuring quality research. In most cases, the weak students become demoralised, and abandon the work. Sometimes, when the dissertation or thesis topic seems suitable, there may be deficiencies in the dimensions and indicators of the concepts or variables studied. It could be observed that these weaknesses may significantly cause a deviation from the study objectives and the expected direction which may change the quality of study instruments used to gather field data. At this point, the following questions are raised:

- i) Why a researcher report on something else other than what ought to have been studied?
- ii) How can a researcher build on well-defined concept(s) used in the study?

The answer to these questions relate to inappropriate conceptualisation of the variables under investigation and poor operational definition of variables used for measurement. This paper attempts to explain how wrong application of concepts can mislead the researcher when conducting research, and the resultant effects on each stage of the environmental research process. The paper is structured into;



definition of variable conceptualisation, types of variables, how to conceptualise variables in environmental research, measurement of variables in quantitative research, and conclusion. The motive behind this paper is to demystify the challenges encountered by unskilful researchers and students when trying to make their readers have a clear understanding of their research reports (dissertations or theses). This will avoid rejection of dissertations or theses for reporting on something else other than what student sought to have studied.

1.1 Definition of Variable Conceptualisation

The definition of variable conceptualisation starts with the clear understanding of what conceptualisation entails in an environmental research.

1.1.1 What is Conceptualisation?

Conceptualisation is a mental process of breaking up and converting research ideas (concepts) into common meanings to develop an understanding among the users. This process eventually leads to framing meaningful concepts that ultimately ends with the creation of a theory. It is the process of development and clarification of concepts that is clarifying one's concepts with words, examples and arriving at precise verbal definitions. A concept can be defined as an abstract or general idea inferred or derived from specific instances. It is accepted as a collection of meanings or characteristics linked with established situations, events, objects, and behaviours. Examples are land use change, environmental degradation, industrial systems, travel, and decision-making.

1.2 What is a variable?

A variable is a characteristic or quantity of a phenomenon that is being researched. In statistical terms, a variable is considered as a quantity that can take on different possible values (Onen, 2016). Variables are essential parts of quantitative research because they can measure concepts and are used to examine the relationship between variables in a study. Variables measure characteristics like income level, height, weight, distance, and hair colour, and can measure abstract concepts such as wellbeing, anxiety, intelligence, self-esteem, sense of religiosity and security level. The variables are considered to be simple like income and age, or complex such as socio-economic status and academic achievement. Sometimes in using complex variables, one dimension of an abstract variable may be studied. For instance, income may be studied as part of socio-economic status.

The variables are derived from the research topic. However, it is difficult for two or more similar studies to handle variables of a similar topic in the same way. For example, consider a research topic titled “Urban areas are more developed than rural areas in Akwa Ibom State, Nigeria” relating to urban – rural dichotomy that is handled by two different researchers will not have different variables for same topic (Essien & Cyrus, 2019; Ibok & Daniel, 2013).

However, some essential variables like means of transportation may be found in both studies but some variables may not be identical depending on the conceptualisation of the variables like political will, provision of facilities/ services and migration. Similarly, if the study is looking at “Oil pollution in the Niger Delta region, Nigeria; non-oil producing regions in Nigeria will not be a variable, but Niger Delta region will be selected as a variable in this case (Ugboma, 2015).

1.3 Identification of Variables

In research, a variable is an unknown value, liable to or capable of change and marked by diversity or difference. A variable in environmental research simply refers to a person, place, thing, situation, or phenomenon that the researcher is trying to measure. Variables provide focus to the study, implying that they form the basic framework of your study. When there is a mistake in selection of variables in a study, the researcher is bound to follow the wrong direction and ends with wrong results. It is also necessary to focus on method and tools for measuring variables because inappropriate methods and tools can mislead

the researcher. The environmental researcher must understand and name variables according to their groups or types.

The variables are grouped into quantitative and qualitative categories. Quantitative variable is a broad category that includes any variable that can be counted, or has a numerical value associated with it, like discrete and ratio variables. Qualitative variable is a broad category for any variable that cannot be counted or has no numerical value attached to it, like nominal and ordinal variables.

During review of related literature, the researcher takes time to think about variables, how they relate to his intended study, and examine different methods and statistical tools used in the studies. The researcher then relates the variables used in the studies to his work with a view of assessing how their choice will affect the findings in his results. It is advisable to select the best variables that fit into the topic of study, conceptualised the variables by narrowing them to be more specific.

The peer-reviewed journals are good sources of your variables. The journals contain keywords that may be valuable for the choice of your variables or serve as a roadmap to your destination in variable selection (Kelly *et al.*, 2014). The researcher can use multiple measures of concept to check the effectiveness of the results. For example, instead of using household income level alone to operationalise the concept of social-economic status, the researcher can use educational level or ownership of different assets in a single study to see how these multiple measures influence his findings.

1.4 Types of Variables

The variables necessary for the study are to be introduced in background to the study. Essential variables are also found in the statement of the problem, research questions, and hypotheses. It is mandatory to identify each variable; label and define them. In environmental research, two types of variables are commonly identified as independent and dependent (Cramer & Howitt, 2004). Confounding (Control), moderating and mediating variables are also identified as important variable in environmental research.

The list of variables provided below cannot be said to be comprehensively and completely used in one research but can be handled depending on research interest like environmental, social, computing, medical and engineering. Many types of variables identified above are explained as follows:

- i) **Independent variables:** An independent variable is stable and unaffected by the other variables to be measured. It refers to the condition of testing an idea that is systematically manipulated by the researcher. It is the presumed cause (Cramer & Howitt, 2004). Independent variables cause, influence, or affect the outcome on the dependent variable. They are the treatment, what is manipulated in a study, or the intervention that the researcher chooses to study. In quantitative analytical method (survey/ experimental research design), the independent variable is called the predictor variable when performing regression analysis and usually plotted on x-axis (Palmer & O'Connell, 2009).
- ii) **Dependent Variables:** These are the variables that depend on other factors that are to be measured in survey/ experimental research design. These variables are expected to change as a result of manipulating the independent variable(s) in the research. It is the presumed effect (Cramer & Howitt, 2004).
- iii) **Confounding (Control) Variables:** A confounding variable is an outside influence that changes the effect of a dependent and independent variable commonly used in experimental research design. According to Kahlert *et al.* (2017) confounding is the concept of comparability in observational studies, which hampers causal inference. It arises when a factor is associated with both the exposure (and treatment) and the outcome, such as a disease or death, and is not part of the causal pathway from exposure to outcome.
- iv) **Moderator Variables:** A moderator variable is that which affects the strength of the relationship between a dependent and independent variable in a model. It can change the strength or direction of the relationship between an independent and dependent variables. For example, in travel behaviour

modelling; it helps to explain when behaviour occurs. In correlation analysis, a moderator is a third variable that affects the correlation of two variables.

- v) **Mediator variables:** A mediator variable is the middle variable or middleman that stands between independent and dependent variables. They are those variables that provide a causal link in the sequence between the independent and dependent variables. For instance, when investigating crime rate in cities, it helps in justifying why deviant behaviour occurs. The mediator variable plays the role of explaining the relationship between independent and dependent variables. An independent variable does not directly influence dependent variable; rather independent variable is indirectly influencing dependent variable through mediator variable. This can be represented as: Independent variable → Mediator variable → Dependent variable. For example, mediator variable can be used when assessing the relationship between urban residents' income and medical check-up expenses of urban residents in third world countries. Income level (independent variable) positively influences education level (mediator variable) then education level positively influences medical check-up expenses (dependent variable) of urban residents in third world countries. When the effect of education level is removed, the relationship between income and medical check-up expenses disappears. MacKinnon (2015) noted that a mediating variable explains and identifies the causal process underlying the relationship between two variables.

It is important to note the differences in types of variables when framing a study. Using relevant variables is a common approach to organising the elements of an environmental research study with a view to discover relevant and meaningful results. Two basic reasons behind the idea are that the researcher must:

- a) understand and be able to evaluate their application in other people's research and
- b) apply them correctly in his/her own research.

To understand the difference between dependent and independent variables is that the meaning of each is implied by what the words tell us about the variable the researcher is using. The independent variable causes a change in dependent variable, and it is not possible that dependent variable could cause a change in independent variable.

Other variables used in environmental research include the following:

- a) **Categorical variables:** These are variables that can be put into categories. For instance, the category toothpaste brands might contain the variables like Close-up, Holdent, Aquafresh and Colgate.
- b) **Continuous variables:** These are variables with infinite number of values, like height, time, or weight.
- c) **Discrete variables:** these are variables that can only take on a certain number of values. An illustration is the number of cars in a parking lot. This could be discrete because a car park can only hold so many cars. The number 5.5 persons cannot be expressed as a discrete variable.
- d) **Nominal variable** is another name for categorical variable.
- e) **Ordinal variable** is similar to a categorical variable, but it has a clear order. For example, when every data point can be put in directional order (low, middle, and high) or every data point can be arranged in positional order (1st, 2nd, 3rd), could be considered ordinal.
- f) **Interval variable** is a measurement where the difference between two values is meaningful. The difference between a temperature of 100 degrees Celsius and 90 degrees Celsius is the same difference as between 90 degrees Celsius and 80 degrees Celsius.
- g) **Ratio variables** are similar to interval variables; they have a meaningful zero making the operations of multiplication and division meaningful.
- h) **Random variables** are associated with randomisation processes and give numbers to outcomes of random events.

2 Importance of Variable Conceptualisation

In quantitative research, conceptualisation helps to translate portions of an abstract theory into testable hypotheses involving specific variables. In quantitative and qualitative research, variable conceptualisation is an important part of the research process that creates conscious awareness of related observations. It expresses the meaning of a word or expression; the way in which a word is expressed or situated can be interpreted.

In practice, researchers use thousands of concepts to describe various objects, phenomena or situations, and their meanings often vary depending on the context in which such concepts are used. Therefore, every researcher should specify the meanings of particular concepts (or terms) as used in the study in order to avoid readers misinterpreting or failing to understand their reports (Tromovitch, 2015).

3 Conceptualisation of Variables in Environmental Research

To conceptualise variables in environmental research requires the researcher to have adequate knowledge of conceptualisation and operationalisation of terms or variables.

3.1 Secrecy of Conceptualisation

Conceptualization is the mental process by which unfocused images called concepts and their fundamental parts are defined in specific terms (Götzsche, 2022). When you have an idea for something, or if you understand something fully, you conceptualise it. During variable conceptualisation, the concept (idea) is considered to be fully understood by the researcher. The phenomenon may be simple idea, like a man walking on a street, running to catch a bus, jogging for fun, driving a car, or paddling on water. During conceptualisation, concepts may be considered simple or complex. Conceptualisation of a simple thought deals with one component while a complex thought involves many elements that require much brain work. According to Jain *et al.* (2013), conceptualisation involves bringing together several considerations and at the same time, to identify a good research idea (Cash *et al.*, 2022). The researcher frames answerable research questions that are worth answering.

The instruments of variable conceptualisation process are identified in the course of review of related literature. Conducting a thorough search for variables in the peer-reviewed journals, considering methodology and research design handled by authors under different conditions helps a researcher to conceptualise variables for study.

3.2 Process of Variable Conceptualisation

The process of variable conceptualisation takes place in varied forms depending on situations or events (Onen, 2016). In environmental research, the process may be based on a single-entity approach, or a game theory approach. In the single-entity approach, the researcher looks at the issues to be investigated in an organisation without considering the influence or current existence of other organisations. In the game theory approach of conceptualisation, the researcher investigates the presence of other firms that influence the behaviour of the firm to be investigated. It is a more realistic approach to conceptualising issues in research than its counterpart, the single entity approach (Onen, 2016).

The social/environmental researchers are concerned with investigating the relationship between entities (people interactions and the society/ environment) in which they live in. It is not possible to conduct a broad investigation on human interactions and society or environment in single research. Therefore, researchers concentrate on specific aspects of some social and environmental issues. The urban transportation planners and sociologists used spatial interaction concept to explain why some public service or locations attract more customers or users than other locations. It can also be used to explain the way in which shopping centres impact on areas within which they are located in terms of traffic and customer flows (Hawkins-Mofokeng *et al.*, 2022; Haynes & Fotheringham, 1985).

The process of variable conceptualisation occurs in five stages, namely:

- i. Forming concepts;
- ii. Definition;
- iii. Indicator selection;
- iv. Operationalisation; and
- v. Observation (or measurements).

The process of variable conceptualisation is illustrated in Figure 1 for clarity.

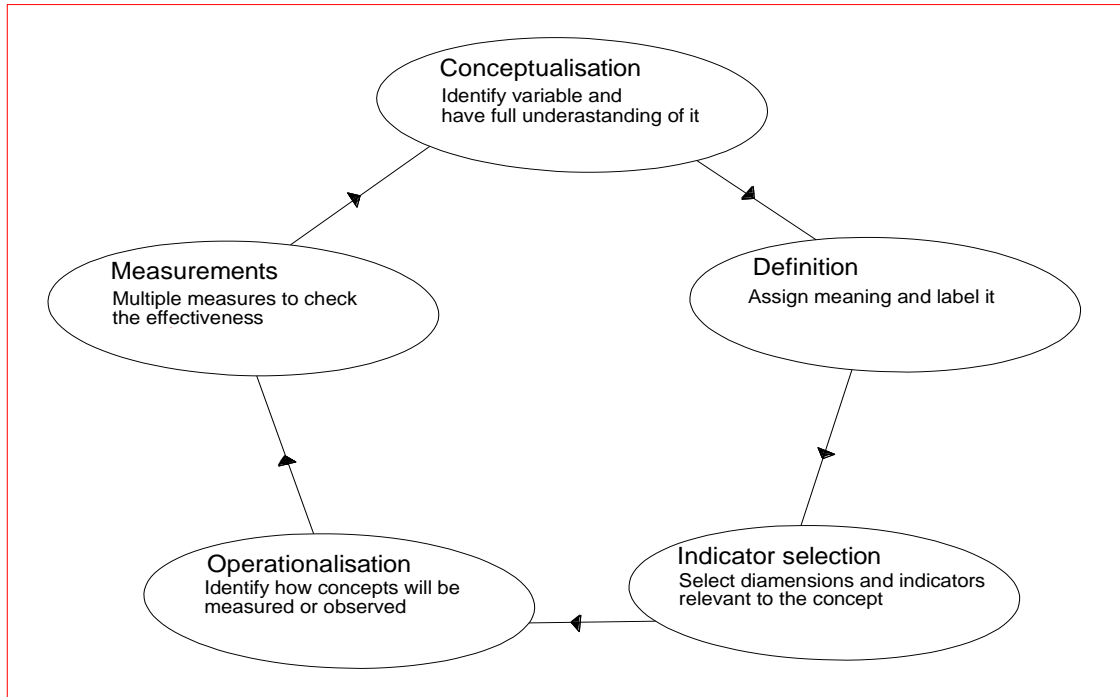


Figure 1: *Explicative Variable Conceptualisation (Onen, 2016).*

Figure 1 illustrates the explicative cyclical pattern of variable conceptualisation, which starts with forming a word to describe someone's idea in the mind. The next stage is followed by defining the concept formed. After the definition stage, the researcher selects the dimensions and indicators that the concept entails. The researcher will give the operational definition of the concept and, identify how such concept will be measured or observed.

According to Onen (2016), this whole process is termed explication; that is, the process of moving from definition to measurement and back to the definition. He further explained that, when conceptualising, the researcher does not always start with a clear, observable, complete and useful conceptual definition, and then attempt to observe (measure) that variable. The researcher undergoes the process of explication to arrive at the final conceptualisation and measurement results that come from interplay between these two activities.

3.3 Operationalisation

Once a theoretical thinking is defined, then how do we measure it? Operationalisation of concepts refers to the process of framing indicators by which objects of the study are defined (Carrasco-Campos & Saperas, 2015). For instance, an unobservable idea like socio economic status can also be defined in terms of household earning.

It can be operationalised using an indicator that asks respondents the question: what is your annual family income? Given the high degree of subjectivity and imprecision inherent in social science, concepts like gender, age, education, and income are measured using many indicators. The simple or complex concept requires operational definition on the how indicators will be measured, for example, "Artificial

Intelligence” or “study effort”. The variable “Artificial Intelligence” may be defined as the simulation of human intelligence processes by machines, especially computer systems that include learning (the acquisition of information and rules for using the information), reasoning (using rules to reach approximate or definite conclusions) and self-correction (Götzsche, 2022). Whereas “study effort” may be defined conceptually as the amount of effort required to master a consistence of material, including reading, looking up definitions, note-taking, practicing, self-quizzing and each component must be operationalised in order to be measured. The variable “study effort” may consist of reading, looking up definitions, note-taking, practicing, and self-quizzing. Operational definitions as follows:

- i) Reading: how many hours per day do you read course related material?
- ii) Looking up definitions; on average, how many words per textbook page do you look up?
- iii) Note-taking; how many pages of notes do you take per textbook page? Do you merge your new notes to the original notes?
- iv) Practicing: how many hours per day do you practice on new terms and formulae?

The operational definitions should be consistent with constructs. Constant reviews of poorly constructed operational definitions can be improved upon. This process allows the researcher to examine the closeness amongst these indicators as an assessment of their accuracy (reliability).

4 Measurement of Variables in Environmental Research

Measurement (or observation) of variables is the process of determining and recording which of the possible characters of variables; an individual case exhibits or possesses. A scale of measurement specifies a range of scores (also called points on the scale) that can be assigned to cases during the process of measurement. The measurement of variables in environmental research is performed using rules of measurement. The rule of measurement is that a scale must allow an assignment of each case into one, and only one, of the points on the scale. This statement implies two separate principles of measurement (exclusiveness and exhaustiveness). The first is the principle of exclusiveness, which states that no case should have more than one value for the same variable. For instance, someone cannot be both 18 years old and 64 years of age at the same time. While the second is that measurement must also follow the principle of exhaustiveness, which states that every case can be classified into a category or group. A scale for wealthy status that restrict to ‘rich’ and ‘very rich’ as the only points on the scale is not sufficient enough. The reason is that anyone who is less than wealthy cannot be measured on this scale. The measurement of variables in environmental research begins with the levels or scales of measurement.

4.1 Level of Measurements

Measurement refers to the process of assigning numbers or labels to the concepts or variables (or the characteristics of the unit of analysis) under investigation (Bhandari, 2022). Measurements are performed on daily basis by different professionals in many fields of endeavour. Social scientists use the questionnaire, medical doctors use stethoscopes and thermometers, engineers use steel band and geographer use the Global Positioning System (GPS) to obtain measurements. In environmental research, variables are measured using many instruments like questionnaire as stated above. There are four different ways of assigning numbers to variables. Or variables under investigation may be measured in four different scales: (1) Nominal scale, (2) Ordinal scale, (3) Interval scale, and (4) Ratio scale (Bhandari, 2022).

- i) **Nominal or classificatory scale:** This is the simplest form of measurement. Nominal scales are the weakest form of measurement because they assume equality among members of a particular category. The numerical values are assigned to act as names of people. Examples of this form of measurement scale include footballers’ jersey numbers, room numbers, car numbers and telephone numbers. The objects are mutually exclusive in that there is no relationship between them, and the numerical value assigned to each category is arbitrary. For instance, if the first player wears jersey number 76, it does not mean he plays better than the second player wearing jersey number 10. The numbers do not have a natural origin in zero (0), neither do they

- specify magnitude. For this reason, they cannot be added, subtracted nor multiplied. This implied that the numbers are not amendable to standard mathematical operations but can be transformed into frequencies if the need arises for further analysis. Nominal scale possesses the properties of symmetry and transitivity. By symmetry, if $A = B$, then $B = A$, implying any relation that holds between A and B also holds between B and A. By transitivity, if $A = B$ and $B = C$, then $A = C$.
- ii) **Ordinal or Ranking Scale:** This level of measurement involves ranking of objects from the highest to the lowest in their order of importance. Globally, countries can be ranked based on income: high income nations, middle income nations and low-income nations. Ordinal scale of measurement does not supply information on the magnitude of the difference between the elements ranked. Ordinal level of measurement uses codes to organise observations into categories that are not only mutually exclusive and exhaustive. The numbers assigned to the attributes do carry values attached to them. These numbers are used for classification as well as for ranking (Bhandari, 2022). For example, data are asymmetrical hence $A = B$ does not hold for B and A, that is, $A > B$, then, $B < A$. However, the ordinal scale retains the properties of transitivity; $A > B$ and $B > C$, then $A > C$. In the same way observations may be grouped into categories like slow and fast, soft, and hard; and short and tall. Data collection instrument use Likert type items like asking workers about their job satisfaction with responses as very satisfied, satisfied, neutral, dissatisfied, or very dissatisfied is using an ordinal scale of measurement.
- iii) **Interval Scale:** The numbers at interval level represent measurement units but have no absolute or fixed zero point. This level of measurement allows for specifications on how far the intervals are from each other, thereby conveying some idea of magnitude. Interval scale can be added, subtracted, and multiplied, and has an arbitrary origin as in the case of temperature. In the interval level of measurement, the unit of measurement established between the categories is common or constant. A temperature of a body at 52 °C is nine degrees cooler than a temperature of another body at 62 °C; likewise, a temperature of an object at 25 °F is one degree warmer than a temperature of object at 24 °F. The measured temperature has an origin in zero whether using Celsius or Fahrenheit (-5 °C, -18 °F), and may be an interval between 10 °C – 50 °C or 20 °F – 30 °F. The interval scale essentially attempts to mimic ratio scale when the use of ratio scales is problematic (Housel & Shives, 2022) .
- iv) **Ratio Scale:** This is the highest level of measurement. It represents fixed measuring units with an absolute zero point, implying no amount whatever the variable is indicating. In other words, every item on the scale has a natural origin in zero, in addition to possession of absolute magnitude. It becomes real to know the interval involved and the actual values on the scale. This enables the researcher to create meaningful ratio, like 80 is four times as much as 20, the distance between A and B is twice the distance between C and D. Therefore, a ratio scale is the highest level of measurement. This level of measurement includes all the features of the other levels, like classification, rank ordering, equal interval and absolute zero point (Bhandari, 2022).

The understanding the level of variable measurements used in research is important since the level of measurement determines the types of statistical analyses that can be conducted. The conclusions that can be drawn from research depend on the statistical analysis used which has to do with the level of variable measurements.

4.2 Quality of Measurements

In the scientific backgrounds, measurement is considered a privileged source of high-quality information, and is commonly associated with precision and accuracy (Maul *et al.*, 2018). Precision is the extent to which detailed measurement in numbers remains meaningful like number of cars and persons. Accuracy is the degree to which the measuring instrument measures what it is intended to measure commonly gauged by reliability and validity.

The accurate key indicators of the quality of a measuring instrument are the reliability and validity of the measures. The process of developing and validating an instrument is focused on reducing error in the measurement process. Validity is the extent to which the interpretations of the results of a test are warranted, which depends on the particular use the test is intended to serve (Kimberlin & Winterstein, 2008).

The reliability test of instrument in each questionnaire needs to be conducted to test the stability, consistency and consistent level of items with each other (Hamzah *et al.*, 2022). The respondents need to understand the questions and response options, and consistently answer to the same stimulus or concepts. Three popular measures of reliability are test-retest (measuring two different points in time), alternate forms (assessing different versions), and internal consistency reliability (a form of correlation between items). According to Hamzah *et al.* (2022), the instrument must have a high degree of reliability, with the use of exact measurement tool. The instrument has no reliability if the researcher obtains a different score when the test had been done at different times while the conditions or requirements are the same from the standpoint of conventional test theory, an individual's observed test score is the sum of two components, the first being the true score representing the expected value of test scores over some set of test replications. The second component is the residual difference, or random error, associated with test for measurement error (Boyd *et al.*, 2008). It is a known fact that measurement error in observed data can lead researchers to draw incorrect inferences (O'Neill & Sweetman, 2013). The researcher is expected to select the correct variables since they form the bedrock of viable research results.

5 Conclusion

In conclusion, a trustworthy research should develop methods of addressing a phenomenon but not just to gather information on a given phenomenon. A worthy research study will have well defined aim and objectives that guide the researcher throughout the research process. A good research should also reveal validity and reliability, and its results should be replicable in other studies. These can be realised if the researcher forms appropriate variables or concepts to capture the study problem and identifies the dimensions and indicators of those concepts that are under investigation. Finally, he develops the objectives, conceptual framework, research instruments and all the other parts of the study in line with the concepts selected.

6 Declarations

6.1 Competing Interests

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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