Kasetsart Journal of Social Sciences 42 (2021) 787–794

Kasetsart Journal of Social Sciences

journal homepage: http://kjss.kasetsart.org

Development and testing of a metacognition scale using computer multimedia for nursing students: An application of multidimensional item response theory

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Article Info

Article history:
Received 10 November 2020
Revised 15 January 2021
Accepted 25 January 2021
Available online 3 December 2021

Keywords:
metacognition scale,
multidimensional item response theory,
nursing students

Abstract

The aims of this research were to develop and test a metacognition scale using computer multimedia for nursing students (MSCM-NS) by applying the Multidimensional Item Response Theory (MIRT). The research was carried out in 2 phases: Phase 1 Instrument Development and Phase 2 Quality Assessment. The participants consisted of 600 fourth-year nursing students in Year 2018 who were selected using multi-stage sampling. Multidimensional analysis and confirmatory factor analysis were performed to analyze the data. The results showed that (1) the MSCM-NS consisted of a 21-item objective test with 3 choices and a 3-item subjective test, and (2) the IOC was between 0.6–1; the OUTFIT MNSQ (unweighted mean square) value was between 0.52–1.36 and the INFIT MNSQ (weighted mean square) value was between 0.51–1.38; the marginal reliability for response pattern scores was .65, the multidimensional approach was a more fitting model than the composite approach (multidimensional approach: G^2 = 24,772.99, AIC = 24,820.99, and composite approach: G^2= 24,791.28, AIC = 24,835.28, x^2 = 18.29, df = 2, $p < .05$), and the consecutive approach (G^2 = 24,792.16, AIC = 24,838.16, x^2 = 19.17, df = 1, $p < .05$), which indicates that the metacognition scale for nursing students had the highest multidimensional construct validity. In addition, the results of confirmatory factor analysis show that the metacognition model was consistent of empirical data (x^2 = 7.724, df = 8, p = .461, GFI = .996, AGFI = .989, RMSEA = .000)

Introduction

Metacognition is an intellectual skill necessary for learning in the 21st century, which helps learners learn how to learn and think. Learners will be able to think and apply the thinking process to learning and obtaining knowledge resulting in work achievement and the ability to solve problems effectively (Junsaipan, Kajornsin, &

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https://doi.org/10.34044/j.kjss.2021.42.4.11
2542-3151/

Pongsophon, 2015). Metacognition, as defined by Flavell (1985), is cognition about cognition. Metacognition skills are believed to play an important role in many types of cognitive activity, including oral communication of information, oral persuasion, perception, attention, memory, problem solving, and social cognition, and various forms of self-instruction and self-control.

Nursing students are challenged to think and learn in ways that will prepare them for practical work in complex healthcare environments that cover all 4 healthcare services: health promotion, disease prevention, treatment and rehabilitation. If nurses have strong analytical thinking skills and can apply knowledge, principles, concepts and theories to practice, they will be able to solve problems systematically and meet the needs of patients (Winalaivanakoon, Suthirat, & Wannapornsiri, 2015). Therefore, metacognition is an important tool for developing nursing students' learning quality in various aspects leading to the ability to learn and develop the thinking process and academic achievement, as well as the ability to choose appropriate approaches to work for different environments.

According to local and foreign research on metacognition (Banphasan, Boonchai, & Jomhsongbhiphat, 2015; Dejamonchai & Darnsawasdi, 2017; Hoseinzadeh & Shoghi, 2013; Kisac & Budak, 2014; Li-Ling, 2010; Sangwong & Patarathitinant, 2012), most research has focused more on the process of metacognition development and learners' applications of metacognition than the development of metacognition scales. In fact, there is only one research study relating to the development of metacognition scales for nursing students. Li-Ling (2010) developed a paper-based metacognition scale for Taiwanese nursing students. Most of the previously developed metacognition scales are paper-based with multiple-choice questions. However, metacognition scales using computer multimedia for evaluating nursing students' metacognition have yet to be developed. The use of computer multimedia to aid in testing can increase test takers' attention and test-taking motivation and generate a clear understanding using test situations that resemble actual situations instead of wording interpretation. Therefore, the researcher was interested in developing a standard metacognition scale using computer multimedia for nursing students suitable for Thai society, and testing its effectiveness. Nursing instructors can use the developed metacognition scale for nursing students to evaluate nursing students' metacognition levels leading to appropriate teaching and learning management, which will be essential for nursing education in terms of theory and practice and help nursing students achieve their goals effectively.

Literature Review

Metacognitive Components

Many psychologists and educators (Anderson & et al, 2001; Flavell, 1985; Jacob & Paris, 1987; Pintrich, 2002) have explained metacognitive components in similar but slightly different ways. It can be summarized that metacognition consists of 2 components: metacognitive knowledge, defined as knowledge about cognitive processes that will help individuals achieve goals effectively, and metacognitive control, defined as approaches to regulation and monitoring of cognitive processes carried out by individuals to process tasks successfully.

In this study, the researcher synthesized metacognitive components of Flavell (1985), Jacob and Paris (1987), and Pintrich (2002) as they are consistent, include metacognitive components described by several educators, and have been used to develop metacognition scales by educators (Suebkeaw, 2008; Teeranurak, 2009). Moreover, the indicators of metacognitive control are consistent with the nursing process consisting of planning, monitoring, and evaluation. Therefore, they are suitable for assessing nursing students' metacognition. Metacognition can be divided into 2 components or dimensions: (1) metacognitive knowledge, consisting of (1.1) self-knowledge, (1.2) cognitive task knowledge and (1.3) strategy knowledge, and (2) metacognitive control, consisting of (2.1) planning, (2.2) monitoring, and (2.3) evaluation as shown in Figure 1.

There are many types of metacognition assessment instruments such as questionnaires (Li-Ling, 2010; Schraw & Dennison; 1994; Taasoobshirazi & Farley, 2013) and interviews (Semerari & et al., 2012). Those instruments are different in terms of targets, types, benefits and limitations. Effective assessment instruments must have design properties, psychometric properties,

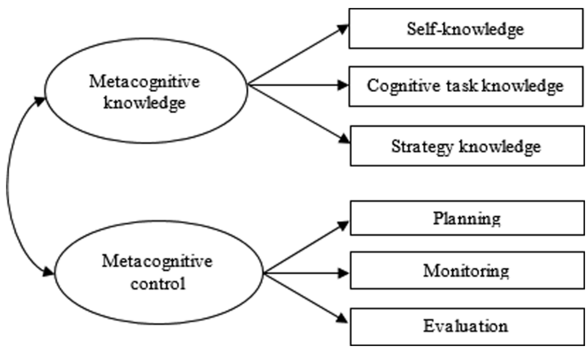

Figure 1 Metacognitive components

validity, reliability and good item statistics (Friendenberg, 1995). Effective techniques for analyzing the instrument structure are also necessary. As metacognition consists of several interrelated dimensions, it should be analyzed using the multidimensional item response theory rather than the item response theory which has unidimensionality as its common assumption. The multidimensional analysis aims at examining each property that comes from different components or dimensions (Wilson & Hoskens, 2005) leading to a more accurate assessment. Accordingly, the multidimensional item response theory is suitable for assessing metacognition that consists of several interrelated components or dimensions.

Multidimensional Item Response Theory (MIRT)

Metacognition consisting of several interrelated dimensions should be analyzed using the multidimensional item response theory as the item response theory has the assumption of unidimensionality. The presentation of construct validity using multidimensional analysis is based on comparing the competing models between the multidimensional approach and the unidimensional approach using Deviance Statistic; G^2 which is used for comparing nested models. The Akaike Information Criterion (AIC) is used for comparing relative fit among non-nested models. The statistics are used to compare the multidimensional approach with the consecutive unidimensional approach. The interpretation of Deviance Statistic; G^2 and the Akaike Information Criterion (AIC) is based on a model's values; a model with low values is more consistent with empirical data (Allen & Wilson, 2006; Briggs & Wilson, 2003).

According to the researchers' literature review, only one metacognition scale for nursing students has been developed; the scale was paper-based and developed for Taiwanese nursing students. In addition, the components of metacognition are multidimensional. Therefore, the researchers were interested in developing a metacognition scale using computer multimedia for nursing students by applying the multidimensional item response theory to develop a standard scale suitable for measuring Thai nursing students' metacognition.

Objectives

The aims of this research were to develop an instrument for measuring nursing students' metacognition and test the psychometric properties of the developed instrument.

Methodology

This research aimed to develop and test a metacognition scale using computer multimedia for nursing students (MSCM-NS) by applying the multidimensional item response theory. The research was carried out in 2 phases: Phase 1 Instrument Development and Phase 2 Quality Assessment.

Participants and Data Collection

Sample

The population consisted of fourth-year nursing students studying in the Nursing Science Program in 78 nursing institutes certified by the Thailand Nursing and Midwifery Council. The sample consisted of 600 fourth-year nursing students from 12 institutes representing 4 supervisions and 4 regions in Thailand and who were selected using multi-stage random sampling. The sample size was determined according to the criteria for appropriate sample sizes for factor analysis of Comrey and Lee (2013) which suggested that a sample size of 500 is very good and a sample size of less than 200 should not be used.

Data collection

The data collection was conducted among fourth-year nursing students between 9 January 2018 and 15 May 2018. The data were collected using the MSCM-NS by the researcher and research assistants. The researcher explained the participation requirements to the research assistants and recorded and analyzed the data gathered from the participants using SPSS and LISREL and ConQuest.

Instrument

The MSCM-NS was developed based on the metacognition components of Flavell (1985), Jacob and Paris (1987), and Pintrich (2002). The testing system was an online-based system with an administrator developed using Adobe Flash (Adobe Inc., San Jose, CA, USA). The MSCM-NS consisted of 2 parts: Part 1 Demographic Data and Part 2 Metacognition of Nursing Students. Part 2 consisted of 4 situational video clips to cover 6 indicators for all 4 situations: health promotion, disease prevention, treatment, and rehabilitation., a 3-item subjective test and a 21-item objective test with 3 choices. The scores were divided into 3 levels: 0, 1 and 2, based on the criteria of Jacob and Paris (1987).

Design

This research was comprised of 2 phases as follows:

Phase 1 Research tool development

The researcher developed a research framework and a metacognition scale for assessing nursing students' metacognition based on the metacognitive concepts of Flavell (1985), Jacob and Paris (1987) and Pintrich (2002). The accuracy and suitability of the research framework, metacognition scale and indicators were examined by 7 experts who were nursing instructors with PhD degrees and knowledge and understanding of educational measurement and evaluation. The metacognition scale was online-based, consisting of 2 parts: (1) demographic data (institution, gender, age and GPA) and; (2) 4 situational video clips covering all 4 nursing dimensions: health promotion, disease prevention, treatment, and rehabilitation. The scale consisted of 3 subjective items with no points allowing students to use their metacognition to answer objective items, and 21 objective items with 3 choices. For the objective test, scores were divided into 3 levels: 0, 1 and 2. The total score was 42.

Phase 2 Quality assessment

1. The content validity of the instrument was examined by 5 experts in nursing, research and educational measurement and evaluation by analyzing the index of item-objective congruence (IOC).

2. The researcher examined the reliability of the instrument using the marginal reliability for response pattern scores by IRTPRO41 among 60 fourth-year nursing students in Year 2018 at Kuakarun Faculty of Nursing, Navamindradiraj University.

3. The item analysis was conducted with OUTFIT MNSQ (OUTFIT Mean Square or Unweighted Mean Square) and INFIT MNSQ (INFIT Mean Square or Weighted Mean Square). The metacognition scale for nursing students was a clinical observation so the appropriate OUTFIT MNSQ and INFIT MNSQ values were in the range of 0.50 to 1.70.

4. The construct validity was examined through the multidimensional analysis, to compare the suitability of the multidimensional approach with those of the composite approach and the consecutive approach, and through the confirmatory factor analysis

Data Analysis

The construct validity was examined through the multidimensional analysis using ConQuest Version 2 (ACER Press, Australia), and through the confirmatory factor analysis using LISREL 9.2 Student (SSI scientific software international). The IOC index was used to determine the content validity and the reliability of the instrument using the marginal reliability for response pattern scores by IRTPRO41. The item analysis was conducted with OUTFIT MNSQ (OUTFIT Mean Squareor Unweighted Mean Square) and INFIT MNSQ (INFIT Mean Square or Weighted Mean Square) using ConQuest.

Results

1. The MSCM-NS consisted of a 3-item subjective test with no points allowing students to use their thinking processes to answer the questions and a 21-item objective test with 3 choices. The scores were divided into 3 levels: 0, 1 and 2. The content validity was assessed using the item-objective congruence (IOC). The IOC score was between .6-1. The reliability of the instrument using the marginal reliability for response pattern scores was .65

2. The results of the item analysis showed that the OUTFIT MNSQ (unweighted mean square) value was between 0.52–1.36, and the INFIT MNSQ (weighted mean square) value was between 0.51–1.38. All 21 items were within the range as shown in Table 1.

3. The construct validity analyzed using the multidimensional analysis showed that the multidimensional approach was a more fitting model than the composite approach (multidimensional approach G^2 = 24,772.99, AIC = 24,820.99, composite approach G^2 = 24,791.28, AIC = 24,835.28, x^2 = 18.29, df = 2, $p < .05$), and the consecutive approach (G^2 = 24,792.16, AIC = 24,838.16, x^2 = 19.17, df = 1, $p < .05$) as presented in Table 2. In addition, the CFA metacognition model had construct validity with x^2 = 7.724, df = 8, p = .461, GFI = .996, AGFI = .989 and RMSEA = .000. The details are shown in Table 3 and Figure 2.

Discussion

The MSCM-NS is an online-based scale, consisting of 3 subjective items with no points allowing students to use their thinking processes to answer questions and 21 objective items with 3 choices. For the objective test, scores were divided into 3 levels: 0, 1 and 2. The IOC score was between .6-1. The marginal reliability for response pattern scores was .65, consistent with Kanjanawasee (2013) who proposed that the reliability coefficient should be at least .50 if the test does not affect decisions regarding important matters and there is a possibility for monitoring and further development. Therefore, the MSCM-NS had an acceptable level of reliability even though it was not very high. The result is consistent with a study on development of a computer-based metacognition scale for grade six students that found an IOC of 0.83–1.00, reliability of .659 (Teeranurak, 2009).

Table 1 Analysis results of OUTFIT MNSQ and INFIT MNSQ in accordance with the multidimensional item response theory

Factor	Item	Difficulty	Error	OUTFIT (Unweighted fit)		INFIT (Weighted fit)	
				MNSQ	T	MNSQ	T
Metacognitive Knowledge	SELF1	-0.457	0.042	1.36	5.7	1.38	5.3
	SELF2	0.140	0.039	0.70	-5.8	0.70	-8.6
	SELF3	0.122	0.039	0.91	-1.6	0.91	-2.3
	STRA1	-0.797	0.045	0.87	-2.3	0.88	-1.6
	STRA2	0.042	0.039	0.67	-6.4	0.67	-8.9
	STRA3	0.754	0.038	1.17	2.8	1.17	4.9
	STRA4	0.225	0.038	0.84	-2.9	0.84	-4.6
	TASK2	0.026	0.039	0.91	-1.6	0.90	-2.4
	TASK4	-0.055	0.113	1.04	0.8	1.04	0.8
Metacognitive Control	PLAN1	-0.332	0.039	1.11	1.8	1.15	2.7
	PLAN2	0.365	0.037	0.56	-9.0	0.56	-15.1
	PLAN3	-0.09	0.038	0.74	-5.0	0.74	-6.5
	PLAN4	0.441	0.037	0.52	-10.1	0.51	-17.4
	MONI1	-0.363	0.039	0.80	-3.7	0.82	-3.6
	MONI2	0.151	0.037	0.87	-2.4	0.87	-3.6
	MONI3	-0.287	0.039	0.86	-2.6	0.87	-2.6
	MONI4	-0.20	0.038	0.74	-4.9	0.74	-0.6
	EVAL1	-0.176	0.038	0.74	-5.0	0.75	-5.9
	EVAL2	0.207	0.037	0.77	-4.2	0.78	-6.6
	EVAL3	-0.086	0.038	1.16	2.7	1.17	3.7
	EVAL4	0.374	0.126	0.76	-4.5	0.75	-7.8

Note: T = t-value; OUTFIT MNSQ = OUTFIT Mean Square or Unweighted Mean Square; INFIT MNSQ = INFIT Mean Square or Weighted Mean Square

Table 2 Results of the approach comparison to test the structural validity of the metacognition scale using the multidimensional analysis

Approach	G^2	AIC	Parameters
1. Composite	24,791.28	24,835.28	22
2. Consecutive	24,792.16	24,838.16	23
3. Multidimensional	24,772.99	24,820.99	24
Difference of G^2 between 1st and 3rd approach $x^2 = 18.29$, df = 2, $p < .05$			
Difference of G^2 between 2nd and 3rd approach $x^2 = 19.17$, df = 1, $p < .05$			

Note: G^2 = Deviance index; AIC, Akaike information criterion; df = Degree of freedom

Table 3 Results of the confirmatory factor analysis of the metacognition scale for nursing students

Factor	Variable	Factor loading		t	R^2	Factor score coefficient
		b(SE)	β			
Metacognitive knowledge	SELF	.102(.033)	.236	3.046*	.056	.358
	STRA	.102(.031)	.300	3.340*	.090	.596
	TASK	.079(.039)	.141	2.035*	.020	.158
Metacognitive control	PLAN	.179(.018)	.496	10.014*	.246	.622
	MONI	.283(.022)	.706	12.793*	.499	1.199
	EVAL	.243(.021)	.592	11.429*	.350	.756
x^2 = 7.724; df = 8; p = .461						
GFI = .996; AGFI = .989 RMSEA = .000						

Note: SELF = Self-knowledge; STRA = Strategy knowledge; TASK = Cognitive task knowledge; PLAN = Planning; MONI = Monitoring; EVAL, Evaluation; b = Factor loading; SE = Standard errors; β = Standardized factor loading; t = t-test; R^2 = Squared multiple correlations; GFI = Goodness of Fit Index; AGFI = Adjusted Goodness of Fit Index; RMSEA = Root Mean Square Error of Approximation.
*p < .05.

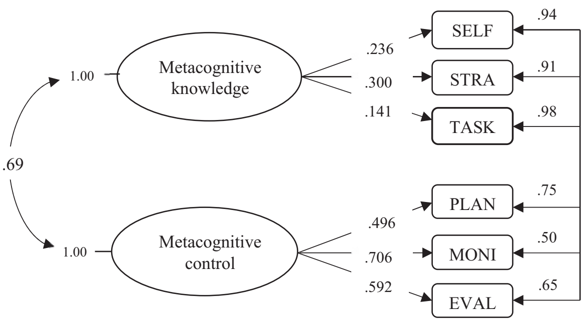

Figure 2 CFA metacognition model

Regarding the item quality of the metacognition scale, the results showed that all 21 items were within an acceptable range. For clinical observations, OUTFIT MNSQ and INFIT MNSQ values should be between 0.50–1.70 (Wright & Linacre, 1994). This indicates that all 21 items of the metacognition scale are fit for use.

The results of the analysis of construct validity using the multidimensional analysis showed that the multidimensional metacognitive approach was more appropriate than the composite approach and the consecutive approach, indicating that metacognition consists of multiple interrelated dimensions. An important assumption for analysis based on the item response theory is the instrument's unidimensionality. If used, there will be 2 consequential problems: (1) violation of the unidimensionality assumption and (2) the instrument's lack of accuracy resulting from the combination of multiple properties into a single dimension. However, the multidimensional analysis requires testing of each property from different components or dimensions (Wilson & Hoskens, 2005). Such evidence indicates the construct validity of the metacognition scale using the multidimensional analysis. In additional, the confirmatory factor analysis showed that the metacognition model was consistent with the empirical data. However, the Chi-Square value is highly sensitive to sample size. Other statistical values were also considered. The GFI and the AGIF were .996 and .989, respectively. Both values were over .90 indicating the overall effectiveness of the approach. The RMSEA was .000, lower than .05, representing discrepancy in parameter estimation (Briggs & Wilson, 2003). It can be summarized that all statistical values were acceptable, indicating that the MSCM-NS was consistent with the empirical data. The result was consistent with studies on CFA of metacognition model by Suebkeaw (2008) and Teeranurak (2009) which found that the two components of the model were consistent with the empirical data. However, there has been no research on development and testing of a metacognition scale using computer multimedia for nursing students: an application of multidimensional item response theory in Thailand. This measurement will guide nursing instructors in organizing learning activities appropriate for nursing students' metacognition levels.

Conclusion and Recommendation

The results showed that the MSCM-NS has quality especially in terms of construct validity, which was examined using the multidimensional analysis and the confirmatory factor analysis.

1. All undergraduate nursing programs offered by nursing institutes must be approved by the Thailand Nursing and Midwifery Council and apply the Thai Qualifications Framework for Higher Education (TQF) consisting of 6 learning outcomes, one of which is cognitive skills aimed at analytical and problem solving skills. Metacognition is a cognitive skill; therefore, nursing institutes can use the developed metacognition scale to assess fourth-year nursing students' metacognition levels in formative and summative assessments to organize learning activities to improve their metacognition levels to prepare them for future professional practice.

2. Further research should improve the metacognition scale using computer multimedia so that it can be accessed via mobile phones or tablets, which will be more convenient and consistent with the Thailand 4.0 policy.

Conflict of Interest

There is no conflict of interest.

Acknowledgments

This research was funded by the 90th Anniversary of Chulalongkorn University Fund (the Ratchadaphiseksomphot Endowment Fund) and received an ethics committee approval letter No. 004/2561 from the Research Ethics Review Committee for Research Involving Human Research Participants, Chulalongkorn University.

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