DESIGN, DEVELOPMENT AND VALIDATION OF A READINESS TEST FOR STATISTICS AND PROBABILITY

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DOI: https://doi.org/10.54476/ioer-imrj/438893

ABSTRACT

The modern world is defined by vast amounts of data that can be accessed instantaneously because of scientific and technological developments. People must make sense of these data in order to make informed decisions. Statistics and Probability is one of the learning areas in the country's Senior High School (SHS) curriculum that immerses students in problem solving and informed decision-making activities based on various data tools and methodologies. Both national and international examinations disclose that Filipino pupils did poorly in comparison to other students from other countries. Such issue existed prior to the COVID-19 pandemic. The pandemic exacerbated the situation by causing significant learning loss as a result of school closures and the abrupt transition from traditional face-to-face classes to online, modular, and hybrid learning modes. This research designed, developed, and validated a Statistics and Probability readiness test for Senior High School students to use as a tool for teachers to assess students' prior understanding of pre-requisite concepts and skills. The test undergone identification of pre-requisite concepts and skills, test development, first pilot testing, and finalization of test items. In identifying the pre-requisite concepts and skills, one of the authors mapped out the contents and skills from the Junior High School Mathematics curriculum that are needed in understanding the contents in the subject. Through a questionnaire, fifteen validators were asked to determine which among these identified pre-requisite skills are needed. Only the pre-requisites with at least 80% agreement formed part of the design and test development. Summary of the validators' responses showed that the pre-requisite contents and skills varies from each SHS Statistics and Probability content. An initial 80-item test was developed and subjected to validity and reliability tests. Through the discriminatory and difficulty indices, this test was reduced to a 45-item test. The final form of the test can be used to measure students' proficiency level in the stated pre-requisite skills. It is composed of multiple-choice items distributed along different cognitive process dimensions such as remembering (11.11%), understanding (28.89%), applying (37.78%), and analyzing (22.22%). Result of the test can be used as basis for remediation activities and or in developing learning materials to address these learning gaps.

Keywords: readiness; assessment; diagnostic test, pre-requisite skills for statistics and probability

INTRODUCTION

The world has rapidly evolved that the access to information becomes available in an instant with the aid of the latest advancements in science and technology. People nowadays have to deal with massive volume of data that they need to equip themselves with the knowledge and skills needed in order to properly manage and analyze

these data to extract meaningful information. When people are able to make sense of these data, they can be able to arrive at informed decisions which can be of help towards the attainment of Sustainable Development Goals (SDGs) and Ambisyon Natin 2040.

The education system is critical in ensuring that all citizens in the country are functionally literate, globally competitive, and equipped for life. In the Philippines, the Department of Education has established a two-year specialized upper secondary education where students can select from numerous specializations under four tracks: Technical-Vocational-Livelihood (TVL); Academic; Sports; and Arts and Design. The Senior High School (SHS) curriculum aims to produce graduates who are holistically developed, endowed with the requisite 21st century skills, and prepared for whatever path he chooses after graduating from senior high school. These exits can include Middle Level skill development, higher education, employment, and/or entrepreneurship.

Statistics and Probability is one of the Senior High School essential subjects that can enable learners strengthen their skills in data management and decision making. It is one of the seven core curriculum subjects that all senior high school students must take regardless of the track and strand they enrolled in. The subject's varied contents are as follows: (1) random variables and probability distributions; (2) normal distributions; (3) sampling and sampling distributions; (4) parameter estimation; (5) hypothesis tests; and (6) correlation and regression analyses as enrichment content (DepEd, 2013). Once completed, the learners are expected to utilize all of the fundamental information and skills in solving a specific real-life problem and in generating real-life challenges across disciplines.

In the pursuit of mastery of all required learning competencies in the learning area, both students and teachers are confronted with situations that may impede this aim. Even before the COVID-19 pandemic, one of the numerous issues confronting the education sector is the poor performance of Filipino students in Mathematics, as demonstrated in both national and international examinations. Elementary and high school learners in the Philippines performed poorly in numerous mathematics examinations, including the 2019 Southeast Asia Primary Learning Metrics (SEA-PLM), Trends in International Mathematics and Science Study (TIMSS), and Programme for International Student Assessment (PISA) (Generalao, et al., 2022). Such problem was worsened when the COVID-19 virus has become a pandemic which resulted to worldwide premature school closures in the early months of 2019 and an abrupt shift to other learning modalities in 2020 which includes modular, online learning and blended learning. Over-all assessment of educators and policy makers supports the notion that the pandemic have worsened the problem due to massive learning loss.

Edward Lee Thorndike's Law of Readiness suggests that in order for the learner to succeed in learning, he must be ready and in good condition. He asserts further that the quality of learner's response is based on his state of readiness (Thorndike, 1932). In the same manner, Dangol & Shrestha (2019) claims that in order for the learners to achieve effective learning process, learning readiness is a vital component. Learner's prior knowledge is an important aspect of learning since they make use of what they already know and connect it with the new materials that they are supposed to learn. The strength and accuracy of prior knowledge, as well as the time with which it is engaged, can either help or hinder learning new content (Ambrose et al., 2010). When prior knowledge for a specific learning task is insufficient, learners may struggle to learn the new content. As a consequence, in order to enable meaningful learning, teachers must have a greater understanding of the degree of their students' prior knowledge.

A diagnostic test of pre-requisite skills is one method by which a teacher can diagnose his students' readiness. Teachers can use diagnostic tests to identify learners' prior knowledge and skills across multiple domains (California Department of Education, 2022). Teachers can utilize the results of this assessment to create learning tasks that will assist students develop on their strengths. In addition, poor learner performance on this type of test can serve as a foundation for the teacher to

develop and implement remediation activities to address the learning issue.

This research was carried out in order to create a statistics and probability readiness test for incoming senior high school students by mapping pre-requisite concepts and skills from the junior high school mathematics curriculum. Devising a diagnostic test can be used by teachers to determine the level of readiness of their learners. Results can be used as basis for remediation and or enrichment activities.

OBJECTIVES OF THE STUDY

Primarily, this study aimed to design, develop and validate a readiness test for Statistics and Probability intended for incoming senior high school students based on the identified pre-requisite contents and skills from the set of Junior High School Mathematics topics identified by key educators teaching. Specifically, the study determined the: (1) set of pre-requisite concepts and skills of each content in Statistics and Probability for SHS; (2) the test items to be developed; and (3) the reliability and validity evidences of the readiness assessment.

METHODOLOGY

The study utilized descriptive-developmental research design. It undergone four phases such as: *Identification of Pre-requisite concepts and skills* (Phase 1); Test Development (Phase 2); *First Pilot Testing* (Phase 3); and *Finalization of Test Items* (Phase 4). In Phase 1, the first author identified the pre-requisite contents and skills from the junior high school mathematics curriculum guide and designed a survey questionnaire. This questionnaire was then distributed to fifteen purposefully selected validators who are teachers in basic education and higher education institutions who have taught Statistics and Probability for three or more years, are pursuing master's and doctorate degrees in the field of mathematics education, and are master's and doctorate degree holders in the aforementioned field. Only those pre-requisite concepts and skills with at least 80% agreement was included in the test design and development. In Phase 2, the first author developed an 80-item test based on the identified pre-requisite contents and skills. For each competency, there were at least two items to make room for items which will be discarded, revised or retained. The face and content validity were determined through a focus group discussion with three other experts. In Phase 3, the initial pilot test was administered in two public secondary schools in the first congressional district (Pilar and Castilla) in the Schools Division of Sorsogon Province. All of the Grade 11 students enrolled in these identified schools during the first semester took the test. However, only 60 randomly selected answer sheets were used for determining the discriminatory, difficulty and reliability indices. Discriminating, difficulty and reliability indices were determined and were used as basis for decisions on test items whether to discard, revise or retain. The internal consistency of the developed test was determined using a statistic, Cronbach's α. In Phase 4, the number of test items were trimmed down into 45 test items. These were items which were revised and retained based on the result of the discrimination and difficulty indices.

RESULTS AND DISCUSSION

1. Pre-Requisite concepts and skills

Table 1 shows the list of identified pre-requisite contents and skills for each content of the Senior High School core subject, Statistics and Probability. These pre-requisite concepts and skills were determined based on the responses of the 15 validators. Only those concepts and skills listed in the researcher-developed survey questionnaire who garnered at least 80% agreement were included in the final list of pre-requisites. It can be gleaned that the pre-requisite contents and skills deemed necessary for the learners in studying the subject are varied and are from different Grade levels in the Junior High School – from Grades 7 to Grade 10. These pre-requisites are distributed across Numbers and Number Sense; Patterns and Algebra; and Statistics and Probability contents.

Table 1
Mapping of Pre-requisite contents and skills for SHS Statistics and Probability subject

Statistics and Probability Contents	Pre-requisite concepts and skills		
	Numbers and Number Sense	**Patterns and Algebra**	**Statistics and Probability**
Random Variables and Probability Distributions	*A. Rational Numbers* 1. Performing operations on rational numbers		*A. Counting Techniques* 1. illustrating an experiment, outcome, sample space and event. 2. counting the number of occurrences of an outcome in an experiment using a table; tree diagram; systematic listing; and/or fundamental counting principle *B. Foundations of Probability* 1. illustrating an experimental and theoretical probability. 2. illustrating mutually exclusive events. 3. finding the P(E) where E is a simple event 4. finding the probability of a union of events. 5. solving word problems involving probability. *C. Basic Concepts in Statistics* 1. using appropriate graphs to represent organized data such as pie chart, bar graph, line graph, histogram, and ogive. 2. organizing data in a frequency distribution table. 3. drawing conclusions from graphic and tabular data 4. evaluating a sum using sigma notation 5. calculating the measures of central tendency of ungrouped and grouped data. 6. illustrating the measures of central tendency (mean, median, and mode) of a statistical data. 7. illustrating and calculating the measures of dispersion (range, average deviation, variance, standard deviation) of grouped and ungrouped data. 8. drawing conclusions from measures of central tendency and dispersion.

Normal Distribution	*A. Rational Numbers* 1. expressing rational numbers from fraction form to decimal form and vice versa. 2. Performing operations on rational numbers	*A. Algebraic Expressions* 1. translating English phrases to mathematical phrases and vice versa. 2. Performing operations on rational algebraic expressions	*A. Basic Concepts in Statistics* 1. evaluating a sum using sigma notation 2. calculating the measures of central tendency of ungrouped and grouped data. 3. illustrating the measures of central tendency (mean, median, and mode) of a statistical data 4. calculating the measures of dispersion of grouped and ungrouped data. 5. illustrates the measures of dispersion (range, average deviation, variance, standard deviation) of a statistical data. 6. interprets measures of position.
Sampling and Sampling Distributions			*A. Foundations of Probability* 1. finding the P(E) where E is a simple event B. *Basic Concepts in Statistics* 1. calculating the measures of central tendency of ungrouped and grouped data. *2.* illustrating the measures of dispersion (range, average deviation, variance, standard deviation) of a statistical data.
Estimation of Parameters	*A. Real Numbers* 1. estimating the square root of a whole number, rational number and irrational number to the nearest hundredth. 2. expressing rational numbers from fraction form to decimal form and vice versa. 3. Performing operations on rational numbers		*A. Foundations of Probability* 1. solving problems involving probability. 2. finding the P(E) where E is a simple event. *B. Basic Concepts in Statistics* 1. illustrating the measures of central tendency (mean, median, and mode) of a statistical data. 2. calculating the measures of central tendency of ungrouped and grouped data. *3.* illustrating the measures of dispersion (range, average deviation, variance, standard deviation) of a statistical data.

Test of Hypothesis	*A. Rational Numbers* 1. Performing operations on rational numbers	*A. Equations and Inequalities* 1. Differentiating between equations and inequalities. 2. Translating English sentences to mathematical sentences and vice versa.	*A. Basic Concepts in Statistics* 1. illustrating the measures of central tendency (mean, median, and mode) of a statistical data.
Correlation and regression analyses		*A. Graphs of Functions* 1. locating the points in the cartesian plane 2. illustrating and finding the y-intercept of linear equation 3. Sketching the graph of linear functions 4. finding the slope of a line given two points, equation and graph	*A. Basic Concepts in Statistics* 1. determines dependent and independent variables.

1. Test Item Development & Pilot Testing

Table 2
Cognitive Processes Required for the First Draft of the Readiness Test

Cognitive Process Dimension	Frequency	Percentage
Remembering	10	12.50%
Understanding	25	31.25%
Applying	28	35.00%
Analyzing	17	21.25%
Evaluating	0	0.00%
Creating	0	0.00%
Total	80	100.00%

The first author designed the 80 multiple choice test items such that the cognitive processes required for the test items are distributed across different dimensions of cognitive process such as remembering, understanding, applying, analyzing, evaluating and creating. These dimensions of cognitive process are derived from the revised Bloom's Taxonomy. In this taxonomy, items that are in the remembering level, understanding level, and applying level are classified as lower order thinking skills while those that fall in the analyzing level, evaluating level and creating level are classified as higher order thinking skills (Anderson et al., 2001). In the first draft of the readiness test, the items were distributed as follows: (10 items) 12.50% for remembering, (25 items) 31.25% for understanding, (28 items) 35% for applying and (17 items) 21.25% for analyzing. Meanwhile, no items were developed for evaluating and creating dimensions.

Two schools from the first congressional district under the Division of Sorsogon Province were chosen for pilot testing of the 80-item test. During the conduct of the pilot test, all of the Grade 11 students enrolled in the first semester were asked to complete the test however, only 60 answer sheets were randomly selected to determine the discriminatory, difficulty and reliability indices of the test.

Difficulty index was determined using the formula,

$$Difficulty\ index = \frac{total\ number\ of\ students\ answering\ the\ item\ correctly}{Total\ Responses}$$

where total responses = (true responses + wrong responses + no responses) (Soraya et al., 2021). In computing the discriminating index, the total scores were calculated and arranged in descending order from highest to the lowest score. The papers were divided into two groups – upper group and lower group. The discriminating index was determined using the formula,

$$D = \frac{R_U}{T_U} - \frac{R_L}{T_L}$$

where D is the item discrimination index, R_u is the number of students in the upper group who got the item correctly, T_u is the number of the students in the upper group, R_L is the number of students in the lower group who got the item correctly and T_L is the number of students in the lower group (De Guzman & Adamos, 2015).

To ensure that the test is valid and reliable, face validity, content validity and reliability were sought. In determining the face validity and content validity of the test, a focus group discussion was organized. Four faculty members from the school of graduate studies in a state university scrutinized the test and the test items. Some of the test items were improved based on the suggestions. The reliability was determined through a pilot test of the 80-item test. The reliability index, using Cronbach's α was determined from the 60 randomly selected answer sheets and was found to be 0.645. As a general rule, a value of 0.60-0.70 is an acceptable level of reliability (Ursachi et al., 2015).

2. Finalization of Test Items

2.1 Percentage of Test Items Across Cognitive Process Dimension

Built on the discriminatory and difficulty indices, the researchers decided to reject 35 items, retain 38 items and revise 7 items.

Table 3
Cognitive Processes Required for the First Draft of the Readiness Test

Cognitive Process Dimension	Frequency	Percentage
Remembering	5	11.11%
Understanding	13	28.89%
Applying	17	37.78%
Analyzing	10	22.22%
Evaluating	0	0.00%
Creating	0	0.00%
Total	45	100.00%

Thus, from the 80 items, the total test items in the final test were reduced to 45 items. The researchers see to it that there is an item representative from each of the identified pre-requisite learning contents and skills. Table 3 shows the distribution of the test items based on the cognitive process dimensions. In the final test, there were 5 items (11.11%) in the remembering level, 13 items (28.89%) in the understanding level; 17 items (37.78%) in the applying level and 10 items (22.22%) in the analyzing level.

1.2. Sample Test Item

Table 4 exhibits a sample test item. The test item was designed to determine whether the student have a grasp of the pre-requisite concept and skill – calculating the measures of central tendency of ungrouped and grouped data. This concept and skill are pre-requisite for the contents, (1) Random variables and Probability Distributions Normal Distribution; (2) Sampling and Sampling Distributions; and (3) Estimation of Parameters.

Table 4
Sample Test Item

Statistics & Probability Content	Prerequisite concept and Skill	Cognitive Process	Sample Item
Random variables and Probability Distributions Normal Distribution Sampling and Sampling Distributions Estimation of Parameters	(Basic concept in Statistics) Calculating the measures of central tendency of ungrouped and grouped data.	Analyzing	Your scores in the first four Mathematics tests have an average of 77. The maximum score in every test is 100. What should you get in the fifth test to have an average of 80? A. 90 B. 91 C. 92 D. 93

CONCLUSIONS

The following conclusions were drawn from the study:

1. There are pre-requisite content and skill for each content in the subject, Statistics and Probability. Key teacher-validators identified 16 pre-requisite contents and skills for Random Variables and Probability Distributions, 10 pre-requisite contents and skills for Normal Distribution, 3 contents and skills for Sampling and Sampling Distribution, 8 pre-requisite contents and skills for Estimation of Parameters, 4 pre-requisite contents and skills for Test of Hypothesis and 4 pre-requisite contents and skills for Correlation and regression analyses. It can be noted that there are pre-requisites that are common to two or more contents.
2. The final form of the developed Statistics and Probability readiness test for incoming senior high school students is valid and reliable as reflected in the face and content validity and reliability index.
3. The test caters both low-order thinking skills which was distributed as follows: 11.11% remembering, 28.89% understanding and 37.78% applying; and higher order thinking skills which constitutes 22.22% of the items in Analyzing level.

RECOMMENDATIONS

In view of the findings and conclusions derived from the study, the following recommendations are proposed:

1. To increase the reliability index, the test can be conducted to a much larger sample size. Students from different tracks and strands must have representative respondents.
2. Since this readiness test have gone through a rigorous process and evidence of validity and reliability were already establish, it is therefore suggested that teachers teaching Statistics and Probability in Senior High School use this test to determine the least mastered pre-requisite contents and skills. Result of the test can also be useful in proposing intervention programs to address the least mastered pre-requisite contents and skills.
3. The researchers also recommend that similar efforts may be done by Statistics and Probability teachers to collaborate and develop more readiness tests utilizing other platforms.

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