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Developing a cognitive ability test for Thai students

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Abstract

This study aims to validate a synthesized framework upon which to develop an instrument comprising indicators for measuring the cognitive abilities of upper primary school students and establish the norm for these cognitive ability scores. Both qualitative and quantitative research methods are employed. In-depth interviews with 30 experts and focus groups with 10 experts are used in the qualitative study to develop a conceptual framework for students' cognitive abilities. Meanwhile, a quantitative study was conducted to validate the framework and measurement model using 1,914 students chosen from six different regions of Thailand. The data analysis employs SPSS for Windows version 28 and LISREL12. The conceptual framework consists of 4 components and 13 indicators obtained, as follows: (1) The information processing component, which comprises (1.1) perception, (1.2) learning new things, and (1.3) applying knowledge; (2) The thinking component, which comprises (2.1) reasoning, (2.2) analytical thinking, (2.3) numerical thinking, (2.4) planning and problem solving, and (2.5) creative thinking; (3) The language component, which comprises (3.1) encoding, and (3.2) decoding; (4) The accomplishment component, which comprises (4.1) utilizing skills, (4.2) goal attainment, and (4.3) adaptability. A second-order confirmatory factor analysis indicated that the measurement instrument has construct validity and fitted well with the empirical data, $\chi^2(49) = 64.743$, $p = .065$, GFI = .995, AGFI = .990, RMR = .018, RMSEA = .013). Thai student cognitive abilities fall into one of four categories: developing, typical, generally exceptional, and outstanding levels.

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Introduction

Testing cognitive abilities in students has significance for a number of reasons, including the fact that it sheds light on their potential intellectually and identifies their areas of intellectual strength and need for development. Therefore, cognitive instruments play an important role in enhancing student development, such as enabling a teacher to understand students in many dimensions, planning for an appropriate curriculum, and placing students in appropriate academic levels. Cognitive ability scale is a major psychological instrument which enables students to discover their core abilities and in turn choose their learning subjects or activities at school optimally. However, most of such cognitive tests in Thailand have been administered in hospital settings by authorized clinical psychologists. Due to a lack of cognitive instrument tests that teachers can utilize in the classroom, cognitive testing in educational settings is limited (Visessuvanapoom & Wintachai, 2022). The majority of standard cognitive tests used in Thailand, such as The Wechsler Intelligence Scale for Children III (WISC-III) and The Test of Nonverbal Intelligence, Second and Third Editions (TONI-2, TONI-3), were created in culturally particular environments, which raises serious concerns about cultural bias. In line with this concern, another issue arises from the consistent problem of variations in cognitive ability test scores among different racial groups (Cottrell et al., 2015; Suzuki, 2021; Ueno & Nakatani, 2003).

Much research lends support for the major role that environment factors play in cognitive development. Thus, developmental contexts, such as culture, are crucial for cognitive development. Indeed, according to Vygotsky's theory, children use language as a tool for cognitive development, therefore, one's sociocultural context plays an important role in cognitive development (Vygotsky et al., 1993). Yet, most cognitive ability tests were developed based on a western context. There might be some bias in terms of language and culture associated with some items. Extant studies have also offered recommendations that the cognitive ability tests ought to be adapted at least for some items to suit local participants (Chen et al., 2003; Kwak, 2003; Sato et al., 2004; Suzuki, 2021; Ueno & Nakatani, 2003).

Historically, there have been culturally neutral classic cognitive ability tests that mostly measured non-verbal cognitive abilities, although some of those instruments were developed many years ago from their predecessor framework. Moreover, most of such cognitive tests have focused only on some cognitive components such as spatial abilities and number abilities, whereas other components such as abilities to deal with situations in the real world have been largely neglected (Benson et al., 2020; Van der Maas et al., 2014). The measurement context of each instrument is also varied and may not cover the core cognitive abilities (Evans & Stanovich, 2013; Sternberg, 1999).

This study represents a significant advancement in the realm of cognitive ability testing, focusing on the development of a more comprehensive assessment tool. The imperative driving this research stems from the critical need to accurately evaluate students' cognitive abilities. Within this context, notable gaps within the existing landscape of research and practical application of cognitive ability tests have come to the forefront. These gaps encompass multiple pivotal dimensions, including the limitations inherent in the cognitive tests currently employed within school settings. These tests, while utilized extensively, often exhibit constraints in effectively gauging the entirety of students' cognitive prowess, thus necessitating a more comprehensive approach. Moreover, the presence of cultural bias within cognitive instruments, rooted in distinct cultural contexts, introduces a layer of complexity that can potentially skew results and undermine the applicability of these assessments across diverse cultural backgrounds. This underlines the critical requirement for culturally sensitive and universally applicable cognitive assessment tools. Additionally, the prevailing cognitive test framework, while valuable in certain aspects, tends to overlook core facets of cognitive abilities, neglecting the intricate interplay of cognitive processes vital for the pragmatic application of acquired knowledge. As such, this study endeavors to bridge these significant gaps by crafting a cognitive ability test that not only addresses these limitations comprehensively but also aligns with the intricate and diverse nature of cognitive abilities among students, ultimately contributing to more accurate, culturally unbiased, and holistic cognitive assessments. Thus, the study aims to develop a framework of cognitive ability for Thai students, validate the framework and measurement model, and establish a norm.

Literature Review

In this section, we trace the historical background of cognitive abilities. We consider the complex concept of cognitive abilities and understand how scholars from various fields have sought to assess it. Throughout, we maintain a particular focus on Thailand's context and how extant well-established tools and instruments may be inadequate for effectively assessing Thai students' cognitive abilities.

The Concept of Cognitive Abilities

Cognitive ability refers to a range of mental skills and capabilities that include such processes as thinking, reasoning, problem solving, memory, attention, language understanding, and perceptual processing. These abilities play a crucial role in how individuals understand, process, and interact with information in their surroundings (Flanagan et al., 2013). Cognitive abilities are associated with educational attainment, occupation, and health outcomes (Plomin & Von Stumm, 2018). Therefore, children's cognitive development is derived from collective experiences more than genetics.

Framework of Cognitive Abilities

The history of cognitive abilities theory can be understood in 4 broad ways. Firstly, cognitive abilities are a target of psychometric investigation. Cognitive abilities are perceived and measured as factors. Spearman's two factors, for example, showed that general intelligence (g factor) is a construct made up of specific cognitive abilities (Spearman, 1927). Thurstone's cognitive abilities predicate on seven independent factors such as word fluency, verbal comprehension, spatial visualization, number facility, associative memory, reasoning, and perceptual speed, called primary abilities (Thurstone, 1938). Cognitive abilities are also based on fluid intelligence and crystallized intelligence (Cattell, 1971). Gilford (1988) believed that cognitive abilities are a combination of multiple abilities. There are 180 different intellectual abilities from three dimensions: operations, content, and products. Furthermore, Jensen (1969) argued that cognitive abilities may consist of two levels of abilities. The first level is associative learning, which relates to basic learning such as short-term memory, rote learning, attention, and simple associative skills. The second level is cognitive learning, which relates to more abstract learning such as abstract thinking, symbolic thought, conceptual learning, and problem solving. The Cattell-Horn-Carroll theory, which is based on Spearman's g-factor theory and includes a wide range of cognitive abilities, is the most commonly used in cognitive ability tests. It is a combination of the Cattle-Horn theory of fluid and crystallized intelligences and Carroll's Three-Stratum theory (Carroll, 1993; Kaufman et al., 2013). Secondly, cognitive abilities were a part of information processing theory. Psychologists observe and examine the mental processes involved in perceiving and handling information to research cognitive abilities (Martorell et al., 2014). They are interested in human perception, attention, encoding, storage, retrieval, memory, learning, and problem solving. Thirdly, cognitive abilities were viewed through cognitive development theories. Piaget's theory, for example, examined 4 stages in the quality of functioning. It investigated the interaction between a child and his/her environment. Piaget was interested in how the mind takes in and interprets information about the world. Vygotstky's sociocultural theory, like Piaget, focused on children's active engagement with their environment (Vygotsky et al., 1993). However, Vygotsky viewed cognitive growth as a collaborative process through social interaction. Without culture and context playing a crucial part, there would have been no cognitive growth. Lastly, cognitive abilities were explained through alternative theories that have focused less on measurement and age development. Sternberg (1999, 2013) mentioned that successful cognitive ability is the capacity to accomplish success in life given one's personal standards and within one's sociocultural setting. Hence, the successful completion of tasks emerges as a fundamental facet intricately linked to student cognitive abilities. Task accomplishment not only showcases the application of cognitive skills but also highlights the integration of various cognitive processes essential for effective problem-solving and knowledge utilization. This encompassing view of cognitive abilities encompasses not only theoretical understanding but also practical implementation, reinforcing the multidimensional nature of students' cognitive capacities.

The Usage of Cognitive Ability Test in Thailand

In Thailand, since 1927, two groups led the creation of the cognitive ability test movement: (1) Thai professors work in universities, and (2) Clinical researchers from medical institutions. The latter group has been more influential in translating and developing cognitive tests for Thai students. The Progressive Matrices (PM) and TONI-2 are two well-liked, culturally-neutral group cognitive ability tests. In 2011, the norm of cognitive abilities for Thai people aged 6 to 15 years old was produced by Thai experts in the fields of medicine and public health. Because the norm is complete, WISC-III is the widely used version of individual cognitive testing in Thailand. Even though some hospitals have been using The Wechsler Intelligence Scale for Children IV (WISC-IV) or The Wechsler Intelligence Scale for Children V (WISC-V), the norm was not updated. Thus, updated norms of cognitive ability test for Thais were needed. The assessment scores criteria of cognitive ability tests are still mostly based on the standardized test (Channarong, 2002). Thai researchers and educators frequently have examined the relationships between cognitive abilities and a variety of factors. In addition, they have tried to develop specific cognitive abilities tests to measure such dimensions as critical thinking (Benjamin et al., 2013; Ennis & Millman, 2005) and creative problem solving (Mitchell & Kowalik, 1999).

Thai schools use the cognitive ability test to operate in accordance with the placement service approach and promotion of individual learner abilities. Even for initiatives with the same goals, different schools may employ various measuring techniques. Moreover, some schools offer specialists. It relies on the school's preparation and contextual factors. The provocative question is: Is the selection of students to be appropriately arranged according to the school's approach optimal? Is it truly fair for all students?

The WISC-III and PM examinations, the most popular in Thailand, which were developed using western frameworks, have some inadequacies for Thai situations. Many experts have mentioned three kinds of bias of intelligence tests (Van de Vijver & Tanzer, 2004). Firstly, construct bias, for example, differences between cultures' perceptions of the appropriateness of behaviors linked to the construct. Secondly, there is method bias. Thirdly, item bias, for example, a bathtub, a man and woman with western face, part of the WISC-III's Picture Completion subtest, or asking a student to organize a vending machine's operation, part of the WISC-III's Picture Arrangement subtest, are not something that most Thai students are familiar with. Culture, religious and philosophical beliefs are major differences in conception of cognitive abilities. Buddhist philosophical traditions and beliefs are more concerned with the individual's self-improvement. In particular, a person's temperament is an important part of knowledge acquisition and intelligence while concepts of intelligence and morality in Western and African cultures are separated (Cocodia, 2014; Das, 1994).

The Raven Matrices may appear to be equitable for all cultures, but they only use spatial analogies, which is limited in its capacity to evaluate an individual's abilities entirely. (Scarr, 1995). Spearman g' factor is controversial. Some psychologists argued that a 'g' concept is not a valid one and the sum of all mental abilities should be emphasized (Cocodia, 2014). The term "cognitive ability" is therefore more useful than "intelligent ability" because it should be used to describe the capacity to carry out tasks that call on the individual to comprehend their environment and draw on their own cognitive resources. Thai schools will benefit from developing cognitive ability tests based on elements derived from Thai children within the Thai context and creating an administrative manual and scoring guide to provide convenience for the testers. This will help ensure that students are fairly selected into certain programs or projects.

In conclusion, the proper cognitive ability test utilized for Thai students in the setting of Thai schools should cover the fundamentals of cognitive abilities and be practical and easy for teachers to apply. The framework for measuring cognitive ability should take into account both empirical data and current theories of cognitive abilities. Therefore, components of cognitive abilities should consider information processing, thinking skills, verbal comprehension, and accomplishment. In order to examine the framework of cognitive skills, validate the suggested framework, and establish norms, research questions are created. The research conduct thus comes into existence to obtain the outcomes.

Research Objectives

1. To develop a conceptual framework of cognitive abilities of Thai students.
2. To validate a framework and measurement model of cognitive abilities of Thai students and develop a norm.

Methodology

This study comprises two phases. Phase 1 focused on developing the framework of Thai children's cognitive abilities, employing a qualitative method. Phase 2 sought to confirm the framework entailing these cognitive abilities and to develop the norm through a quantitative method.

Phase 1: Developing a Framework of Cognitive Abilities of Thai Students

Participants

Participants of this phase consisted of 2 groups: Group 1 had 30 educators, teachers, school administrators, and clinical psychologists who participated in in-depth interviews, and group 2 had 10 educators, teachers, school administrators, clinical psychologists, and psychiatrists who participated in a focus group discussion. A sampling method using gatekeeping was employed to ensure the selection of relevant participants from the target population.

Data collection

The first phase was to develop the new framework for cognitive abilities through in-depth interviews and focus group. Prior to the in-depth interviews, a literature review was conducted to gain extant definitions of cognitive abilities. After that, in-depth phone interviews were undertaken to get perspectives on cognitive ability in a school setting. The results from the interviews were analyzed to code the keywords of cognitive abilities. The focus group was organized to validate the framework of cognitive abilities. The research instrument in this phase was a structured interview form.

Data analysis

Contents derived from the literature review were integrated and synthesized to establish a comprehensive framework. In conducting a content analysis, data were systematically examined to identify and code keywords related to cognitive abilities along with their respective definitions.

Phase 2: Validating a Framework and Measurement Model of Cognitive Abilities of Thai Students and Developing a Norm

Participants

Participants were 1,914 Thai students in Grade 4–6 (42.6% were male, 57.1% were female, 0.3 percent were undisclosed) from a total of six regions of Thailand, including central (18.65%), the north (15.73%), the north-east (16.93%), the east (15.99%), the west (15.72%), and the south (16.98%), aged between 9 and 13 years (M = 10.98, SD = 0.97). Moreover, student participants were from three school sectors: public, private, and demonstration schools (40.02%, 29.78%, 30.20%, respectively). Stratified random sampling was employed as the preferred sampling technique to account for reginal variations in the target population and obtain a diverse and unbiased sample.

Data collection

The study in Phase 2 was to confirm the new framework of cognitive ability using empirical data and develop the norm. According to the framework of cognitive ability scale derived from Phase 1 study, cognitive abilities consist of 4 components: (1) An information processing component consisting of perception, learning new things, and applying knowledge subscales, (2) A thinking component consisting of reasoning, analytical thinking, numerical thinking, planning and problem-solving, and creative thinking subscales, (3) A language component consisting of encoding and decoding subscales, (4) An accomplishment component consisting of utilizing skills, goal attainment, and adaptability subscales. Items are carefully crafted according to definitions of subscales. The Cognitive Ability Scale comprises 3 parts: multiple-choice questions comprising 27 items in total, a single fill-in-the-blank item, and rating scales comprising 21 items in total. In the multiple-choice sections, students are required to select the correct answer from the given situation. The scoring for this section is straightforward, with one point awarded for a correct response and zero for an incorrect one. The fill in the blank section requires students to generate possible solutions to a problem, and responses are scored based on criteria encompassing fluency, flexibility, novelty, and elaboration, each with a maximum score of 3. Finally, the rating scales section assesses student preferences and suitability rating for provided items using a 5-point Likert Scale.

The content validity was evaluated by three experts who are university professors in the field of Educational Psychology, Behavioral Sciences, and Psychological Measurement, respectively. To validate the framework of cognitive abilities, data from 1,914 participants were collected after giving the scale to 145 students as part of a pilot study.

Data analysis

Licensed SPSS for Windows version 28 was employed for analyzing the analysis of corrected-item-total correlation (CITC), t-test, and correlation coefficient. CITC was analyzed to select the qualified items and the internal consistency was analyzed for the reliability of the scale. Cronbach's alpha coefficient of the whole scale is .811. Component 1 to 4 gains Cronbach's alpha coefficients as .551, .610, .806, and .817, respectively.

Construct validity was investigated by employing a t-test to analyze the mean differences between two known groups of students. The results show that cognitive abilities of students who are from high group and low group are significantly different [$t(99) = 6.960, p < .001$)]. The correlation coefficient was also obtained to ascertain the criterion validity. The findings indicated that the results from the standard test, The Raven's Standard Progressive Matrices, and The Cognitive Ability Test for Thai Students (CATTS) in this study were positively correlated ($r = .675, p < .01$). Confirmatory factor analysis was employed to investigate the new framework of cognitive abilities with the current empirical data, using LISREL 12. Intercorrelation between all factor pairs was calculated. Fit indices and criteria for evaluating CFA models include: (1) Relative Chi-Square (χ^2) Test is less than 3, (2) Comparative Fit Index (CFI) is more than .90, and (3) Root Mean Square Error of Approximation (RMSEA) is below .08 (Kline, 2023).

In order to establish the norm for Thai students' cognitive abilities, data were analyzed to produce percentile norms.

Results

According to objectives of this study, the results are divided into two sections: (1) the conceptual framework of Thai students' cognitive abilities developed from qualitative approaches; and (2) the validity and norms of Thai students' cognitive abilities.

Objective 1: To develop a Conceptual Framework of Cognitive Abilities of Thai Students

Content analysis from in-depth interviews demonstrates that cognitive abilities of Thai students consist of 4 dimensions, as follows;

Firstly, an information processing component includes 3 subscales: (1) perception (perceptions of stimulus and responses to sensory stimulations), (2) learning new things (abilities to memorize, store and recall information, assimilate information, use stored information), and (3) applying knowledge (applying prior knowledge and experiences to the present learning situations).

Secondly, a thinking component has the following 5 subscales: (1) reasoning (appropriate reasoning, using criteria for judgement, making logical decisions, and summarizing); (2) analytical thinking (examining data, classifying, and understanding causes and effects); (3) numerical thinking (using mathematical skills to understand numerical data); (4) planning and problem-solving (setting a goal, organizing the working process, and prioritizing things to solve a target problem); and (5) creative thinking (imagine, adapting, and looking for the novel ideas to address issues).

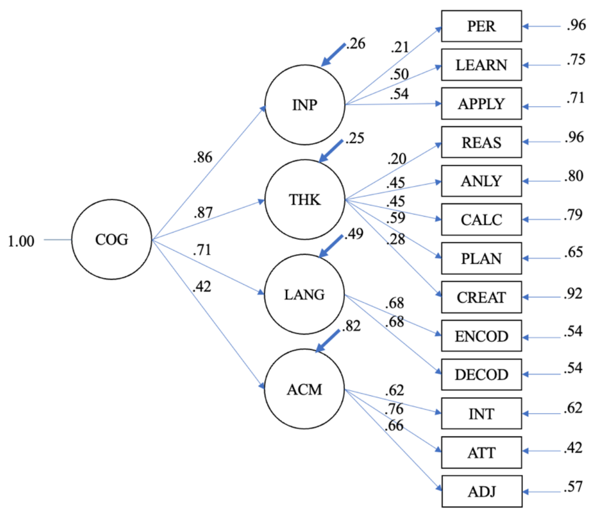
Thirdly, a language component comprises 2 subscales: (1) encoding (understanding verbal language and interpreting information), (2) decoding (using verbal language to communicate).

Fourthly, an accomplishment component includes 3 subscales: (1) utilizing skills (utilizing a variety of abilities to complete a task), (2) goal attainment (keeping up to works, using strategies to complete tasks and overcoming obstacles), and (3) adaptability (admitting to changed unpredictable causes and adapting one's strategy for accomplishing tasks).

In this phase, the feedback received from the focus group indicates a high level of agreement among participants regarding the cognitive ability's framework derived from the in-depth interviews.

Objective 2: To Validate a Framework of Cognitive Abilities of Thai Students and develop a Norm

A framework of cognitive abilities derived from a qualitative study in Phase 1 was confirmed by a quantitative study in this phase. Construct validity using confirmatory factor analysis in Phase 2 shows that the measurement model of Thai youth's cognitive abilities fitted with empirical data, $\chi^2(49) = 64.743, p = .065$, GFI = .995, AGFI = .990, RMR = .018, RMSEA = .013. The component "Thinking (THK)" has highest level of factor loading ($\beta = .868$), followed by "Information Processing (INP)" ($\beta = .863$), "Language (LANG)" ($\beta = .714$), and then "Accomplishment (ACM)" ($\beta = .424$), respectively. Considering standardized coefficients (β) as shown in Figure 1 and Table 1, it is found that standardized coefficients of 13 variables are positive and located in the range of .040 to .583 and statistically significant at .05 level.



$\chi^2(49, n = 1914) = 64.74, p = .06528$, RMSEA = .013

Figure 1 Final model of cognitive abilities of Thai students

Table 1 Second order confirmatory factor analysis for cognitive abilities in Thai students

Variables	*b*	*SE*	*t*	*B*	*FS*	R^2
First order confirmatory factor analysis						
1. Information processing (INP)						
PER	1.000	<->	<->	.212	.013	.045
LEARN	2.376	.372	6.381*	.503	.054	.253
APPLY	2.555	.422	6.052*	.541	.068	.293
2. Thinking (THK)						
REAS	1.000	<->	<->	.200	.011	.040
ANLY	2.242	.274	8.173*	.451	.029	.203
CALC	2.261	.286	7.905*	.454	.041	.207
PLAN	2.953	.350	8.426*	.594	.052	.353
CREAT	1.382	.201	6.889*	.278	.017	.077
3. Language (LANG)						
ENCOD	1.000	<->	<->	.680	.249	.462
DECOD	1.002	.055	18.065*	.682	.257	.464
4. Accomplishment (ACM)						
INT	1.000	<->	<->	.616	.157	.379
ATT	1.240	.063	19.670*	.764	.290	.583
ADJ	1.071	.054	19.822*	.659	.185	.435
Second order confirmatory factor analysis						
INP	.183	.029	6.310*	.863	<->	.745
THK	.174	.025	6.927*	.868	<->	.753
LANG	.485	.035	13.803*	.714	<->	.510
ACM	.261	.023	11.259*	.424	<->	.180
$\chi^2(49, n = 1914) = 64.743$, $p = .065$, $\chi^2/df = 1.32$						
GFI = .995 AGFI = .990 RMR = .018 RMSEA = .013						

Note: $*p < .05$.

For the first component of cognitive abilities "Information Processing (INP)", an indicator "APPLY" has the highest level of factor loading (β = .541), followed by "LEARN" (β = .503), and "PER" (β = .212), respectively. In the second component for "Thinking (THK)", an indicator "PLAN" has the highest level of factor loading (β = .594), followed by "CALC" (β = .454), "ANNY" (β = .451), "CREAT (β = .278), and "REAS" (β =.200). In the third component for "Language (LANG)", an indicator "DECOD" has a higher level of factor loading than an indicator "ENCOD" does (β = .681, .680, respectively). In the fourth component for "Accomplishment (ACM)", an indicator "ATT" has the highest level of factor loading (β = .764), followed by "ADJ" (β = .659), and "INT" (β = .616), respectively.

Results of factor score coefficient analysis can be used to propose component equation for cognitive ability.

Equation of cognitive ability of Thai students is (Equation (1));

$$COG = .013\,(PER) + .054\,(LEARN) + .068\,(APPLY)\ .011\,(REAS) + .029\,(ANLY) + .041\,(CALC) + .052\,(PLAN) + .017\,(CREAT) + .249\,(ENCOD) + .257\,(DECOD) + .157\,(INT) + .290\,(ATT) + .185\,(ADJ) \quad (1)$$

Equation of each component is (Equation (2), (3), (4), and (5));

$$INP = .013\,(PER) + .054\,(LEARN) + .068\,(APPLY) \quad (2)$$

$$THK = .011\,(REAS) + .029\,(ANLY) + .041\,(CALC) + .052\,(PLAN) + .017\,(CREAT) \quad (3)$$

$$LANG = .249\,(ENCOD) + .257\,(DECOD) \quad (4)$$

$$ACM = .157\,(INT) + .290\,(ATT) + .185\,(ADJ) \quad (5)$$

Table 2 reveals the mean scores and standard deviations for various components. The language component reaches highest mean scores *(M* = 81.91, *SD* = 23.10), followed by the information processing component (*M* = 71.16, *SD* = 20.98), the accomplishment component *(M* = 70.37, *SD* = 11.64), and the thinking component (*M* = 67.68, *SD* = 17.09), respectively. Lastly, the mean and standard deviation of cognitive ability scores are 74.27 and 12.43, respectively.

Based on the above criteria, individual scores are plotted into 4 grades:

GRADE I: Scores below the 25th percentile indicate that an individual's cognitive ability is at a developing level.

GRADE II: Scores between the 25th percentile and less than the 50th percentile indicate a typical level of cognitive ability.

GRADE III: Scores between the 50th and 75th percentiles indicate a generally high level of cognitive ability.

GRADE IV: Scores below the 75th percentile indicate exceptional cognitive ability.

Discussion

Based on current findings as presented above, our new framework of Thai children's cognitive abilities consists of 4 key components: "Information Processing" (INP), "Thinking" (TNK), "Language" (LANG), and "Accomplishment" (ACM). According to factor loading of each component in cognitive ability model presented in this study, thinking component (TNK) has the highest factor loading, followed by information processing component (INP), language component (LANG), and work accomplishment component (WOA), respectively. This finding is supported by previous studies (e.g., Maharani et al., 2018), whereby thinking is the key component of cognitive abilities. Tikhomirova et al. (2020), and Wu and Tsai (2005) also found that information processing is an indicator of cognitive ability. Moreover, the association between language ability and cognitive ability was supported by Agnoli et al. (2012), and Blums et al. (2017)'s study, implicating a direct link between language ability and cognitive ability. However, previous cognitive ability scales did not include motivation component. This study found that work accomplishment subsumes under cognitive abilities, as corroborated by Van Iddekinge et al. (2018), who reported an interaction between work accomplishment and cognitive ability. It should be pointed out, however, that work accomplishment component has the least factor loading in the model. Of note, AI researchers (e.g., Barr & Feigenbaum, 2014; Masum et al., 2002; McCarthy, 2007; Schank, 2014) have viewed that work accomplishment such as using working strategies and adaptability are parts of cognitive ability.

Concordance of Extant Cognitive Ability Scale with Previous Instruments

The purpose of the cognitive ability test is to determine a student's capacity to employ mental processes to solve problems based on both general and mental capacities. Unlike Standard Progressive Matrices (SPM), for example, in which only general mental ability was focused as a single factor. This cognitive ability test measures overall scores from each specific mental ability (i.e., information processing, thinking, work accomplishment, using language for communication) to represent the general mental ability and an individual resulting score from each of the specific types of abilities represents the specific mental abilities. Without neglecting the general factor, this cognitive ability test also pays attention to important specific abilities. It is similar to the perspective of the psychometric theories, accepting a variety of mental abilities under a general (g) factor. For example, Cattell (1971) mentioned that there are two levels under general ability, which are fluid ability (Gf) and crystallized abilities (Gc).

Table 2 Descriptive statistics analysis of CATTS

Components	*M*	*SD*	MIN	MAX	Shapiro-Wilk		Percentile		
					SW*	*p*	25th	50th	75th
Information processing (INP)	71.16	20.98	0.00	100.00	.95	<.001	60.00	76.79	86.67
Thinking (THK)	67.68	17.09	15.50	99.06	.98	<.001	56.61	69.11	78.94
Language (LANG)	81.91	23.10	0.00	100.00	.77	<.001	67.19	83.60	100.00
Accomplishment (ACM)	70.37	11.64	29.48	100.00	.99	<.001	63.34	70.85	78.48
Cognitive Abilities (COG)	74.27	12.43	29.85	97.01	.93	<.001	68.04	77.03	83.26

* Shapiro-Wilk for Normality Test

Fluid abilities are considered to influence biological factors on intellectual development such as solving abstract-reasoning problems while crystallized abilities are considered to influence education, experience, and acculturation. As Sternberg (1999) suggested, intellectual functioning could be classified by 3 metaphors: (1) A geographic metaphor based on psychometric theories, information-processing theories, for example, (2) An epistemological metaphor based on the process of cognitive development, and (3) A contextual metaphor focused on the external world of the individual, thus, the performances derived from interaction with context and cultures in this cognitive ability test could reflect student cognitive ability. Even though WISC-III, a popular cognitive abilities test in Thailand, measures both verbal and performances, the test cannot be administered to large groups of Thai students at one time. This cognitive ability test could work as predictors of real-world performance (Sternberg et al., 1995).

Neo-Piagetians supports information processing that perceiving, memorizing and processing capacity shape cognitive development by interaction of biological maturation with experience and learning (Morra et al., 2008). A perception component appears similarly to visual matching, cross out, picture recognition and spatial relation subtests of The Woodcock-Johnson Tests of Cognitive Ability (WJ- COG), representing the Gf and Gc based on intellectual processing (Woodcock, 1990), and close to similarities and symbol search subtests of the WISC-III. The subtest of learning new things is similar to concept formation and comprehension of WJ-COG and WISC-III respectively.

The subtests of *reasoning, analytical thinking*, *numerical thinking*, *planning*, and *creative problem solving* of thinking component could be found in the subtests of complete an analogy and systematically alter a pattern of the Standard Progressive Matrices, the picture completion and arithmetic of WISC-III, and in the analysis-synthesis, calculation, and applied problems subtests of WJ-COG. Encoding and decoding subtests of using language for communication component are similar to listening comprehension of WJ-COG, instead of listening to a short tape-recorded passage, but a student has to read a passage reflecting conversation to communicate. The verbal comprehension subtest of WISC-III is also similar to encoding and decoding subtests. Utilizing skills, goal attainment, and adaptability subtests of the work accomplishment are new subtests which are developed based on the idea of researchers in the artificial intelligence research that support adding these subtests in to cognitive abilities (Masum et al., 2002; McCarthy, 2007)

Concordance of Test Development and Standardized Tests

CATTS in this study is standardized, as were previous standardized cognitive ability tests such as SPM, TONI-3, WISC-III. For instance, the quality of criterion validity, SPM's criterion validity derived from Stanford-Binet and WISC showed the correlation coefficient was at .54 and .88 respectively (Raven et al., 1992). TONI-3's criterion validity derived from WISC-III and WISC-IV showed the correlation coefficient was at .70 and .78 respectively (Banks & Franzen, 2010). Likewise, the criteria validity of CATTS, which was obtained from the SPM, revealed that the correlation coefficient was at .77. Furthermore, a tester could finish CATTS in 45 minutes as opposed to 70–120 minutes for WISC–III. CATTS provides convenience for the testers as Ackerman and Kanfer (2009) discovered that as test takers spend more time on a task, their level of weariness increases. According to students who are between 10–12 years old, they tend to experience cognitive fatigue when doing long tests in 100 minutes (MacCormack, 2011). However, older students may be provided with the option to take the test with an extent time limit. For example, Sujiva et al. (2020) conducted an online cognitive skills test for secondary school students, allowing them a total of 210 minutes for completion.

CATTS is suitable to assess cognitive abilities for Thai students because its development is based on Thai contexts. While there are several standard cognitive tests used to evaluate children's cognitive abilities, most of them have been developed out of a western context which might not suit children from different cultures. Ueno and Nakatani (2003) used WISC-III for Japanese and found that some items have culture bias and are not compatible with Japanese culture. Several studies in other countries revealed similar results, indicating that several standard cognitive tests drawn from other cultures needed to be adapted to suit local users (Chen et al., 2003; Kwak, 2003; Sato et al., 2004; Suzuki, 2021).

Criterion Norm of Cognitive Ability Test

CATTS created a norm-referenced test based on the percentile, similar to previous cognitive ability tests, such as SPM. Moreover, norm classification of CATTS scores also parallels with SPM scores in term of level classification. For example, SPM are classified into five grades (Raven et al., 1992), whereas CATTS scores are grouped into four grades. To make user friendly, CATTS provides details for each criterion and adjusts Thai words to be more positive such as GRADE I: Scores lying below the 25th percentile mean "developing level".

Conclusion

Findings from this study have demonstrated a valid measurement model of cognitive abilities of Thai students, including 4 components and 13 indicators; (1) The information processing component: perception, learning new things, and applying knowledge subscales; (2) The thinking component: reasoning, analytical thinking, numerical thinking, planning and problem-solving, and creative thinking subscales; (3) The language component: encoding and recoding subscales; (4) The accomplishment component: utilizing skills, goal attainment, and adaptability subscales. Norm of Thai student cognitive abilities has been categorized into four categories: developing, typical, generally exceptional, and outstanding levels.

Recommendations

Recommendations for Application

CATTS created in this study is a reliable cognitive ability test and can be implemented in a classroom setting, allowing a teacher to use the test to facilitate student progress. A school teacher must strictly adhere to the instructions when administering the test. A school teacher can also use the framework of cognitive abilities that has been established from this study to increase students' cognitive abilities by applying it to a curriculum outline.

Recommendations for Future Research

Firstly, this study has formulated a robust measurement model that encompasses four pivotal core components of cognitive abilities. This model was meticulously developed and empirically examined in collaboration with upper primary school students. Consequently, to enhance the robustness and generalizability of the findings, future research endeavors should consider extending the investigation to encompass diverse cohorts. By including different age groups or educational levels, these subsequent studies can facilitate a comprehensive comparative analysis of the results vis-à-vis the outcomes of the current study, thereby offering a more comprehensive understanding of the broader implications of the proposed measurement model. Next, given that learning platforms have lately gone online, future studies should think about creating a cognitive test in an online format. Therefore, an online cognitive test would be an additional choice for evaluating students' cognitive ability.

Conflict of Interest

The authors declare that there is no conflict of interest.

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