



Development of learning and innovation skills assessment criteria for upper secondary school students: A multilevel confirmatory factor analysis using mixed-method design

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Abstract

This research aimed to analyze multilevel confirmatory factors and develop learning and innovation skills assessment criteria by using a multilevel mixed-method design. Six hundred upper secondary school students derived from multi-stage random sampling for quantitative study were analyzed, and 13 experts from purposive sampling were interviewed by an in-depth interview technique. Questionnaires on learning and innovation skills were distributed to the students in 60 schools around Thailand. The results of this study showed: (1) the multilevel confirmatory factor analysis model; consisted of five factors namely critical thinking, effective communication, quantitative and scientific reasoning, technological competency and information, and responsible citizenship; was consistent with the empirical data, and (2) learning and innovation skills assessment criteria for upper secondary school students consisted of 21 indicators and 21 assessment criteria and were in outstanding level, both student and school level.

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Introduction

21st Century skills have a great impact on global education. Many countries have embarked on educational reform to meet the challenge of the demand for 21st Century skills. For example, Thailand decided to launch the national education reform, called the educational reform of the second decade, by adjusting the basic education curriculum to be the core curriculum with the teach-less-learn-more concept. The reform aims were that all students who complete basic education must have universal knowledge (Ministry of Education, 2008). Over the last decade, there has been evidence that the education reform needs to be refined. Extensive expansion of advanced media and technology has played an important role in human life (Kay, 2010). In this era of disruptive changes, the previous educational system is not adequate in meeting the goal of bringing a better quality of life to

the present young generation and the generations to come. Thus, a new design for learning and assessment of the 21st Century skills must be developed for the learners to ensure that they learn and possess the necessary skills which will help them have a good quality of life and live happily. Of the 21st Century skills set, learning and innovation skills are considered one of the most important ones for everyone in the 21st century (Deemee & Lincharoen, 2017).

Darling-Hammond and McCloskey (2008) proposed the idea of assessing learners' skills in the 21st Century skills where real assessments should not be limited to only tests, but the assignment of works for students to do on their own. After that, suggested ideas and comments from instructors could then foster students' perception in a detailed manner. Moreover, there are many studies related to 21st Century skills assessment such as interactive learning assessment for 21st Century (Svhila et al., 2009), and thinking skills assessment of students at Matthayomsuksa 6 (Chaktrmongkhon, 2015) in this study.

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From the importance of learning and innovation skills, as well as the importance of assessing the 21st Century skills, teachers at basic education levels must teach students to have international characteristics and potential. Learners should be able to think, analyze, synthesize, create, and communicate effectively. Thus, assessing students' skills is also important.

The study aimed to analyze multilevel confirmatory factors of learning and innovation skills for upper-secondary school students and develop learning and innovation skills assessment criteria for upper-secondary school students at student level and school level.

Conceptual Framework

Assessment Task Force (2007) was used as the conceptual framework of this research, which divided learning and innovation skills into five factors such as effective communication, technological competency and information literacy, critical thinking, quantitative and scientific reasoning, and responsible citizenship. The multilevel mixed-method design (Edmonds & Kennedy, 2017) with multilevel confirmatory factor analysis and in-depth interview were used in this study as shown in Figure 1.

Literature Review

The 21st Century skills set is an important and necessary element for students' learning skills in the 21st century. The traditional education system during the 20th century, which emphasized only learning and memorizing the main subject content such as mathematics, science, linguistics, social studies, is no longer enough or cannot be used in mundane activities and especially in a technologically-focused environment. The 21st Century skills concept is based on the learning achievement, "skills", such as advanced thinking

skills, learning and innovation skills, life and working skills, and information and communication skills. Some authors hold slightly different views of the 21st Century skills. For example, Trilling and Fadel (2009) consider the 21st century skills to consist of learning and innovation skill, information, media and technology skills, and life and career skills. There are many research studies on the 21st Century skills such as by Ongardwanich, Kanjanawasee, and Tuipae (2015) who developed the 21st Century skills' scales consisting of learning and innovation skill, information, media and technology skills, and life and career skills. Deemee and Lincharoen (2017) developed an approach for assessment of learning and innovation skills using assessment of learner's method in the 21st Century. Furthermore, Issarapap and Samutai (2019) studied indicator development of the 21st Century skills in learning and innovation for lower secondary school students with a sample size of 1,030 students.

In USA, College of Philadelphia has used Community College of Philadelphia Learning Outcomes Assessment Model (Assessment Force Task, 2007) as the model of learning and innovation skills, by dividing such into five factors such as effective communication, technological competency and information literacy, critical thinking, quantitative and scientific reasoning, and responsible citizenship. All these skills will be needed by students for life. Criteria play a role in building the competitiveness of the organization, such as improving operation methods, empowering and effectiveness of organization. Moreover, criteria should work as a tool to understand and manage the performance of the organization (National Productivity Institute, 2013). The development of criteria and indicators should focus on precision and validity (Roongruangsri, 2007). Thus an assessment of learning and innovation skills criteria is needed.

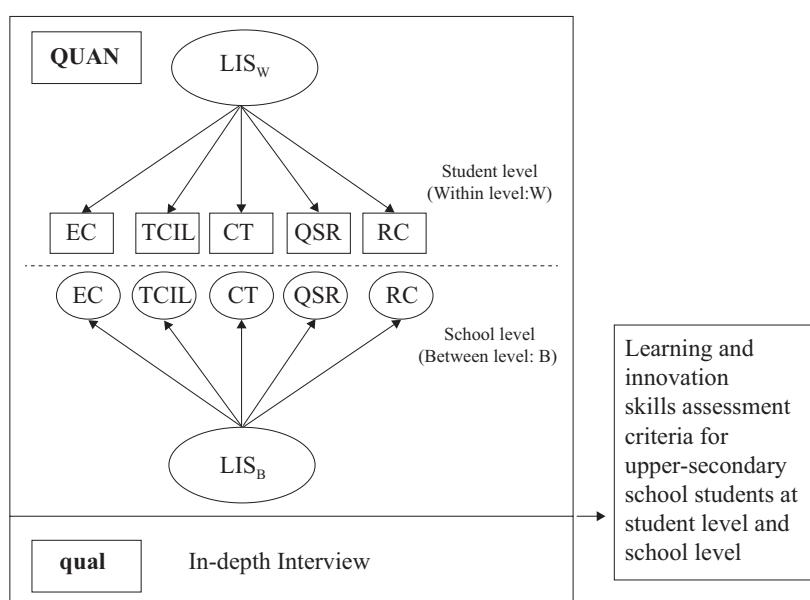


Figure 1 Conceptual Framework

Methodology

This study used multilevel mixed-method design (Edmonds & Kennedy, 2017), with 600 upper-secondary students derived from multi-stage random sampling and 13 experts from purposive sampling. Multilevel confirmatory factor analysis and content analysis from in-depth interviews were used for data analysis. The research was conducted in steps as follows Figure 2:

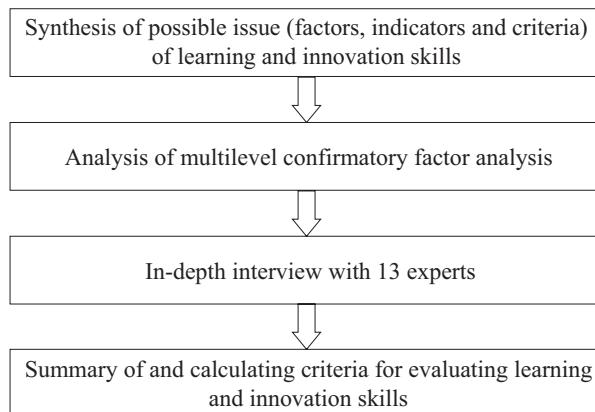


Figure 2 The step for the development of learning and innovation skills assessment criteria for upper secondary school students

Calculation of criterion scores is emphasized by the following Equation (1):

$$\sum_{(i=1,n)}(W_iIS_i) = W_1IS_1 + W_2IS_2 + W_3IS_3 + W_4IS_4 + W_5IS_5 \quad (1)$$

S means the sum of five factors assessment score

N means the number of factors (five factors)

W means weighted factor

IS means indicator score

This research was endorsed by the Human Ethic Research Committee, Burapha University, and granted the certificate of approval, Hu099/2561.

Results

Multilevel Confirmatory Factor of Learning and Innovation Skills

The result of the multilevel confirmatory factor analysis of learning and innovation skills showed that all fixed index values were consistent with the model criteria. Table 1 shows the model fixed index and factor loading for multilevel confirmatory factor of learning and innovation skills.

In-depth Interview Result

The result of in-depth interview of 13 experts in relation to the important factors of learning and innovation skills showed that 9 experts among 13 agreed that critical thinking was the most important skill and the second most important was effective communication. Most of them said that critical thinking should be an important skill for students because everyone must think or analyze information before speaking or making decisions. Moreover, students should be able to think independently. However, 4 experts said that effective communication was the most important skill and the second most important was critical thinking.

Table 2 shows the results of all factors loading for all expert comments where Table 3 shows all the factors and indicators loading respectively.

The synthesis of learning and innovation skills' factors and indicators, multilevel confirmatory factor analysis, and in-depth interview with experts revealed that there were five factors, 21 indicators and 21 assessment criteria as shown in Table 4, where the calculation level of learning and innovation skills criteria are emphasized in Table 5.

Table 1 Factor loading and fixed index

Variables	Student level (Within level: W)				School level (Between level: B)				ICC
	β	SE	t	R^2	β	SE	t	R^2	
EC	.722**	.056	12.814	.521	.997**	.039	25.605	.995	.196
TCIL	.542**	.068	7.929	.294	.996**	.120	8.291	.991	.163
CT	.732**	.048	15.135	.536	1.000**	.000	28254.324	.999	.214
QSR	.641**	.039	16.608	.411	.993**	.024	41.235	.987	.163
RC	.132*	.053	2.481	.017	.746**	.185	4.042	.556	.075

$\chi^2 = 14.169$, df = 9, $\chi^2/df = 1.574$, $p = .116$, RMSEA = .031, CFI = .993, TLI = .984,
 $SRMR_W = .009$, $SRMR_B = .040$

Note: Effective Communication: EC, Technological Competency and Information Literacy: TCIL, Critical Thinking: CT, Quantitative and Scientific Reasoning: QSR, and Responsible Citizenship: RC, standardize factor loading: β , Standard Error: SE, t-value: t, Coefficient of Determination: R^2 , Intraclass Correlation Coefficient: ICC. * $p < .05$, ** $p < .01$.

Table 2 Factor loading of learning and innovation skills at student level and school level from 13 experts

Factor	Percentage	
	Student level (Within level: W)	School level (Between level: B)
Critical Thinking	25.750	26.000
Effective Communication	24.000	24.166
Quantitative and Scientific Reasoning	19.333	16.084
Technological Competency and Information Literacy	16.333	18.750
Responsible Citizenship	14.584	15.000

Table 3 Indicator loading of learning and innovation skills in student level and school level

Indicators	Percentage	
	Student level (Within level: W)	School level (Between level: B)
Critical Thinking		
Able to use logic in decision making	31.112	31.111
Able to seek answers from various facts and evidence	28.333	27.778
Able to separate and analyze data	18.889	12.222
Able to anticipate things in advance	13.333	15.556
Able to use various principles and reasons to solve problems	8.333	13.333
Effective Communication		
Able in choosing to use communication methods to achieve goals	37.500	35.000
Able to explain to others to understand easily	31.667	19.167
Able to communicate with others effectively	20.000	28.333
Able to speak in public with confidence	10.833	17.500
Quantitative and Scientific Reasoning		
Able to learn course related to numbers	37.500	26.667
Able to think logically	30.833	16.666
Able to learn new things related to science and mathematics	18.334	30.000
Able to calculate numbers quickly without errors	13.333	26.667
Technological Competency and Information Literacy		
Able to search information through internet and website	38.889	31.945
Able to use information technology for school and daily life activities	36.111	29.167
Able to do basic computer care	25.000	38.889
Responsible Citizenship		
Able to do whatever we can do to protect the environment	32.222	23.889
Not making a loud noise when others are studying	26.111	23.889
Able to soothe friends when they feel sad	20.556	21.667
Not cheating	13.889	23.889
Able to make a better difference in the community or classroom	7.222	6.666

Table 4 Assessment criteria of learning and innovation skills

Factor	Indicator	Criteria
Effective Communication	1. Able to communicate with others effectively 2. Able in choosing to use communication methods to achieve goals 3. Able to explain to others to understand easily 4. Able to speak in public with confidence	- Speak or use appropriate language for communication - Choose various methods to increase communication efficiency in order to achieve goals - Speak and explain to others to understand easily - Prefer to speak or do presentation in the classroom
Technological Competency and Information Literacy	1. Able to do basic computer care 2. Able to search information through internet and website 3. Able to use information technology for school and daily life activities	- Understand how to use and maintain the computer - Understand how to search information through the internet, websites or various information systems - Use a computer or the internet to do homework or find Information data to use in studying
Critical Thinking	1. Able to separate and analyze data 2. Able to use logic in decision making 3. Able to seek answers from various facts and evidence 4. Able to anticipate things in advance 5. Able to use various principles and reasons to solve problems	- Distinguish information, whether true or false - Make decisions based on reason, not emotion - Seek answers from the facts and evidence to solve problems. - Able to anticipate in advance - Able to solve immediate problems by using reasoning
Quantitative and Scientific Reasoning	1. Able to learn new things related to science and mathematics 2. Able to learn course related to numbers 3. Able to think logically 4. Able to calculate numbers quickly without errors	- Prefer learning science and mathematics - Prefer doing math exercise - Think reasonably and logically - Think or calculate quickly with little error
Responsible Citizenship	1. Able to make a better difference in the community or classroom 2. Able to do whatever we can do to protect the environment 3. Not making a loud noise when others are studying 4. Able to soothe friends when they feel sad 5. Not cheating	- Prefer finding ways to improve the better classroom or community - Creating new innovation that enables reducing global warming - Not making a loud noise while others are studying - Being a counselor or a person who helps to soothe others when they feel sad or have stress - Being a good person and not doing any fraud

Table 5 The calculation level of learning and innovation skills criteria

Factor	Student level		School level	
	Weight (W)	IS	Weight (W)	IS
Critical Thinking	.258	5	.260	5
Effective Communication	.240	4	.242	4
Quantitative and Scientific Reasoning	.193	4	.161	4
Technological Competency and Information Literacy	.163	3	.188	3
Responsible Citizenship	.146	5	.150	5

The calculation level of learning and innovation skills criteria emphasized by the following Equation (2)–(4):

$$\sum_{(i=1,n)}(W_iIS_i) = W1IS1 + W2IS2 + W3IS3 + W4IS4 + W5IS5 \quad (2)$$

Student level

$$\text{Weighted Sum Model} = (.258*5) + (.240*4) + (.193*4) + (.163*3) + (.146*5) = 4.241 \quad (3)$$

School level

$$\text{Weighted Sum Model} = (.260*5) + (.242*4) + (.161*4) + (.188*3) + (.150*5) = 4.226 \quad (4)$$

The level was ranged as following:

Level 1, points from 0.000–1.000 results of the level of the learning and innovation skills in the level of need to improve.

Level 1, points from 1.001–2.000 results of the level of the learning and innovation skills in fair level.

Level 3, points from 2.001–3.000 results of the level of learning and innovation skills in good level.

Level 4, points from 3.001–4.000 results of the level of learning and innovation skills in very good level.

Level 5, points from 4.001–5.000 results of the level of learning and innovation skills in the outstanding level.

As stated above, learning and innovation skills in both student and school level were in the outstanding level.

Discussion

To address the first research aim, the multilevel confirmatory factor analysis of learning and innovation skills for the upper-secondary school students was analyzed. It was found that the model was consistent with the empirical data (all the fixed indices were consistent with the model criteria), implying that the model developed was consistent with the Assessment Task Force (2007) concept with the most important factor of learning and innovation skills being critical thinking. As discussed in Ketnam (2007), adolescents must focus on analytic, critical thinking, and problem solving to be able to evaluate various information for decision making or to have different perspectives needed for proficient problem solving. This study is in-line with Nold (2017) who said that critical thinking helped the students to synthesize complicated information and then transferred such to be new intervention. Moreover, Fong, Kim, Davis, Hoang, and Kim (2017) showed that critical thinking and problem solving were a part of student long-term success, and the World Health Organization (WHO, 1997) specified that critical thinking skill profoundly affects lifestyle. This is in agreement with Phanit (2015) who stated that it was an important goal for students to learn to

think logically and analytically to be able to compare and evaluate different opinions.

Effective communication was the second most important skills and very necessary for studying. Trilling and Fadel (2009) explained that communication and collaboration was the ability to communicate effectively with clear thinking, clear concepts and having good attention with the partners' speaking.

Learning and innovation skills assessment criteria of this study consisted of five factors as follows (1) Critical Thinking consisted of five indicators and five assessment criteria; (2) Effective Communication consisted of four indicators and four assessment criteria; (3) Quantitative and Scientific Reasoning consisted of four indicators and four assessment criteria; (4) Technological Competency and Information Literacy consisted of three indicators and three assessment criteria; and (5) Responsible Citizenship consisted of five indicators and five assessment criteria. This is consistent with the framework of the Assessment Task Force (2007) learning and innovation skills consisting of five factors, however, differs from the results of Jaikla and Ketchatturay (2019); Trilling and Fadel (2009) and Ongardwanich et al. (2015) who found that learning and innovation skills had three factors, namely, creative thinking and innovation, critical thinking and problem solving, and communication and cooperation. Although there are differences, these three factors are consistent.

Conflicts of Interest

There is no conflict of interest.

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