

Cognitive Component Analysis of Basic Mathematics Achievement Assessment

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Abstract—To provide some useful information into teaching practice adjustment, teachers usually need some professional supports. In this study, an analysis framework on item cognitive component is proposed and implemented. The sample for this study consisted of the Nursing and Management College student from eight schools in Taiwan. A sample of 2051 students was drawn for this study. A 3 cognitive components coding schema was developed to predict the item difficulty parameters. The results suggest that the framework proposed can predict around 70.9% of the difficulty variance across seven contents.

Keywords—cognitive component; item difficulty; basic mathematics achievement assessment

I. INTRODUCTION

Chen [1] pointed out that the control item difficulty, there are also other reasons can help construct measurement. Some achievement test, the preparation of the larger topic of the difficulty range, used to measure the different ability levels of examinees, the test contains too many easy or too many difficult items of would result in skewed mark distributions. Traditionally, the validity of the tests verify that only focus on the content less focus on the construct validity [4]. To make the test tool more quality, the results of the assessment is more representative of the examinee's ability distribution, can provide the reference of the teachers in the teaching, the construct validity is an important issue. Furthermore, the tests of cognitive component analysis is one of the important basis for construct validity, and take into account the cognitive psychology and psychological measurement model [2, 5, 6, 7].

Many studies have shown that cognitive component analysis of item difficulty for test validity, design and education has important implications [3]. By cognitive component analysis can help distinguish the disadvantage of test and test constitutive comparisons between the different forms of items and different tests based on the systematic development of test quite helpful. As teacher knowing what cognitive component may cause changes in item difficulty for these cognitive components of student teaching, in turn, can improve the effectiveness of learning.

Basic mathematics is one of the important lessons of learning mathematic, basic mathematics is an important tool links to the most basic and useful in other applications courses. In general, students fear of math, even hate or rejection [8, 9]. Some studies have indicated that male students tended to score higher than female students in math. Many students choose studying nursing related management departments, their main reason is to avoid math, so nursing management department students generally do not like math.

Students graduated form college of nursing management schools in Taiwan, straight is of great importance to medical institutes and welcome talent. Students after graduation, whether to obtain licenses, to successfully enter the clinic, has been one of the important indicators of the school's effectiveness. With the evolution of the times, and nursing education to be more closely integrated with clinical. Therefore care professional certification exam about clinical was increasingly more and more and more hospitals in the recruitment of new nurses exam also increasingly attach importance to the intravenous infusion, safe dose associated with the care of patients very closely related to the calculation of the problem. Many nursing graduates often lack of mathematical ability or do not really understand the meaning, and can not get into the ideal ward or hospital. Math is an important basic discipline, its application is very broad and, therefore, how to improve nursing students in professional subjects related to math ability become an important issue of school teachers.

II. ORGANIZATION OF THE TEXT

Method

This study is to investigate the cognitive component model of the basic mathematics achievement assessment test. To analysis the cognitive component by multiple regression, and further discuss the results.

Participants

In this study, the sample from eight the Nursing and Management Colleges in Taiwan, a total of 2051 students completed the basic mathematics achievement assessment.

Measure

The mathematics achievement assessment, a multiple-choice assessment designed to compute college of nursing management schools students' mathematics ability was

administered. The author constructed a mathematics achievement assessment comprised of 25 multiple choice items with four answer choices. The items on the achievement test were categorized into seven content domains: polynomials, Cartesian coordinate system, linear equation, exponential and logarithmic, trigonometric functions, permutations and combinations, probability seven content areas.

Procedure

The students were given the assessment after receiving instruction for the assessment. The students completed the assessment for one hour under the lookout of their teachers. The purpose of the teacher-proctors monitoring of the test was to minimize measurement errors that could arise during the actual test.

Data Analysis

Two sections of analysis were done to establish psychometric properties. SPSS software was used to determine reliability of the test. Second, item response theory method was employed to calibrate for item and person difficulties. BILOG-MG software was used for this analysis.

III. Results and Discussion

This section is divided into three parts. First is the presentation of the psychometric properties of the mathematics achievement assessment. The validity and reliability analyses presented here were done following both Classical Test Theory (CTT) and Item Response Theory (IRT). The statistical package for Social Sciences (SPSS 18) was used to perform the analyses according to CTT. Second, the presentation of IRT analyses, were the software BILOG-MG was utilized to estimate students' abilities and item difficulty for the assessment as well as the goodness of fit of the items. The third and last part is the presentation of the multiple regression results

Reliability and Validity

The internal consistency of the test was found to be high with a Cronbach's (alpha) value of .78. This value indicates a good reliability for the achievement assessment.

To obtain higher validity researchers invited two math professor and a mathematical teacher for the subject content, difficulty detailed review and assessment items sampling appropriate.

Item Difficulty and Discrimination

Basic mathematics achievement assessment items IRT parameters were presented in Table 1, the mean of difficulty of the items was 1.061, and the standard deviation was 0.549. It could be implied from this result that the achievement assessment was difficult for students.

Table 1 Summary of items IRT parameters

IRT parameters	Discrimination(a)	Difficulty(b)	C
Mean	1.845	1.061	0.284
S.D.	1.096	0.594	0.101

Cognitive component encoding framework

Operational definitions and coding interpretation :

In this study, according to the logic of mathematical problem solving cognitive load analysis, adapt three cognitive components as the framework of the analysis, the components operability are defined as follows:

1. Computing loading: Define the computing loading were the number of computing required to successfully solve the problems.

2. The number of problem solving concepts: Problem solving formulation of mathematical concepts and calculation steps .

3. The phase of concept learning: Solve the problem on the use concept learning stage to define this ingredient encoding.

This research uses descriptive statistics to illustrate the framework contents of the basic mathematics achievement assessment items, and multiple regression analysis to explore the amount of computing loading, the number of problem solving concepts and the stage of concept learning to explain item difficulty.

Items cognitive component coding consistency

In order to avoiding personal bias cause in encoding status, it's necessary to participant a senior Mathematics full-time teachers with researcher to encode a consistency check, Table 2 presents the two coding results in the three cognitive component. The coding consistency correlation between .84 to .92 means there is small gap between the participant and researcher.

Table 2 The correlation of cognitive component coding consistency

Cognitive component	Computing loading	The number of problem solving concept	The stage of concept learning
Encoder	.84	.88	.92

Items cognitive components for difficulty prediction

This research proposes cognitive components including the computing loading, the number of problem solving concept, and the stage of concept learning. The Table 3 presented the correlation matrix between the item difficulty and cognitive component. The correlation between item difficulty and the number of problem solving concept is the highest .728. Those three cognitive component related with item difficulty reach to .01 level of significance.

Table 3 The correlation matrix between the item difficulty and cognitive component.

	Computing loading (X_1)	The number of problem solving concept (X_2)	The stage of concept learning (X_3)
Item difficulty	.517**	.728**	.624**
Computing loading		.382	.040
The number of problem solving concept			.433**

**p < .01

Cognitive components on the item difficulty multiple regression prediction results presented in Table 4, the three cognitive components forecast variables explain 74.5% (adjusted 70.9%). Table 5 basic mathematics achievement assessment item difficulty parameters multiple regression prediction equation coefficients summary table, items difficult regression prediction equation:

The number of problem solving concept is the most important cognitive component, standardized regression coefficients of the three components of order 0.343, 0.409, 0.433 standardized regression coefficients concept learning stage, showing the stage of concept learning difficulty upgrading impact because less learning specialist for more than the life of the students, relatively abstract, a new concept of item difficulty rendered difficult phenomenon. Therefore teachers should strengthen teach and application of the concept for new students learning the concept exercises.

Table 4 Model for cognitive component

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	Sig.
1	.863	.745	.709	.287954	.745	20.464	.000**

**p < .01

Table 5 Regression's Coefficients for Modeling of cognitive component

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
constant	-.962	.282		-3.406	.003**
Computing loading	.287	.101	.343	2.845	.010**
The number of problem solving concept	.431	.141	.409	3.064	.006**
The stage of concept learning	.357	.102	.433	3.499	.002**

**p < .01

IV. Conclusions and Recommendations

According to this research, researcher provide 3 cognitive components for Nursing and Management College students, which could also explained 74.5% of the item difficulty variance. The number of problem solving concept is the highest associated with item difficulty. The highest

standardized regression coefficient concept learning stage represents that the stage of conceptual learning of cognitive loading for Nursing and Management College students is an important factor affecting item's difficulty [10-12]. Overall, the proposed cognitive loading components can effectively explain the difficulty of the basic mathematics achievement assessment items, also supporting teachers to implement remedial teaching for learning backward students in coming future. Referring to the proposed 3 cognitive components mentioned as above, the teachers could pick 5 units cognitive loading to organize with mathematical problems for the active involvement and assistance.

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