A Second Order Confirmatory Factor Analysis of Senior High School Students' Learning and Innovation Skills Model Guidelines

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Abstract

This study aimed to investigate construct validity of the learning and innovation skills model for senior high school students with the empirical data which supported the guidelines for learning and innovation skills development of senior high school students. The sample consisted of 300 senior high school students from the Office of Secondary Education Area 39 for the academic year 2021, who were chosen through multi-stage random sampling. The instrument was a Behaviorally Anchored Rating Scale (BARS) for assessing learning and innovation skills. A second order confirmatory factor analysis was used to examine the data. The findings revealed that senior high school students' learning and innovation skills comprised of three major components: 1) critical thinking and problem solving, 2) communication and collaboration, and 3) creativity and innovation. The correlation matrix analysis of 8 observed variables of senior high school students' learning and innovation skills revealed a level of statistical significance of .05, the correlations ranged from .141 to .515, and KMO was 0.807. A second order confirmatory factor analysis of learning and innovation skills revealed that the model was consistent with the empirical data (c^2 (14, n = 300) = 21.566, p = .088, CFI = .989, TLI = .979, RMSEA = .041, SRMR = .026). This empirical evidence showed that there were 3 main components for learning and innovation skills assessment of senior high school students that supported the guidelines for learning and innovation skills development of senior high school students.

Keywords: Learning and Innovation Skills Development, Learning and Innovation Skills, Second Order Confirmatory Factor Analysis

Introduction

Learning approaches of the 21st century are essential for effective and creative learning development. Partnership 21st century current knowledge and skills levels have created a framework that supports the outdated attitudes towards learning. Critical thinking and problem solving; communication and collaboration; and creativity and innovation are all components of revolutionized learning and innovation skills. Skills, which will allow students to survive and prosper in the 21st century, for students must adjust and use these skills as tools for life-long learning, living, and working creatively in a society that rapidly changes and becomes more complex (Deemee & Lincharoen, 2017; Battelle for Kids, 2019a).

Thailand 4.0, in particular, is an economic model that aims to create a value-based economy driven by innovation, technology, and creativity. As a result, learning activities must improve students' learning skills and the process of knowledge acquisition through learning-by-doing; so that students can construct a body of knowledge which can be applied in various sciences for creative integration in order to develop innovation that can meet the needs of society (Office of the Education Council, Ministry of Education, 2018). As a result, students who lack the necessary learning and innovation skills will have a difficult time when dealing with social issue; therefore, it is important for educators and stakeholders to develop learning approaches that can improve students' learning and innovation skills (Panich, 2012).

Learning and innovation skills are being recognized as the essential 21st century skills. Competences that help identify those students who are prepared for an increasingly complex life and work environments versus those who are not. Critical thinking and problem solving; communication and collaboration; creativity and innovation are all necessary fundamentals to prepare students for future work responsibilities, learning, and living (Battelle for Kids, 2019b). The Critical thinking and problem-solving concept is an important viewpoint that affords students the ability to think critically and conduct in-depth investigations on their own, while the Communication and collaboration concept provides students with the ability to effectively collaborate with others; that is, articulate their thoughts and ideas clearly and effectively through communication with diverse teams. Equally important to the perceptions of learning, the Creativity and innovation concept enable students to think creatively, allowing them the aptitudes required to solve problems through formation of an idea in which the innovation process will be developed (Ferrés & Masanet, 2017; O'Hara, 2017; Battelle for Kids, 2019a; Soderlund, 2020).

After discussing the components of learning and innovation skills, it is clear to the researcher that learning and innovation skills focus on critical thinking and problem solving, communication and collaboration, and creativity and innovation. These skills are beneficial for students who are preparing for increasingly complex lifestyles or work environments. However, the results of an international math and science assessment (TIMSS 2015) and the Program for International Student Assessment - PISA (PISA 2012 and PISA 2015) revealed a problem with Thai education quality. According to the TIMSS 2015 results, Thai students ranked 26th out of 57 countries in mathematics and science. Furthermore, PISA 2012 and PISA 2015 results revealed that Thailand was ranked 50 and 55, respectively, with a mean score in Reading, Mathematics, and Science lower than the OECD. These international assessment findings can be summarized as Thai students having low academic abilities in Reading, Mathematics, and Science. It is critical to develop students' abilities in comprehensive reading, critical thinking, problem solving, and creativity, particularly in Mathematics and Science, which are essential knowledge for creative thinking and innovation creation in order to develop Thailand's economy and industry (Office of the Education Council, Ministry of Education, 2018).

Additionally, the vision of the National Scheme of Education B.E. 2560-2579 (2017-2036), created by the Office of the Education Council, Ministry of Education (2017), aimed to encourage Thai people to learn. That is, they should obtain the fundamental educational skills and knowledge that will help them improve their quality of life, while maintaining learning aptitudes regarding life-long learning values related to living synchronously with the sufficiency economy philosophy and the changing world trends. Students must develop their cognitive learning skills; as well as, the process of knowledge acquisition through learning by doing in order for students to construct a robust body of knowledge. This new knowledge base will provide individuals with the skills needed to apply the knowledge to various sciences and arts fields which instigates creative integration that promote innovations which meet the social needs of a community. Thus, it is important to develop guidelines related to the learning and innovation skills development of senior high school students. A second order confirmatory factor analysis therefore can be used to verify the variables pertaining to the learning and innovation skills of senior high school students. Hair et al. (2010) and Literat (2014) have stated that confirmatory factor analysis is a statistical analysis technique used to reduce the overall amount of data in a research project. This technique enables researchers to comprehend the structure of variables that have been divided into distinct factor. One distinct advantage of factor analysis is that there is a reduction of measurement error, which allows the analyzed factors to be used more accurately in the future. The second order confirmatory factor analysis process,

which was performed, allowed the researcher to generate policies that could appropriately be applied to the learning and innovation skills of senior high school students.

Literature Review

Learning and innovation skills ideology is comprised of three words: skill, learning, and innovation. Skill is explained as a person's ability to do something well, particularly because that person has practiced a particular task. Learning is defined as the acquisition of knowledge, skills, attitudes, or desirable behavior through experience, study, or being taught both formality and informality, while innovation is denoted as a completely new or updated idea, method, action, or product of the thinker, Khammani (2011) and the Office of the Royal Society (2012; 2015).

Learning and innovation skills are being recognized as the essential 21st century proficiencies that separate students who are prepared for an increasingly complex life and work environments from those who are not. Critical thinking and problem solving, communication and collaboration, creativity and innovation are all necessary to prepare students for accessing and obtaining new knowledge and skills, so that they are able to enter into the future workforce, and prosper (Battelle for Kids, 2019b). According to Battelle for Kids (2019a), a person with learning and innovation skills will exhibit the following characteristics. The critical thinking and problem-solving perspective is an important viewpoint that provides students with the ability to reason effectively by employing various types of reasoning (inductive, deductive, etc.) as appropriate to the situation. Another aspect of critical thinking and problem solving is the ability to analyze how parts of a whole interact with one another to produce overall outcomes in complex systems. Then, judgments and decisions must be made using effective evidence, argument, claim, and belief analysis and evaluation. Individuals must analyze and evaluate major opposing points of view in order to synthesize and connect information and arguments. In order to solve various types of unfamiliar problems in both conventional and innovative ways, information and conclusions must be interpreted and drawn using the best analysis and critical reflection.

Communication and collaboration, another characteristic of learning and innovation skills, include the ability to communicate clearly using oral, written and nonverbal communication skills to effectively articulate thoughts and ideas in a variety of forms and contexts. Individuals must also be able to listen effectively in order to decipher meaning, which includes knowledge, values, attitudes, and intentions. Communication with others must be used for a variety of purposes (e.g., to inform, instruct, motivate, and persuade), and individuals must know how to use multiple media and technologies and judge their effectiveness a priori as well as assess their impact, as well as communicate effectively in diverse environments (including multi-lingual). Collaboration is essential for individuals who want to demonstrate their ability to work effectively and respectfully with diverse teams. Furthermore, team members must be flexible and willing to make necessary compromises to achieve a common goal, as well as share responsibility for collaborative work that contributes to an individual's value (Battelle for Kids, 2019a).

The perspective of creativity and innovation is an important viewpoint that allows individuals to think creatively using a variety of idea creation techniques (such as brainstorming) in order to generate new and worthwhile ideas (both incremental and radical concepts). To improve and maximize creative efforts, individuals must elaborate, refine, analyze, and evaluate their own ideas. Furthermore, when it comes to developing, implementing, and communicating new ideas, individuals must collaborate creatively with others. Being an open and responsive individual is essential for incorporating a group for the generation and acceptance of diverse perspectives and feedback into the work. Work must demonstrate originality and inventiveness while keeping in mind the practical

constraints of implementing new ideas. Individuals must view failure as an opportunity to learn; understand that creativity and innovation is a long-term, cyclical process of small successes and frequent mistakes. Innovations Act on creative ideas must be implemented to make a tangible and useful contribution to the field in which the innovation will occur (Battelle for Kids, 2019a).

It is clear that learning and innovation skills focus on critical thinking and problem solving; communication and collaboration; and creativity and innovation concepts that are important characteristics for students to possess as Thai citizens, global citizens in the 21st century. According to the National Scheme of Education B.E. 2560-2579 (2017-2036), created by the Office of the Education Council, Ministry of Education (2017), the aims of the administrators are to encourage Thai people to obtain basic education levels and life-long learning skills in conjunction with the Sufficiency Economy philosophy that helps improve the quality of life on individuals. Students must have learning skills as well as the processes in place to retain knowledge. They must also have the opportunity to develop through learning by doing; whereby, students are encouraged to construct a body of knowledge that can be applied in various sciences from practical learning.

It is important that individuals are able to comprehend the components of learning and innovation skills, using confirmatory factor analysis of learning and innovation skills to develop a pattern for development of learning and innovation skills. A second order confirmatory factor analysis therefore can be used to verify the variables pertaining to the learning and innovation skills of senior high school students. Hair et al. (2010) and Literat (2014) have stated that confirmatory factor analysis is a statistical analysis technique used to reduce the overall amount of data in a research project. This technique enables researchers to comprehend the structure of variables that have been divided into distinct factor. One distinct advantage of factor analysis is that there is a reduction of measurement error, which allows the analyzed factors to be used more accurately in the future. The conceptual framework of a second order confirmatory factor analysis of learning and innovation skills is shown in Figure 1.

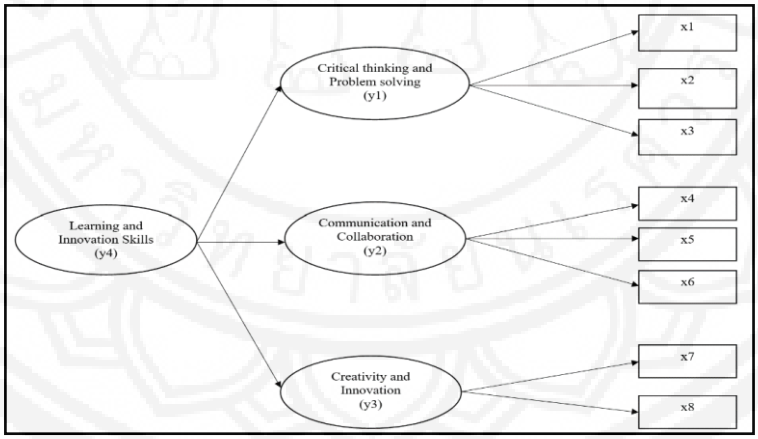

Figure 1 The Conceptual Framework.

Note: x1 = Examine the interactions of individual crisis by clearly defining the cause of the problems,
x2 = Effectively search, analyze, and synthesize information to develop a suitable solution,
x3 = Reflect critically on resolutions that will achieve better outcomes,
x4 = Effectively articulate one's thoughts and ideas orally, in written form, or nonverbally,
x5 = Effectively collaborate with others regardless of the form of communications to achieve a common goal,
x6 = Take advantage of multimedia and technology innovations to creatively improve and impact the learning of others,
x7 = Prompt brainstorming activities, creative thinking as a group, as a unit, which allows for the critically reflections on ideas that help generate creative ideas which produce innovation development,
x8 = Implement innovations projects that create robust and provoking which form tangible and useful contribution to a field of study.

Methods and Materials

This research was conducted using the steps involved in quantitative research as follows.

1. The components and observed variables of learning and innovation skills were studied and synthesized in accordance with the concepts of Fakkao (2015); Panich (2012); Sung-ong (2012); Sanrattana (2013); and Battelle for Kids (2019a). The study's components and observed variables involved the areas of Critical thinking and problem solving examines the interactions of individual crisis by clearly defining the cause of the problems. Moreover, allowing the participant to effectively search, analyze, and synthesize information to develop a suitable solution. Critical thinking and problem solving provides an opportunity for the individual to reflect critically on resolutions that will achieve better outcomes.

Communication and collaboration, another component of learning and innovation skills, included the ability to effectively articulate one's thoughts and ideas orally, in written form, or nonverbally. It is also imperative that individuals are able effectively collaborate with others regardless of the form of communications to achieve a common goal, while taking advantage of multimedia and technology innovations to creatively improve and impact the learning of others.

Creativity and innovation included the following observed variables that help to prompt brainstorming activities, creative thinking as a group, as a unit, which allows for the critically reflections on ideas that help generate creative ideas which produce innovation development and the implementation of innovations projects that create robust and provoking which form tangible and useful contribution to a field of study.

2. The instrument was a Behaviorally Anchored Rating Scale (BARS) of 24 items adapted from Ongardwanich's (2013) assessment test for evaluating learning and innovation skills. For this study, the 24 items were slightly modified, and the questions used an application of test accessibility approach, which included item stimulus, item stem, visuals, answer choices, and page/item layout. The content validity of the assessment test was determined using the Index of Item - Objective Congruence (IOC). The Index of Item - Objective Congruence (IOC) ranged from 0.67 to 1.00. The Cronbach Alpha Coefficient was used to determine the reliability of the assessment test, and the alpha coefficient was 0.91.

3. The sample consisted of 300 senior high school students from the Office of Secondary Education Area 39 for the academic year 2021, who were chosen through a multi-stage random sampling. The number of samples was determined using Kline's (2011) criterion, which recommends a minimum sample size of 200 for satisfactory results in confirmatory factor analysis. The sample size for this study involved 300 senior high school students, which exceeded the criterion for satisfactory results in confirmatory factor analysis. Stratified random sampling was used to divide schools into four school sizes: extra-large (over 2,500 students), large-sized (1,500 to 2,499 students), medium-sized (500 to 1,499 students), and small-sized (less than 500 students). However, simple random sampling was used to select 12 out of 41 schools, while three schools were selected from the four school sizes, whereas cluster random sampling was used to select 36 individual classrooms, while three individual classrooms were chosen from the four school sizes. The number of participants can be shown as follow.

Table 1 The Number of 300 Senior High School Students who Participated in this Study and were Selected Using a Multi-stage Random Sampling

The Steps of a Multi-stage Random Sampling Technique	The Number of Participants
Step 1 Stratified Random Sampling	The four school sizes were divided as follow. - Extra-large (over 2,500 students) - Large-sized (1,500 to 2,499 students) - Medium-sized (500 to 1,499 students) - Small-sized (less than 500 students)
Step 2 Simple Random Sampling	Three schools were selected from the four school sizes. Simple random sampling was used to select 12 out of 41 schools.
Step 3 Cluster Random Sampling	Three individual classrooms were chosen from 12 schools, which were chosen from the four school sizes. Therefore, cluster random sampling was used to select 36 individual classrooms.

4. The assessment test of learning and innovation skills was used to collect data from 300 senior high school students under the supervision of the Office of Secondary Education Area 39 for the academic year 2021, who were chosen through multi-stage random sampling. The Bartlett's test and the Kaiser-Meyer-Olkin (KMO) Test for Sampling Adequacy (KMO) were used to test the basic assumption of a second order confirmatory factor analysis by analyzing the correlation matrix of 8 observed variables in a learning and innovation skills model, and a second order confirmatory factor analysis was used to investigate the validity of the conceptual elements of the learning and innovation skills model for senior high school students with empirical data.

Results

The correlation matrix analysis of 8 observed variables on senior high school students' learning and innovation skills revealed a level of statistical significance of .05, the correlation ranged from .141 to .515, and KMO was 0.807. The results are shown in Table 2.

Table 2 The Correlation Matrix Analysis of 8 Observed Variables in a Learning and Innovation Skills Model

Variables	1	2	3	4	5	6	7	8
1. x1	1.000							
2. x2	.422	1.000						
3. x3	.421	.389	1.000					
4. x4	.266	.390	.515	1.000				
5. x5	.165	.273	.349	.383	1.000			
6. x6	.310	.260	.300	.308	.514	1.000		
7. x7	.149	.210	.264	.303	.495	.417	1.000	
8. x8	.278	.141	.282	.298	.399	.491	.484	1.000
M	3.359	3.356	3.304	3.189	3.356	3.283	3.362	3.259
SD	0.796	0.799	0.848	0.860	0.788	0.836	0.827	0.833
Bartlett's Test of Sphericity = 721.873; df = 28; p = .00; KMO = 0.807								

Note: $p < .05$

A second order confirmatory factor analysis of learning and innovation skills revealed that the model was consistent with the empirical data (c^2 (14, n = 300) = 21.566, p = .088, CFI = .989, TLI = .979, RMSEA =

.041, SRMR = .026). Communication and collaboration had the highest factor loading (0.995), followed by creativity and innovation (0.889) and critical thinking and problem solving (0.673). Variable factor loading ranged from .502 to .741, and the discrepancy ratio was expressed as a percentage of variables ranging from 25.5 to 55.0. The results are shown in Table 3 and Figure 2.

Table 3 The Validity Analysis of the Conceptual Elements of Learning and Innovation Skills Model

Variables	ß	SE	t	R^2
Critical Thinking and Problem Solving	**0.673**	**0.055**	**12.214**	**0.453**
x1	0.668	0.049	13.605	0.446
x2	0.589	0.048	12.288	0.347
x3	0.641	0.047	13.616	0.411
Communication and Collaboration	**0.995**	**0.001**	**819.529**	**0.989**
x4	0.502	0.047	10.661	0.252
x5	0.741	0.038	19.395	0.550
x6	0.694	0.039	17.974	0.482
Creativity and Innovation	**0.889**	**0.048**	**18.402**	**0.791**
x7	0.713	0.043	16.598	0.508
x8	0.680	0.043	15.930	0.463
$c^2(14, n = 300) = 21.566$; p = .088; CFI = .989; TLI = .979; RMSEA = .041; SRMR = .026				

The following figure depicts a second order confirmatory factor analysis of a learning and innovation skills model.

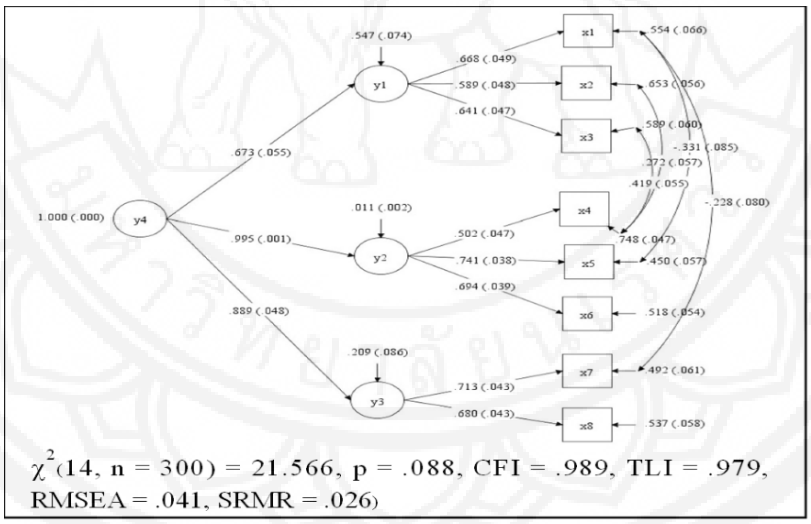

Figure 2 A Second Order Confirmatory Factor Analysis of a Learning and Innovation Skills Model.

Discussion

A second order confirmatory factor analysis of learning and innovation skills revealed that the model was consistent with empirical data (c^2 (14, n = 300) = 21.566, p = .088, CFI = .989, TLI = .979, RMSEA = .041, SRMR = .026). This was tangible evidence that there are 3 main components for learning and innovation skills of senior high school students. The components included critical thinking and problem solving,

communication and collaboration, and creativity and innovation. Communication and collaboration had the highest factor loading (0.995), followed by creativity and innovation (0.889) and critical thinking and problem solving (0.673). The results were in line with Thephinlap et al. (2022) who conducted a confirmatory factor analysis of learning and innovation skills (4Cs) of student at University of Phayao and discovered that communication had the highest factor loading, followed by creativity, collaboration, and critical thinking respectively.

According to the findings mentioned earlier; critical thinking and problem solving had the lowest factor loading. Thus, the guidelines for learning and innovation skills development of senior high school students should focus on critical thinking and problem solving because students will develop innovation to meet society demands or solve the problems in the society, if they can examine the interactions of individual crisis by clearly defining the cause of the problems. After that, students need to effectively search, analyze, and synthesize information to develop a suitable solution. Finally, students must reflect critically on resolutions that will achieve better outcomes. As a result, students should have the opportunity to observe, survey, and interact with users in the community in order to empathize their needs or problems through critical thinking and finding a solution that can develop innovation that meets users' demands or solves their problems. The findings agreed with the Battelle for Kids (2019a), which stated that critical thinking is important for working because critical thinking is the ability to think critically for making judgements and decisions in problem solving, as well as the IDEO.org (2015), which stated that the first stage of innovation development should be an empathetic understanding of the user's problem or need, typically through user research to develop innovation that meets users' demands or solves their problems.

Communication and collaboration had the highest factor loading. It was discovered that communication and collaboration are the most important characteristics for improving students' learning and innovation skills because students must effectively articulate one's thoughts and ideas orally, in written form, or nonverbally. Moreover, students must effectively collaborate with others regardless of the form of communications to achieve a common goal, while taking advantage of multimedia and technology innovations to creatively improve and impact the learning of others. Thus, students should have the opportunity to communicate and collaborate with others in order to generate innovation. The findings were consistent with Jaroensa & Sengsri (2020), who stated that students should have communication and collaboration skills in order to work effectively with others, as well as with IDEO.org (2015), which stated that students should be able to communicate and collaborate with users in order to create innovation that meets users' demands or solves their problems.

Creativity and innovation were inferior to communication and collaboration, but they were also important for students because they required students to prompt brainstorming activities, creative thinking as a group, as a unit, which allows for the critically reflections on ideas that help generate creative ideas which produce innovation development and the implementation of innovations projects that create robust and provoking which form tangible and useful contribution to a field of study. As a result, students should have the opportunity to develop innovation with users in society in order to create the process of innovation development and test innovation with users for improved innovation efficiency. The findings agreed with Carroll et al. (2012), who stated that the culture of innovation development should create prototypes of innovation and test them with users in order to adjust the prototype based on user feedback for increased innovation efficiency.

Conclusion and Suggestions

This research had as focal point to investigate construct validity of learning and innovation skills model for senior high school students with the empirical data to support the guidelines for learning and innovation skills development of senior high school students. From the research findings, a second order confirmatory factor analysis of learning and innovation skills model was consistent with the empirical data (c^2 (14, n = 300) = 21.566, p = .088, CFI = .989, TLI = .979, RMSEA = .041, SRMR = .026). This was tangible evidence that there are three main components that supported the guidelines for learning and innovation skills development of senior high school students. The components included critical thinking and problem solving, communication and collaboration, and creativity and innovation. Thus, the guidelines for developing senior high school students' learning and innovation skills should focus on critical thinking and problem solving because students must examine the interactions of individual crisis by clearly defining the cause of the problems. Furthermore, the participant will be able to effectively search, analyze, and synthesize information in order to develop a suitable solution. Critical thinking and problem solving allow an individual to critically reflect on resolutions that will result in better outcomes.

Students' communication and collaboration should be improved by giving them the opportunity to effectively articulate their thoughts and ideas orally, in writing, or nonverbally. Individuals must also effectively collaborate with others, regardless of communication mode, to achieve a common goal, while taking advantage of multimedia and technological innovations to creatively improve and impact the learning of others. Furthermore, students should be educated to improve their creativity and innovation because they must encourage brainstorming activities, creative thinking as a group, as a unit, which allows for critical reflections on ideas that help generate creative ideas that produce innovation development and the implementation of innovation projects that create robust and provoking which form tangible and useful contribution to a field of study.

Suggestions

Suggestions for a second order confirmatory factor analysis of senior high school student's learning and innovation skills model:

1. According to the results of a second order confirmatory factor analysis of senior high school students' learning and innovation skills model, there were three main components for senior high school students' learning and innovation skills assessment to support the guideline for learning and innovation skills development of senior high school students. Thus, the guidelines for developing senior high school students' learning and innovation skills should emphasize critical thinking and problem solving, communication and collaboration, and creativity and innovation.

2. In a second order confirmatory factor analysis of senior high school students' learning and innovation skills model, critical thinking and problem solving had the lowest factor loading. As a result, teachers should consider the study's components and observed variables in the areas of critical thinking and problem solving examines the interactions of individual crisis by clearly defining the cause of the problems. Furthermore, the participant will be able to effectively search, analyze, and synthesize information in order to develop a suitable solution. Critical thinking and problem solving allow an individual to critically reflect on resolutions that will result in better outcomes.

Suggestions for Future Research

The research scope focused on a second order confirmatory factor analysis of a learning and innovation skills model for senior high school students. Future research should concentrate on testing measurement invariance across measured groups using structural equation model analysis to design the guidelines for developing learning and innovation skills in students of varying educational levels.

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