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Cognitive skills of secondary school students: A tentative model and an online test

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Abstract

The current research endeavour aimed to 1) develop a measurement model, 2) develop an online test, and 3) evaluate the quality of a cognitive skills test. The developed online test was assessed by a trial with a sample group consisting of 1,299 secondary students. The results showed that the cognitive skills measurement model consisted of 1) critical thinking, with 3 indicators (quantitative critical thinking, verbal critical thinking, and social situations), and 2) creative problem solving, with 3 indicators (mess finding, problem finding, and solution finding). Tests for each level consisted of 2 sub scales, which were 1) critical thinking, in the form of multiple-choice questions, and a situation test, 60 items overall, which were scored by computer, and 2) creative problem solving, in the form of 10 essay-type questions, which were scored by 3 evaluators. For quality of the cognitive skills test based on a classical test theory, the discrimination index (r) was mostly medium, while the difficulty index (p) was moderate and quite difficult, respectively. The reliability index was .79 and .86, respectively. The results of the test validation based on Multidimensional Item Response Theory revealed that the cognitive skills tests for both grades appeared to be multidimensional as follows. The results on each item showed that most questions possessed a medium discrimination parameter and difficulty parameter. Also, the confirmatory factor analysis suggested that the cognitive skill model for students in both grades possessed construct validity.

Introduction

Cognitive skills are a significant human neurological system consisting of critical thinking, problem solving and creative thinking skills (Bowman, 2010). Recently, scholars in Thailand have attempted to develop measurements in numerous areas for students of all grades under the Office of the Basic Education Commission, particularly measurements for the cognitive domain, which is as important as the affective and the psychomotor domains (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). For example, advanced thinking tests for lower secondary students, consisting of critical thinking, decision making, and problem-solving skills (Jandokmai, Pasiphol, & Sujiva, 2011), were tools developed to test separate small skills, which lacked unity. A number of limiting factors prevented them from being up-to-date national standard tests including the test method, which was paper-and-pencil tests, inconvenience in test administration, for example, delayed grading and result reports, and human errors in times of grading.

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All things considered, it is obvious that cognitive skills account for crucially important skills. Once they are honed and systematically and appropriately supported, students, as well as Thailand, could benefit a great deal from the skills in a number of facets. However, Thailand currently lacks a standard and up-to-date cognitive skills test to measure students' educational quality, and there is suspicion about the accuracy, reliability, and validity of tests currently used. Due to the fact that cognitive skills are psychological by nature, which involves latent traits and the relationship of data is not equal to zero (Cheng, Wang, & Ho, 2008), problems concerning the relationships of factors could arise leading to inaccuracy in measurements in case of inappropriate analysis. For this reason, the writers are interested in developing a cognitive skill model and test for secondary students. The focus was on critical thinking and creative problem-solving skills. The test was administered in the form of an online test, which made use of a computer as a tool, and which was widely accepted and prevalently adopted abroad. This was because it could inspire imagination, and be more interesting than the classical test. Furthermore, the grading was always accurate and the result reports were immediate (Way, Davis, Keng, & Strain–Seymour, 2016). The objectives of the current research endeavour included: 1) to develop a cognitive skill model 2) to develop an online test, and 3) to evaluate the quality of an online cognitive skills test for secondary students.

Literature Review

Critical thinking is the basis of all kinds of thinking skills; thus, it is a necessary development tool for students. By possessing effective critical thinking skills, students can also develop other areas of academic abilities, such as reading and writing (Kim & Lundberg, 2016). Problem-solving is another indispensable skills for students in today's society, which has become increasingly complicated and is rapidly changing, potentially bringing about difficulties, in both concrete and abstract forms, in work and daily life in general. However, once students possess effective problem-solving skills, they can accomplish their goals better than students who are not able to properly solve their problems. Therefore, problem-solving skills are considered crucial for learning and daily life, which is consistent to Piaget (1977) claiming that 12-15-year-old children have the ability to reason and solve complicate problems; hence, their skills should be appropriately honed for their future life. Creative thinking is another desirable skill for students in the modern world; those with creative thinking skills automatically adopt a variety of thinking strategies to create new things. For instance, new theories, innovations, or new useful products (Burleson, 2005). From the reasons mentioned earlier, critical thinking, problem-solving, and creative thinking skills are regarded as indispensable for students' learning and daily life. Nevertheless, in the current constantly transforming world, it is not sufficient to acquire only problem-solving skills or only creative thinking skills, in order to enhance students' learning skills. For this reason, problem-solving skills and creative thinking skills should be integrated into creative problem-solving skills (Treffinger, Isaksen, & Dorval, 2010).

The development of the model and the cognitive skills test was in the form of an online test, consistent with the basic education core curriculum, and consisted of 2 skills. The first skill was critical thinking, integrating concepts of Bloom et al. (1956) Watson and Glaser (1964 as cited in Fernando, 2011) Dewey (1997) and Ennis (1993). There were 3 indicators including (1) quantitative critical thinking, (2) verbal critical thinking, and (3) critical thinking in social work. The second skill area was creative problem solving, integrating concepts of Osborn-Parnes (1967 as cited in Mitchell & Kowalik, 1999). There were 6 indicators: (1) mess finding, (2) data finding, (3) problem finding, (4) idea finding, (5) solution finding, and (6) acceptance finding.

Methodology

The current research and development consisted of 3 stages as follows:

Stage 1: the development of the cognitive skills model

This stage began by studying the problem conditions of the test and the validation of cognitive skills, principles, concepts, test techniques, validations, and relevant research studies both inside and outside the country. The information was synthesized in order to identify the components. Afterwards, the model appropriateness was evaluated by focus group method of 13 experts.

Stage 2: the development of the cognitive skills test

The developed test was divided into 2 sub-tests, the cognitive skill-test for grade 9 and 12 students. Each test contained 2 sub-scales: (1) a critical thinking scale and (2) a creative problem-solving scale. Each subscale is elaborated as follows:

1. The critical thinking scale was in the form of a multiple-choice test, with 5 multiple–choice options, altogether 60 questions. 1 score was given to a correct answer and 0 score was given to an incorrect answer. The students were given 60 minutes to finish the test. There were 3 test components: (1) 20 questions testing their quantitative critical thinking, calculation ability, quantitative reasoning, quantitative relation determination, and inference to quantitative facts, (2) 20 questions testing their verbal critical thinking, verbal understanding, verbal reasoning, verbal relation determination, and inference to verbal facts, and (3) 20 questions testing their social situations, based on 5 skills by Watson and Glaser (1964 as cited in Fernando, 2011): Inference and information, recognizing assumptions, deduction, interpretations, and evaluating arguments. The questions had 5 options and were presented by VDO Clips, which demonstrated every day social situations for the students to make decisions based on their individual experience in order to come to the right and reasonable conclusion. Each test contained 4 situations. The developed scales had been primarily evaluated by means of consulting a group of experts and evaluating the content accuracy by Item-Objective Congruence (IOC) with the result range between .71–1.0.

2. The creative problem-solving scale was in the form of essays based on situations and information from different sources. The scale was adapted from Collegiate Learning Assessment tests and Programme for International Student Assessment essay writing. Questions were based on creative problem solving by Osborn-Parnes (1967 as cited in Mitchell & Kowalik, 1999). The answering forms were adapted from essay writing used for international students. One of them was

closed-ended essay writing questions, which was adapted to multiple-choice questions which had more than 1 correct answer, ranging from 0–3 points, where one point was given to one correct answer, and the scores range according to the levels of importance. The second was open-ended essay writing questions, which had 6 levels of analytic scoring rubric, from 0–5 points. Scoring points were adapted from creative thinking theory of Torrance, including 4 considerations: appropriateness, originality, flexibility, and fluency. Students' whose answers showed the accomplishment of all 5 considerations were given 5 points. Once their answers showed partial accomplishment of the 5 considerations, they were given 1–4 points, but were given 0 points when their answers were irrelevant. Each test scale contained 2 situations, 10 questions, and 5 components: (1) mess finding, (2) data finding, (3) problem finding, (4) idea finding and (5) solution finding and acceptance finding. Each component was the base for 2 questions. The test duration was 90 minutes.

Stage 3: the double validations of the quality of the cognitive skills test were as follows:

1. The first trial used the cognitive skills tests with 200 secondary school students who studied in the schools under the Office of the Basic Education Commission.

2. The second trial used the cognitive skills tests with 1,099 secondary school students who studied in the schools under the Office of the Basic Education Commission.

Participants

Participants 1

The first trial used the cognitive skills tests with 100 grade 9 students and 100 grade 12 students, who studied in the schools under the Office of the Basic Education Commission, by means of multi-stage random sampling.

Participants 2

The second trial used the cognitive skills tests with 504 grade 9 students and 595 grade 12 students, who studied in the schools under the Office of the Basic Education Commission, by means of multi-stage random sampling.

Data Collection

The researcher coordinated with the sampled school to prepare for equipment usage, including computers, headphones and mouse at least 1 week in advance before proceeding to data collection. The cognitive skills test was an online test carried out and controlled during the test by a computer system, under a 210-minute test administration.

Since the students would answer the questions for a very long hour, the researcher had to prepare them to ensure that they correctly approached the test: motivating the students to answer the questions intently, presenting high quality audio and video clip questions that were consistent with their lifestyle, arranging an environment suitable for the exam, and managing time for the exams to prevent the students getting bored and consequently becoming inattentive.

Data Analysis

A critical thinking scale was evaluated, item by item, by using a discrimination index (r) and a difficulty index (p), based on classical test theory. Discrimination parameter (a) and difficulty parameter (b) were based on item response theory. Items that were not consistent with the criteria were improved. The consideration on the items was based on .20 or more of the discrimination index (r), the discrimination parameter (a) and difficulty parameter (b) based on IRT. Practically, items that obtained +0.50 to +2.50 discrimination parameter (a) were selected, and parameter (b) difficulty was supposed to range from -2.50 to +2.50. If b value was close to -2.50, it meant that the item was easy and if the value was close to +2.50, it meant that the item was difficult.

To evaluate the quality of answers, a creative problem-solving scale was adopted. To improve the quality of the research tools, the research tool experts were consulted. As well, the validation of internal consistency of the tools was also conducted.

At the end, the data were primarily analyzed, as in the first trial, for multidimensional analysis (MIRT) and construct validity analysis by means of second-order confirmatory factor analysis.

Results

The study results could be divided into key points as follows:

1. The result of the development of the cognitive skill-model revealed that the cognitive skill-model for grade 9 and grade 12 students was composed of 2 skills: 1) critical thinking (CT), with 3 indicators including (1) quantitative critical thinking (CTN), (2) verbal critical thinking (CTL), and (3) social situations (CTS), and 2) creative problem solving (CPS) with 3 indicators including (1) mess finding (MF), (2) problem finding (PF), and (3) solution finding (SF).

2. The result of the development of the cognitive skill test showed that the cognitive skill test was suitable particularly with grade 9 and 12 students, in an online form. Tests for each level consisted of 2 sub scales: scale 1: critical thinking skills, in the form of multiple choice questions, and an everyday situation test, consisting of 5 options, and scale 2: creative problem solving, in the form of essay questions, whose item-objective congruence (IOC) was evaluated by 13 experts. The result showed that IOC ranged from .57–1.00 before the trial with 100 grade 9 students and 100 grade 12 students to investigate verbal clarity.

3. The validation result of the cognitive skill tests was as follows:

1) *Trial 1*: The question-by-question validation result of the cognitive skill tests, based on the classical test theory, found the critical thinking of grade 9 and 12 students had .12–.72 and .13–.65 discrimination powers, and .17–.88 and .10–.83 difficulty, respectively. The discrimination parameter based on item-response theory (IRT) revealed that the critical thinking scale of grade 9 and 12 secondary students had -3.39–4.97 and -.42–4.45 difficulty parameter and -1.09–4.83 and -3.28–4.42 discrimination parameter, respectively. The creative problem-solving scale of grade 9 and 12 students revealed that

the possible scale improvement was the suitability of each situation in various facets, namely, the number of situations, consistency of sexes and ages, length, questions, language usage, answering format, answers, grading rubrics and weight, and the number of questions.

The validation of test internal consistency reliability, based on Cronbach's Alpha Coefficients, revealed that critical thinking scale of grade 9 and 12 secondary students contained .91 and .85, respectively.

2) *Trial 2*: The question-by-question validation result of the cognitive skill tests, based on classical test theory, found the critical thinking scale of grade 9 and 12 students had .16–.48 and .18–.42 discrimination powers, and .18–.74 and .12–.77 difficulty, respectively. The discrimination parameter based on multidimensional item-response theory (MIRT) revealed that the critical thinking scale of grade 9 and 12 secondary students had -0.69–1.96 and -0.19–1.06 difficulty parameter and -1.09–2.67 and -0.11–1.32 discrimination parameter, respectively. The creative problem-solving scale of grade 9 and 12 students revealed that the threshold $\beta1 > \beta2 > \beta3 > \beta4 > \beta5$ ranged from 1.75–4.14 and 2.64–4.59, respectively.

The result of multidimensional analysis of the cognitive skill tests for grade 9 and 12 students found that the questions were more statistically consistent to the multidimensional model than the single dimensional model. The statistical difference valued .01 and chi-square valued 410.930 (df = 3, p = .000) and 109.408 (df = 2, p = .000), respectively. In summary, the result showed that the cognitive skill tests for grade 9 and 12 students were suitable with multidimensional analysis.

The result of the validation of internal consistency reliability of both tests using Cronbach's Alpha Coefficients revealed that the critical thinking scales of grade 9 and 12 students valued .79 and .86, respectively.

The result of the validation of construct validity using secondary order confirmatory factor analysis revealed that grade 9 students' cognitive skills model was consistent with empirical evidence. χ^2 = 26.60, df = 24, p = .323, CFI = .995, TLI = .992, RMSEA = .0177, SRMR = .048. The factor score coefficients (β) of the 6 variables revealed that the statistical significance of the factor score coefficients was .01 and .05, in which the variable with the most significance was problem finding (PF) (β = .681), and the variable with the least significance was verbal critical thinking (CTL) (β =.390). These variables had 39.00–68.10 percent covariance with grade 9 students' cognitive skill model. The factor score coefficients (β) of the 2 subscales discovered that there was .01 statistical significance, where critical thinking (CT) had more factor loading (β = .940) than creative problem solving (CPS) (β = .220). Both factors had 15.00 percent and 45.00 percent covariance with cognitive skill-model, as shown in Figure 1.

The result of the validation of construct validity by using secondary order confirmatory factor analysis revealed that grade 12 students' cognitive skills model was consistent with empirical evidence. χ^2 = 13.735, df = 7, p = .056, CFI = .988, TLI = .982, RMSEA = .0501, SRMR = .0442. The factor score coefficients (β) of the 6 variables revealed that the statistical significance of the factor score coefficients was .01 and .05, in which the variable with the most significance was solution finding (SF) (β = .921), and the variable with the least significance was mess finding (MF) (β =.233). These variables had 23.30–92.10 percent covariance with grade 12 students' cognitive skills model. The factor score coefficients (β) of the 2 subscales discovered that there was .01 statistical significance, where critical thinking (CT) had more factor loading (β = .971) than creative problem solving (CPS) (β = .222). Both factors had 24.10 percent and 62.20 percent covariance with cognitive skill model, as shown in Figure 2.

Discussion

1. The cognitive skill test had characteristics suitable particularly with grade 9 and grade 12 students, with 2 skills: 1) critical thinking, with 3 indicators including quantitative critical thinking (CTN), verbal critical thinking (CTL), and social situations (CTS), and 2) creative problem solving with 3 indicators including mess finding (MF), problem finding (PF), and solution finding (SF). The model developed was consistent with modern concepts, theories; and appropriateness for testing cognitive skills, along with the benefits in diagnosis, and giving feedback to teachers and schools. This cognitive skills model integrated The life skill-concepts of World Health Organization (World Health Organization, 2001) together with Watson and Glaser (1964 as cited in Fernando, 2011) Bloom's Revised Taxonomy of Cognitive Process Dimensions (Hess, Jones, Carlock, & Walkup, 2009) that uses cognitive process for Critical Thinking, Creative Thinking, Problem solving, Decision making and Collaboration, which is a process of value-added to cognitive

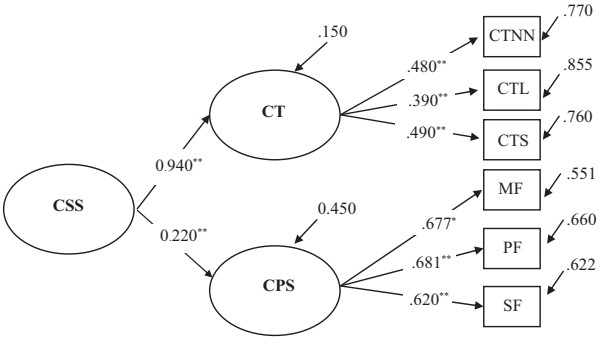

Figure 1 Confirmatory factor analysis of grade 9 students' cognitive skill mode

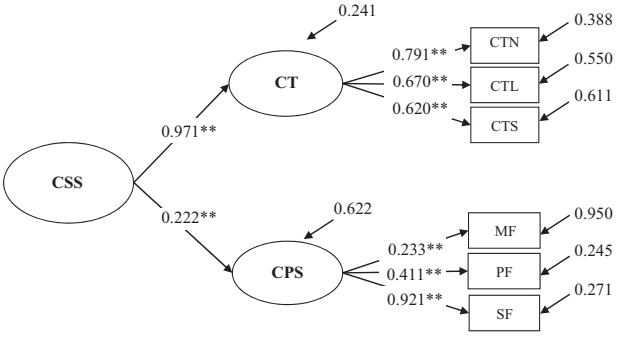

Figure 2 Confirmatory factor analysis of grade 12 students' cognitive skill mode

process and this process can be changed through the learning process efficiently (Carlsson, Dahl, Ockert, & Rooth, 2015; Lai & Viering, 2012). Both components are key *performance* indicators for thinking that are used to solve problems in both learning and daily life. Therefore, the evaluation of cognitive skills in turn could provide guidelines for the improvement of students' critical thinking and for students' further studies (Ennis, 1993) in accordance with Hwang and Kuo (2015), discovering that students' creative problem solving abilities are the ability to think critically, creatively, reasonably, and the ability to look for information. Thus, this Cognitive Skill Model is appropriate and in accordance with the context for the evaluation of grade 9 and grade 12 students.

2. To develop cognitive skills, questions were based on multi-dimensions between items, which tested particular skills and each factor is correlated, therefore, manifestly reflected data and facilitated grouping. There were 2 forms of cognitive skill tests: multiple-choice questions and essay writing; each type had its own strengths and limitations. To illustrate, multiple-choice questions with a number of options could cover all required skills to measure; they were clear cut, easy to grade, and advantageous when assessing specific behaviors. However, advanced thinking was limited and multiple-choice questions opened guessing chances. On the other hand, essay writing could effectively assess advanced thinking, was conveniently designed, and guessing was impossible. Nevertheless, the content comprehensiveness could be limited and grading could be a labor (Kubiszyn & Borich, 2013). For this reason, in the development of a cognitive skills test, more than 1 testing format was essential, which meant multiple-choice questions and essay writing should be integrated in order to test all skills required for the measurement of student achievement and to be beneficial and practical data of the school.

The developed tests were online tests which applied a computer multimedia system in the test administration, by means of VDO Clips, providing the sense of reality (Way et al., 2016) and reducing test bias since all test takers encountered the same test situations. Moreover, the tests were up to date and convenient to assess and grade students, and multiple-choice scores were easily calculated and converted. However, the limitations lay in test administration when there were a lot of test takers because there needed to be an advanced computer system to avoid previously observed errors like inconsistent downloading speed, the tendency for the leaked test without a security system. Hence, in the development of this type of test, there should be a test-taking demonstration in order to familiarize test takers with the method before the actual test.

3. In the question-by-question validation of a cognitive skills test, discrimination index of the 2 tests for both students of both grades, based on overall classical test theory, was medium, which was in accordance with the criteria: above 0.20. In testing the quality of the test, according to item-response theory, where multiple-choice questions were analyzed based on two parameter logistics model (2PL), the result showed that both tests had medium discrimination power. Practically, based on IRT, discrimination power should range from +0.50 to 2.50 (Kanjanawasee, 2012). The discrimination index of both tests ranged from very good, good, fair, and poor, indicating that the quality of tests based on traditional theory and item-response theory were correlated. Difficulty index based on item-response theory of both tests, in which multiple-choice questions were based on two parameter logistics model (2PL), found that the overall difficulty parameter of the test was at the average level. The test development revealed that there should be an integration of 25 percent of easy questions, 50 percent average questions, and 25 percent difficult questions (Ghiselli, Campbell, & Zedek, 1981), which was consistent with the current research study, in which a test for each grade contained questions with multiple difficulty levels from average to difficult, integrated for the appropriateness and practicality of contexts for students with various abilities.

The content validity validation revealed the value of .71–1.00, which was in accordance with the criteria of question selection IOC ≥ .50, which meant that each question in the tests could measure content and cover the skills required to measure such content; therefore, the cognitive skill-tests could be actualized to test students' cognitive skills.

Conclusion and Recommendation

The main points in conclusion are as follows:

1. The cognitive skills model consisted of 2 skills: 1) critical thinking, with 3 indicators, including 1) quantitative critical thinking, 2) verbal critical thinking, and 3) social situations, and 2) creative problem solving, with 3 indicators, including (1) mess finding, (2) problem finding, and (3) solution finding.

2. The cognitive skills tests were administered and controlled in terms of time by a computer system (online test). Each test contained 2 subscales: 1) critical thinking, in the form of 60 multiple-choice questions and everyday situations test with 5 options within 60 minutes of test taking and were graded by a computer system, and 2) a creative problem solving scale, in the form of 10 essay questions within 90 minutes of test taking, and were graded by 3 human raters.

3. The validation of the cognitive skills tests for students of both grades based on classical test theory (CTT) had low to high levels of discrimination index (r), and quite easy to very difficult index (p). The reliability of the tests for grade 9 and 12 students valued .79 and .86, respectively. The test validation based on multidimensional item-response theory, found that the cognitive skill-models contained multi-dimensions. The item validation showed that most of the items had medium discrimination parameter and difficult parameter. Confirmatory factor analysis showed that the cognitive skill-models of both levels had construct validity.

The main points in recommendation are as follows:

1. Recommendations for future use of the research results are 1) administrators, teachers, parents, and related individuals, should adopt the secondary students' cognitive skills tests as useful in assessing and developing skills in critical thinking and creative problem solving, both elements are important skills that are used to solve problems in both learning and daily life, and 2) in the adoption of the tests, the main concern should lie in test administration, the key to accurate results, such as motivating the students to answer intently; developing questions and video clips that are consistent with student

lifestyle to stimulate their interest, to make them better thinkers, and to motivate them to answer the questions. Time management for the exams to prevent the students getting bored, tired and consequently becoming inattentive should a matter of concern.

2. Recommendations for future research are: (1) to enhance the test standard, the validation of students' cognitive skills tests in various facets must be implemented following the use of the tests, and 2) short forms of secondary students' cognitive skills tests based on multidimensional item-response theory in the form of within item should be developed. There were too many questions which could exhaust test takers.

Conflict of Interest

There is no conflict of interest.

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References

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals*. New York, NY: David McKay Company.

Bowman, N. A. (2010). College diversity experiences and cognitive development: A meta–analysis. *Review of Educational Research*, *80*(1), 4–33.

Burleson, W. (2005). Developing creativity, motivation, and self-actualization with learning systems. *International Journal of Human–Computer Studies*, *63*(4–5), 436–451.

Carlsson, M., Dahl, G. B., Ockert, B., & Rooth D. O. (2015). The effect of schooling on cognitive skills. *The Review of Economics and Statistics, XCVIII*(3), 534–547.

Cheng, Y. Y., Wang, W. C., & Ho, Y. H. (2008). Multidimensional rasch analysis of a psychological test with multiple Subtests: A statistical solution for the bandwidth–fidelity dilemma. *Educational and Psychological Measurement*, *69*(3), 369–388.

Dewey, J. (1997). *Experience and education*. New York, NY: Touchstone.

Ennis, R. H. (1993). Critical thinking assessment. *Theory In to Practice*, *32*(3), 179–186.

Fernando, R. (2011). Do college students learn to critically evaluate claims? A cross–sectional study of freshmen and senior psychology majors (Unpublished doctoral dissertation). The University of Michigan, Ann Arbor, MI.

Ghiselli, E. E., Campbell, J. P., & Zedeck, S. (1981). *Measurement theory for the behavioral sciences*. San Francisco, CA: Freeman and Company.

Hess, K. K., Jones, B. S., Carlock, D., & Walkup, J. R. (2009). *Cognitive rigor: Blending the strengths of Bloom's Taxonomy and Webb's Depth of Knowledge to enhance classroom-level processes*. ERIC database. (ED517804)

Hwang, G–J., & Kuo F–R. (2015). A structural equation model to analyze the antecedents to students' web-based problem–solving performance. *Australasian Journal of Educational Technology*, *31*(4), 400–421.

Jandokmai, S., Pasiphol, S., & Sujiva, S. (2011). Development of higher–order thinking skill tests for lower secondary school students. *SDU Research Journal Humanities and Social Sciences*, *7*(3), 75–85. [in Thai]

Kanjanawasee, S. (2012). *Modern test theories* (4th ed.). Bangkok, Thailand: Chulalongkorn University Printing House. [in Thai]

Kim, Y. K., & Lundberg, C. A. (2016). A structural model of the relationship between student–faculty interaction and cognitive skills development among college students. *Research in Higher Education*, *57*, 288–309.

Lai, E. R. & Viering, M. (2012). *Assessing 21st century skill: Integrating research finding*. Paper presented at the annual meeting of the meeting of the National Council on Measurement in Education, Vancouver, Canada.

Mitchell, W. E. & Kowalik, T. F. (1999). *Creative Problem Solving* (3rd ed.). New York, NY: Genigraphics Inc.

Kubiszyn, T., & Borich, G. (2013). *Educational testing and measurement: Classroom application and practice* (10th ed.). New York, NY: John Wiley & Sons.

Piaget, J. (1977). *Epistemology and psychology of functions*. Dordrecht, The Netherlands: D. Reidel Publishing Company.

Treffinger, D. J., Isaksen, S. G., & Dorval, K. B. (2010). *Creative problem solving (CPS version 6.1™) a contemporary framework for managing change*. Sarasota, FL: Center for Creative Learning.

Way, W. D., Davis, L. L., Keng, L., & Strain–Seymour, S. (2016). *Technology and testing: Improving educational and psychological measurement*. New York, NY: Routledge.

World Health Organization (WHO). (2001). *Regional framework for introducing lifeskills education to promote the health of adolescents*. Based on Intercountry Meeting to Promote the Incorporation of Lifeskills for Health of Adolescents into School Education, Bangkok, Thailand. Retrieved from http://apps.searo.who.int/pds_docs/B3352.pdf