# *Testing Measurement Invariance of Synthesizing Mind Model of Thai Students: Multi-group Analysis*

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**Abstract**
Nowadays, information flows quickly without any limitations on distance. Humans possessing synthesizing mind do not waste time when synthesizing the deluge of data, are able to select useful data and avoid data causing danger. This study aimed to examine the consistency of the synthesizing mind model with empirical data and to study invariance of the synthesizing mind model of students classified in accordance with the demographical variable of gender. The research sample consisted of 580 lower secondary school students. The research instrument was a 30 item self-report survey on synthesizing mind developed according to the 4 factors of synthesizing mind including access, synthesize, evaluate, and create. An analysis of Second Order Confirmatory Factor showed that the synthesizing mind model is consistent with empirical data. There was no invariance of the synthesizing mind model between the groups of male and female students.


Keywords: Measurement Invariance, Synthesizing Mind, Gender, Factor Analysis

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**Introduction**

Nowadays, it is the era of rapid economic and social changes due to the power of Information Technology (IT). These rapid changes in the global society (James et al., 2010) directly affect Thai society in the aspects of economy, politics, education and society. The advancement of technology allows the deluge of information. Educational management plays an essential role in cultivating learners to have effective thinking so that it can be applied as a tool for data management, knowledge quest and learning in the present and the future world. Teaching learners to be effective thinkers is an urgent aim for educational management because thinking is a significant tool that learners can be further applied in information management in the rapidly changing world and for things that may happen in the future. Many countries across the world have realized the importance of preparing learners with high potential who are ready to live their lives in the world with unexpected future.

As mentioned earlier, educational management for thinking development is an urgent matter for Thailand, especially emphasizing on development of analysis and synthetic thinking abilities. These abilities enhance sequential thinking processes. Beyer (1983) mentioned that critical thinking involved processing data through analytical thinking and synthesizing thinking. Similarly, Gardner (2007) summarizes that synthesizing mind is an ability to gather information from several sources for selection and evaluation, leading to classify issues or significant factors and create new information technology meaningful to themselves and others. It is a creative and innovative concept since people are currently facing increasing amount of information. Gardner (2007) receives the concept of Synthesizing Mind from Murray Gell-Mann, a Nobel Prize winning physicist from America. He stated 15 years ago that the most significant mind in the 21st century is synthesizing mind. Especially, in the current world where information flows quickly without any limitations on distance, humans possessing synthesizing mind do not waste time when synthesizing the deluge of data, are able to select useful data and avoid data causing danger. Importantly, cultivating the youth with synthesizing thinking ability is similar to building a shield against the threat for their future. Furthermore, synthesizing mind is more complicate than analyzing because it brings what is analyzed together or classify matters. This allows new knowledge creation and thorough and insight understanding which can be applied beyond analyzing level. Therefore, synthesizing thinking is significantly essential to those who seek success in working life, personal life and peaceful life in the society (Gelen, 2015; Hartnett-Edwards, 2013).

The researcher is interested in investigating the synthesizing mind model of learners in Thai context. The investigation was carried out with lower secondary school students. Invariance of the measuring model in accordance with the demographical variable of students' gender was conducted since there might be the differences of mental characteristics between males and females in different environment. That is, different environment may differentiate the variables to be measured (Herrera, Grossman, Kauh, Feldman, & McMaken, 2007; Karcher, 2008). The researcher wanted to know whether students with different gender are similar or different and how they are similar or different. The present study addressed the following research objectives. First, it aimed to examine the consistency of the synthesizing mind model with empirical data. Second, it aimed to study invariance of the synthesizing mind model of students classified in accordance with the demographical variable of gender.

**Objective**

This research aims to 1) examine the consistency of the synthesizing mind model with empirical data, and 2) study invariance of the synthesizing mind model of students classified in accordance with the demographical variable of gender.

**Methodology**

**1. Sample**

The research sample consisted of 1,555,060 lower secondary school students (Grade 7 − 9) under the Basic Education Commission across the country. The concept of Hair at al. (2010) called rule of thumb was applied to identify the size of the research sample. It is said that a size of the sample should consist of at least 10 − 20 persons per one parameter. Since there were 10 observable variables in this study, 29 parameters were identified. As a result, the appropriate size of the sample consisted of at least 580 students. The cluster random sampling was employed to each region. The stratified random sampling was applied to select schools in each province. Lower secondary school level was selected to be stratified. The sample size was proportionally identified by the rule of three.

**2. Measure**

In this study, the researcher examined the variables from the 4 factors of synthesizing mind including 1 access, 2 synthesize, 3 evaluate, and 4 create.
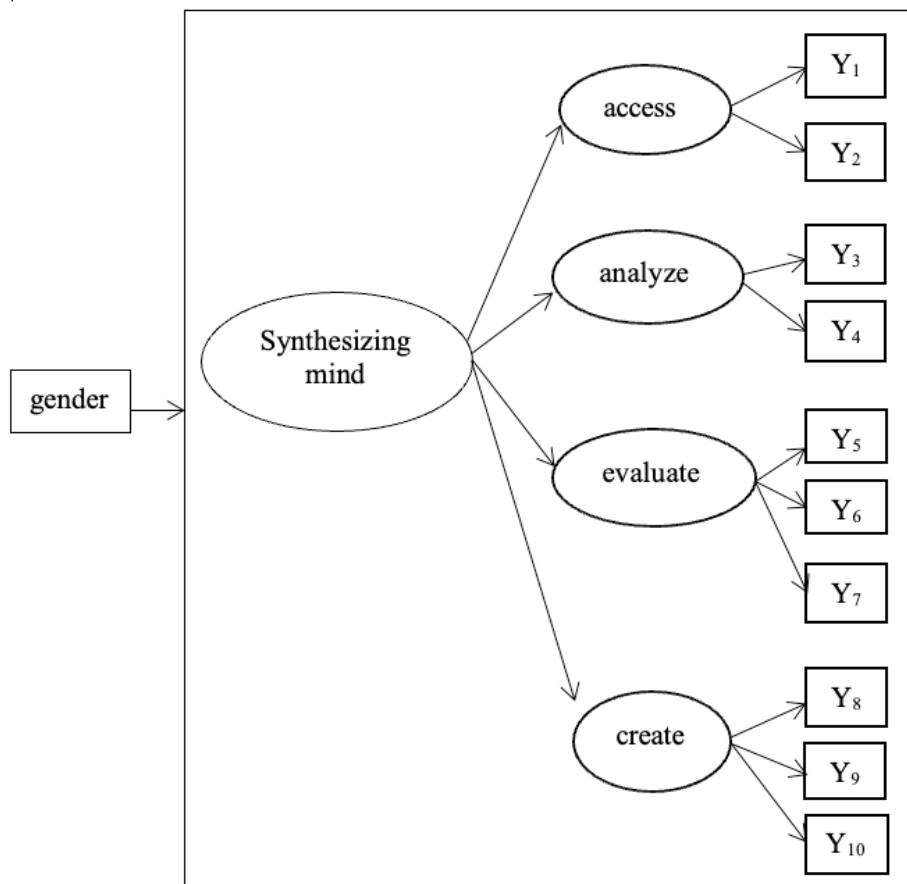


Figure 1: Conceptual Framework

The research instrument was a self-report survey on synthesizing mind developed according to the 4 factors of synthesizing mind. The survey was divided into 2 sections as follows.

Section 1: General information survey consisting of gender, grade and age. The question items were in a checklist format.

Section 2: Synthesizing mind test consisting of 30 items based on the 4 factors of synthesizing mind. The test provided 5 rating alternatives including 1= not at all true to 5 = very true. The rating alternatives were conversed for negative question items.

## 3. Construction of Research Instrument

The researcher carried out the following steps to construct measuring tool of synthesizing mind.

1) Identify objectives of research instrument construction.
2) Study theories, documents and research related to synthesizing mind to be used as guidelines to create operational definitions for constructing measuring test.

Table 1: Definitions and factors of synthesizing mind

| Technical terms/ Factors | Definitions | References |
|---|---|---|
| Synthesizing mind | An ability to gather information from several sources for selection and evaluation, leading to classify issues or significant factors and create new information technology meaningful to themselves and others. It is a creative and innovative concept and an ability to create new things with structures or roles different from the existing ones. | - Gardner (2007)<br>- Harrison & Bramson (2002)<br>- Tallim (2003)<br>- Thoman & Jolls (2008) |
| Access | Expression of Information Technology with full and rapid receiving, understanding of content, seeking information from several sources and not overly limited to one source. Ability to synthesize different types of information consistently. | - Partnership for 21$^{st}$ Century Skills (2011)<br>- Tallim (2003)<br>- Thoman & Jolls (2008)<br>- Baran (2004)<br>- Potter (2013)<br>- Wood (2011)<br>- Hobbs (2007)<br>- Bachmair & Bazalgette (2007) |

| Technical terms/ Factors | Definitions | References |
|---|---|---|
| Analyze | Expression of informing or explaining in order to analyze truths, exaggerated offers, advantages, disadvantages from data of information technology influencing themselves and others by selectively receiving information and to give reasonable reasons to support it. | - Partnership for 21st Century Skills (2011)<br>- Tallim (2003)<br>- Thoman & Jolls (2008)<br>- Baran (2004)<br>- Potter (2013)<br>- Wood (2011)<br>- Hobbs (2007)<br>- Bachmair & Bazalgette (2007) |
| Evaluate | Decision making demonstrating whether to believe or not, to receive or refuse information from different sources that has been analyzed information innovative and useful for themselves and others, leading to interpretation and translation of meaning of information. | - Partnership for 21st Century Skills (2011)<br>- Tallim (2003)<br>- Thoman & Jolls (2008)<br>- Baran (2004)<br>- Potter (2013)<br>- Wood (2011)<br>- Hobbs (2007)<br>- Bachmair & Bazalgette (2007) |
| Create | Expression of presenting data from information technology, body of knowledge and opinions appropriately and directly through different forms with innovative and creative ideas. | - Partnership for 21st Century Skills (2011)<br>- Tallim (2003)<br>- Thoman & Jolls (2008)<br>- Baran (2004)<br>- Potter (2013)<br>- Wood (2011)<br>- Hobbs (2007) |

3) Define operational definition of synthesizing mind from what has been studied and identify questions.

4) Write 30 questions according to the operational definition consisting of 4 main factors and 10 sub-factors.

5) The constructed test was examined by 5 experts to justify whether the questions were able to accurately measure students according to the operational definition and whether the language was appropriate or needed revision. The IOC was 0.6-1.00. Then, the constructed test was revised according to the suggestions.
6) The approved test was used among 100 students to verify its reliability, using Cronbach's Alpha. The reliability of synthesizing mind indices was at 0.96.
7) The revised test was employed to collect data from the sample to verify construct validity and measure invariance of model in accordance with the demographical variable of gender.

**Results**

The sample consisted of 580 lower secondary school students including 290 male and female students equally or 50 percent. A majority of the students or 210 students was in Grade 9 (36.21%). Most of the students or 239 students was 15 years old (41.21%).

1) Analytical results of the second order confirmatory factor analysis of the synthesizing mind model

Statistical value of KMO was at 0.873 and Bartlett's Test value was at a statistical significance of 0.01. Therefore, indicator information of synthesizing mind was highly appropriate for the next factor analysis.



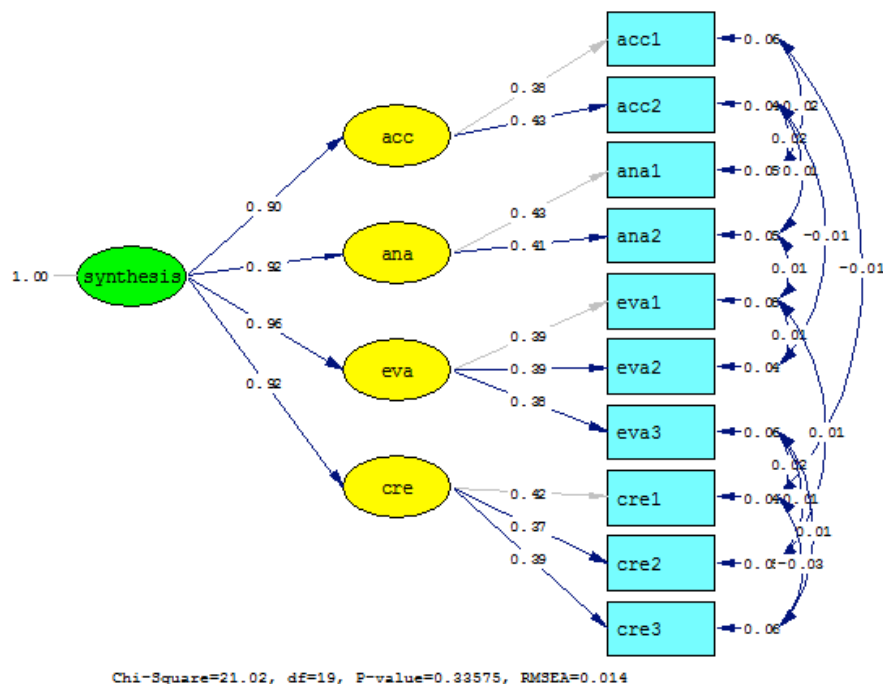Chi-Square=21.02, df=19, P-value=0.33575, RMSEA=0.014

Figure 2: Factor analysis model and indicators of synthesizing mind

According to Figure 2, the developed synthesizing mind model was consistent with empirical data. The consistency between the model and empirical data was statistically significant as follows. The chi-square was at 21.02 (P=0.336) with the degree of freedom at 19, GFI was at 0.993, AGFI was at 0.979, RMR was at 0.002 and RMSEA was at 0.014.

Factor analysis model and synthesizing mind indices showed the consistency with empirical data. When factor loading was considered, the factor loading was significantly at .01. This showed that factor analysis model and synthesizing mind indices possessed construct validity.

2) Analytical results of invariance of the synthesizing mind model of students classified in accordance with the demographical variable of gender

For the testing measurement of invariance of the synthesizing mind model, the researcher employed the developed synthesizing mind model to verify the validity of the model until the model was consistent with empirical data (2= 21.01, P= 0.336, df= 19, GFI= 0.993, AGFI= 0.979, and RMSEA= 0.002). The testing was carried out in accordance with the demographical variable of gender of the 2 groups consisting of 290 male students and 290 female students each.

Table 2: Results of testing on invariance of the synthesizing mind model

| Model according to assumption | $\chi^2$ | P | RMR | RMSEA | GFI | CFI | RFI | NFI |
|---|---|---|---|---|---|---|---|---|
| 1.Format | 0.12 | 0.94 | 0.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2.Format, LX | 6.35 | 0.39 | 0.01 | 0.01 | 1.00 | 1.00 | 0.99 | 1.00 |
| 3Format, LX, TD | 42.50 | 0.00 | 0.05 | 0.05 | 0.99 | 0.99 | 0.98 | 0.99 |
| 4.Format LX, TD, PH | | | | Test ended | | | | |

According to Table 2, the synthesizing mind measuring model between the groups of male and female students demonstrated invariance of the model format and of the parameters of regression coefficient of observable variables on exogenous latent variables. Therefore, the developed synthesizing mind test did not demonstrate variance among students' gender as shown in Figure 3 and 4.
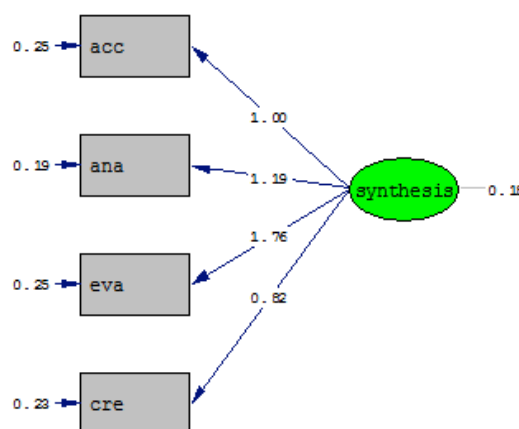


Chi-Square=6.35, df=5, P-value=0.38504, RMSEA=0.009

Figure 3: Parameters of invariance of male students when LX=IN
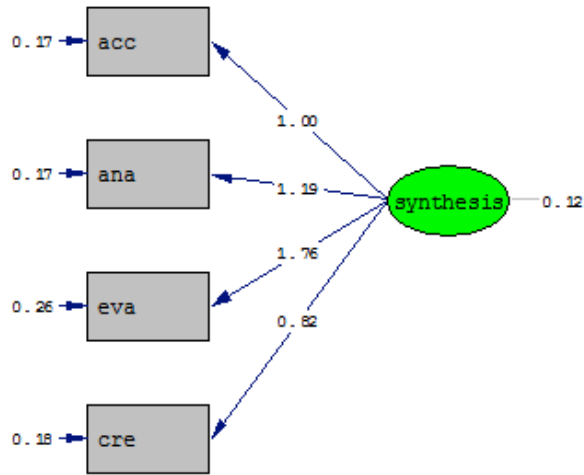
Chi-Square=6.35, df=5, P-value=0.38504, RMSEA=0.009

Figure 4: Parameters of invariance of female students when LX=IN

**Conclusion and Discussion**

According to the results mentioned above, this study shows interesting points as follows.

1) The validity result between the synthesizing mind model of Thai students and empirical data made from second order confirmatory factor showed that the model was consistent with empirical data. Since the researcher studied related documents and literature about synthesizing mind written by several scholars, the model was developed to be consistent with empirical data. The factor with the highest factor loading was evaluation probably due to the fact that the schools trained the students to be diligent for knowledge quests, to seek different sources of information and to be information collectors. Sufficient information database can be advantages. The collected information was analyzed to classify information innovative and useful for themselves and others, leading to interpretation and translation of meaning of the information (Gardner, 2020; Altındağ, & Sinemoğlu, 2018).

2) The testing result of structural equation model invariance of multi-groups of synthesizing mind indices among students classified in accordance with the demographical variable of gender showed that there was invariance of model format. That is, the 4 factors could be employed to measure synthesizing mind in both male and female students. This is consistent with the theory of Bollen (1989) stating that a model from 2 groups of population demonstrates a format with invariance when all variables in that model and structural relationship between the variables in both models is the same. In other words, matrix parameters of both models are similar and have the same size. In addition, mode of parameters in that matrix is fixed parameters, free parameters and constrained parameters. However, parameter values are not necessarily equal.

**Suggestion**

1) The synthesizing mind test should be interpreted together with observation form, interview form and other evaluation tools to obtain information consistent with the truth, accurate and can be guidelines for student behavior development.

2) Comparative studies using other demographical variables such as race, region or organization etc. for testing measurement of invariance should be further examined to identify whether there is invariance of measurement. This will allow interesting information beneficial for development of synthesizing mind model.

3) There are several issues about synthesizing mind to be investigated. For instance, casual factors influencing possession of synthesizing mind which probably composes of different factors essential to development of synthesizing mind should be further studied.

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