**International Journal of Educational Methodology**
**Volume 10, Issue 1, 835 - 844.**
ISSN: 2469-9632
http://www.ijem.com/

# Development and Validation of a Reliable and Valid Assessment Tool for Measuring Innovative Thinking in Vocational Students

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*Received: August 11, 2023 ▪ Revised: September 28, 2023 ▪ Accepted: October 14, 2023*

**Abstract:** The objective of this study was to develop a measure that possesses both reliability and validity in order to evaluate innovative thinking within the realm of education. To achieve this, the instrument's validity and reliability were evaluated through quantitative methods in two distinct phases. A team of educational experts conducted the process of establishing content validity and ensuring that the items on the instrument accurately reflected the intended constructs of creative thinking. Following that, the assessment of concept validity was conducted using confirmatory factor analyses. The aforementioned investigations resulted in the discovery of a five-factor solution consisting of 25 elements, all of which demonstrated scores beyond the crucial threshold. This successful outcome confirmed the presence of distinct factors representing different dimensions of innovative thinking. The study enrolled 1250 students from vocational education institutions as participants. The data obtained from the participants was subjected to principal component analysis and confirmatory factor analysis, leading to the development of a model that exhibited a good match with the empirical data. This indicated the effectiveness of the developed instrument in measuring innovative thinking capacity. In conclusion, the research effectively developed an accurate and dependable tool for evaluating innovative thinking in the realm of education. The gathering of positive data from the participants and meticulous quantitative analyses were responsible for this.

**Keywords:** *Innovative thinking, measurement tool, reliability, validity.*

**To cite this article:** Sukkeewan, P., Songkram, N., & Nasongkhla, J. (2024). Development and validation of a reliable and valid assessment tool for measuring innovative thinking in vocational students. *International Journal of Educational Methodology*, *10*(1), 835-844. https://doi.org/10.12973/ijem.10.1.835

## Introduction

In an era of rapid change, leveraging pioneering approaches is proving to be a critical success factor (Barak & Usher, 2019; Organization for Economic Co-operation and Development [OECD], 2016). With technological advances producing new types of work, replaced by automation and robots that typically perform repetitive tasks, both lifestyles and the world of work are in flux. However, creative thinking, analytical thinking, innovative thinking, communication, and teamwork are in demand and represent the workplace of the future, as they are specific skills that modern technology cannot yet replace with human labor. To succeed in the 21st century, learners must have a comprehensive knowledge base that emphasizes cultivating innovative thinking skills. In addition, it is critical for learners to develop a systematic approach or methodology that allows them to effectively use their creativity to address and resolve difficulties that arise during data collection.

Vocational education plays a central role in preparing individuals for the ever-evolving world of work by equipping them with specialized skills and knowledge. In the face of constant technological advances and changing market demands, it is imperative for vocational education to remain adaptable and innovative. By integrating advanced practices and methodologies, vocational education not only enhances its quality but also ensures that graduates are adequately equipped to meet the dynamic challenges of the modern labor market. In response to the changing needs of industry, vocational education must undergo a transformation process to maintain its relevance and responsiveness. Introducing innovative approaches is crucial to closing the skills gap and aligning vocational education and training with the demands of a technologically advanced and fast-moving labor market. Therefore, the organization and promotion of vocational training emphasize the importance of innovation, technology, and creativity. Special emphasis is placed on promoting skills in the areas of "new skills," "re-skills," and "up-skills" (Khumphai et al., 2021). These skills are widely recognized

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as crucial tools that enable individuals to learn new talents or broaden their present skill set in the labor market, particularly in light of technological advancements and shifts in the industrial sector.

Innovative thinking is considered an intellectual process that leads to the application of knowledge (Barak et al., 2020). New thinking is a behavior that contains elements of innovative thinking. It consists of five aspects:

1. Associating refers to making associations between things, especially when those things are not obviously related or have different backgrounds or experiences.
2. Questioning refers to asking questions that stimulate the thinking process, especially when trying to find an answer to a specific question.
3. Observation is a skill that involves watching people's behavior and asking why they behave this way or that way to get ideas for new possibilities.
4. Experimenting refers to trial and error to learn and correct what went wrong.
5. Idea networking refers to cooperation in exchanging knowledge to create and develop new knowledge (Dyer et al., 2009; Schar et al., 2017; Strange, 2012; Tobar-Muñoz et al., 2020).

In a profession or business that allows for diverse experiences and new ideas, innovative thinking is a skill that can be developed and improved. By organizing teaching and learning activities that stimulate and promote learners' innovative thinking skills, but how can learners' innovative thinking be measured? Accordingly, it is imperative for researchers to undertake an examination and construction of measurement tools pertaining to innovative thinking. This ensures the precision of developed instruments and facilitates their utilization in tandem with educational practices to foster and cultivate learners' innovative thinking abilities.

## Literature Review

### *The Content and Structure of Innovative Thinking Skills*

The concept of innovative thinking is multifaceted and has been considered from various perspectives in the literature. It's not just about inventing something new; it goes beyond that. The views of many authors are different and similar, as follows:

Wongyai and Pattanapol (2019) show that they view innovative thinking as the creation of something new that's not only better but also fulfills the needs of a group or a large number of people better than what currently exists. This notion emphasizes the practical aspect of innovative thinking and its potential to address real-world problems.

Morad et al. (2021) approach innovative thinking from a problem-solving angle, emphasizing the cognitive ability to identify existing needs or challenges and generate fresh ideas that alter outcomes. This perspective underlines the practical aspect of innovation, where it's not merely about ideation but about effecting change and solving real-world problems.

Tobar-Muñoz et al. (2020) outline innovative thinking as a multistep cognitive process. They emphasize the phases involved, from generating novel ideas to developing entirely new goods, services, or processes, or even enhancing existing ones. This process-oriented view emphasizes the dynamic nature of innovation, involving continuous ideation, refinement, and implementation.

Barak and Yuan (2021) focus on both the generation and implementation of new concepts, suggesting that innovative thinking is not confined to the theoretical realm but has real-world applications. Their perspective underscores the importance of translating creative ideas into tangible outcomes, whether in the form of products, services, or processes.

Orakcı et al. (2020) accentuate the conscious nature of innovative thinking, categorizing it as an essential feature of deliberate thought processes. They stress its role in problem-solving and decision-making, positioning it as a fundamental skill crucial in various contexts.

Examining these viewpoints collectively, it becomes evident that innovative thinking is a multifaceted cognitive ability. It is not merely about generating novel ideas but also about translating these ideas into practical solutions. It involves understanding needs, ideation, problem-solving, and the conscious effort to implement these ideas effectively. Additionally, the emphasis on interactive strategies and collaborative efforts highlights the collaborative aspect, which emphasizes the social nature of innovation. It's not a solitary endeavor but a process nurtured through shared knowledge, diverse perspectives, and collaborative endeavors. Integrating these diverse perspectives into theoretical frameworks enriches our understanding of innovative thinking, emphasizing its adaptability and the transformative potential it holds within various contexts.

*Measurement of Innovative Thinking Skills*

Innovative thinking skills are incredibly important for generating fresh ideas, solving complex problems, and ultimately driving innovation forward. Accurately assessing these skills is key to understanding both individual and collective capacities for innovation. This review dives into the existing literature to provide a comprehensive overview of how innovative thinking skills are measured. Various approaches, constructs, and measurement tools have been employed in previous research to gauge innovative thinking skills. By dissecting these methods, we can gain deeper insights into how we assess these critical abilities. Typically, this assessment involves individuals evaluating their own creative problem-solving prowess, idea generation capabilities, flexibility in thinking, and openness to novel concepts. To capture these self-assessments, researchers often use tools like Likert rating scales or semantic differential scales, which allow participants to express their perceptions of their innovative thinking abilities.

However, it's worth noting that there exists an ongoing debate within the field regarding the nature and measurement of innovative thinking. Some scholars argue that innovative thinking encompasses a range of skills and attitudes beyond self-assessment, including the ability to associate ideas, pose thought-provoking questions, engage in keen observation, have a willingness to experiment and learn from mistakes, and engage in effective networking. For instance, associating ideas or skills involves linking different pieces of knowledge to generate fresh ideas. Questioning stimulates critical thinking, especially when seeking answers to posed questions. Observation is the art of keenly watching the behavior of individuals and asking why or how they behave as they do. Experimentation involves a trial-and-error approach, a readiness to learn from errors, and the ability to spot opportunities. Finally, networking is about sharing knowledge through various avenues, including engaging with people in one's own field and those from diverse backgrounds to discover new ideas. This divergence in perspectives highlights the complexity of measuring innovative thinking. While self-assessment scales are valuable, they may not capture the full spectrum of innovative thinking skills. As a result, the field is continually evolving to find comprehensive ways of understanding and assessing these vital capabilities, recognizing that they are not one-dimensional but multifaceted and interconnected (Barak & Yuan, 2021; Dyer et al., 2009; Schar et al., 2017; Strange, 2012; Tobar-Muñoz et al., 2020).

*Relationship Between Elements of Innovative Thinking Skills*

The impetus for innovation stems from individuals' capacity to engage in creative thinking and generate novel concepts. The capacity for innovative thinking covers a range of cognitive processes and actions that contribute to the invention and execution of novel ideas. The elements of innovative thinking skills are interconnected and mutually reinforcing. Observation is about paying attention to the environment and gathering information from it. By carefully observing people, processes, and objects, individuals can identify patterns, trends, and opportunities for innovation. Observation thus forms the basis for identifying areas of interest and potential innovations (Barak & Usher, 2019; Janger et al., 2017; Kanter, 1996). Questioning means asking thought-provoking and challenging questions to examine existing assumptions, uncover underlying issues, and stimulate critical thinking. Questioning thus helps to challenge assumptions and identify new perspectives based on observations (Barak & Asakle, 2018; Kanter, 1996; Unterschuetz et al., 2008). Experimentation means actively exploring, testing, and prototyping ideas and concepts. It promotes a hands-on approach to learning and innovation. Experimentation allows individuals to validate and refine their ideas, uncover potential obstacles or limitations, and gain new insights. Experimentation allows individuals to test and refine their ideas, drawing on insights gained through observation and inquiry (Amabile, 1983; Cabra & Uribe-Larach, 2013; Miron-Spektor et al., 2011). The idea networking refers to actively seeking out and connecting with diverse individuals and communities to share ideas, perspectives, and knowledge. By networking with others, individuals can draw on collective intelligence and leverage diverse experiences and expertise. The idea networks thus facilitate the exchange of ideas and allow individuals to gather different perspectives and feedback to improve their innovation efforts (Barak & Usher, 2019; Kanter, 1996; OECD, 2016; Parise et al., 2015; Reid & de Brentani, 2015). Associating encourages individuals to draw on observations, questions, experiments, and networks to create new connections and develop innovative ideas (Morad et al., 2021). A number of research studies indicate a significant positive correlation with one another, such that elements of innovative thinking skills in the five domains of observing, questioning, experimenting, networking ideas, and associating can be considered cognitive constructs that are interrelated (Barak et al., 2020; Morad et al., 2021).

*Measurement Model Assumptions and Index System Construction*

The development of the Innovative Thinking Skills Scale for Vocational Students, which is a self-evaluation instrument for measuring and assessing vocational students. The evaluation form is a 7-step assessment scale (Likert scale), where the method of creating the questions determines the definition and importance of the variables to be measured, consisting of 5 aspects: (a) Observing is a skill that pays attention to details, (b) Questioning is the ability to ask questions to expand knowledge by seeking answers and thinking analytically to create a body of knowledge, (c) Experimentation is the ability to identify problems, hypothesize, plan, and select appropriate methods to find answers or solutions, (d) The idea networking is a skill that creates collaboration in sharing knowledge to create and develop new knowledge, and (e) Association is a cognitive process that involves connecting pre-existing knowledge with novel information in order to problem-solve and generate innovative ideas. This process is facilitated through the utilization of techniques such as questioning, observation, experimentation, and the exchange of ideas through networking. The questions were then constructed using the research tools of (Barak et al., 2020; Barak & Yuan, 2021; Morad et al., 2021; Verdin et al., 2020) to be appropriate for the context of vocational students in Thailand. Therefore, there are 25 questions in this section.

*Research Goal and Question*

The objective of this study was to construct a valid and accurate assessment tool for evaluating the aptitude for innovative thinking within the realm of education, with a specific emphasis on vocational students. In order to achieve this objective, a self-assessment questionnaire was designed and afterwards subjected to rigorous evaluation to ascertain its validity and reliability. The research question addressed in this study pertains to the validity and reliability of the innovative thinking questionnaire, which aims to assess individual innovative thinking in an educational context. The investigation focused on two aspects: (a) content validity, as determined by inter-rater agreement; and (b) construct validity, as assessed through confirmatory factor analysis.

## Methodology

*Participants*

Research participants were vocational students (N = 1250). The study adhered to ethical protocols, which encompassed obtaining informed permission from participants who willingly chose to partake in the research, granting them the freedom to withdraw from the study at their discretion, and ensuring the preservation of anonymity and confidentiality of their personal data. The act of participation was not obligatory, and there was no provision for additional credit or payment. The data was gathered from vocational training institutes located in Thailand. The samples were a stratified random sample divided into 5 regions: (a) north, (b) northeast, (c) eastern, (d) central, and (e) south

*Descriptive Statistics*

The construction of the scale for evaluating Innovative Thinking Skills involved an analysis of survey data obtained from a demographically representative sample of 1250 individuals. The findings indicate that there were 581 male participants and 669 female participants. The majority of participants in the study were 19 years old, comprising the largest group at 42.00%. The second-largest group consisted of 18-year-olds, accounting for 38.80% of the participants. In relation to academic achievement, the study revealed that a significant proportion of participants, specifically 57.36%, were registered as first-year students in higher vocational education. In contrast, it was observed that the second year of vocational education had the lowest level of representation, as reported by 42.64% of the participants. The study sample consisted of students from both public schools (62.64%) and private institutions (37.36%). After conducting a thorough examination of the data segmented by geographical areas, it was seen that the eastern region exhibited the highest percentage of participants, including 20.50% of the total respondents. The central area, comprising 20.00% of the participants, ranked second. Likewise, the northern region exhibited a notable presence, as evidenced by 20% of the respondents hailing from this geographical area. The demographic insights provided in this document provide a comprehensive picture of the sample's makeup. This information serves as the basis for the subsequent analysis and interpretation of the data collected from the test scale.

*Instrument and Procedure*

The two sub-sections provide a comprehensive description of the data collection process, the characteristics of the participants, and the analysis conducted at each stage.

*Phase 1: The Content Validity of Innovative Thinking Skills*

The primary objective of Phase 1 was to assess the degree to which the questions included in the questionnaire accurately captured the dispositional inclination towards innovative thinking within the context of education. The foundation for the adaptation was derived from the 25 items. These items were then categorized into five distinct subscales, namely Observing (consisting of five things), Questioning (consisting of five items), Experimenting (consisting of five items), Idea Networking (consisting of five items), and Associating (consisting of five items). In this study, a quantitative approach was employed to assess the content validity of an instrument designed to measure students' innovative thinking skills. The Lawshe (1975) equation, specifically the content validity ratio (CVR), was utilized for this purpose. The CVR formula is expressed as $[E - (N/2)]/(N/2)$, where N represents the total number of raters and E denotes the number of raters who deemed the item essential. The researcher determined content validity by examining how much agreement there was between the different raters. The raters consisted of five innovation, technology, and education communications experts who have specialized knowledge in innovation. They were chosen for their professional familiarity.

*Phase 2: The Construct Validity of the Innovative Thinking Scale*

During Phase 2, the researchers used confirmatory component analysis (Cronbach & Meehl, 1955; Little, 2013) to look into the construct validity of the scale. Confirmatory factor analysis (CFA) is a statistical technique utilized to validate the construct of the questionnaire by examining these components with pre-existing theoretical frameworks. In addition, we performed confirmatory factor analysis to investigate the underlying factor structure and implemented structural equation modeling (SEM). The measures of innovative thinking included in this study have been derived from many sources that have demonstrated adequate levels of validity and reliability. The constructs in question were assessed using a 7-point Likert scale, where a rating of 1 indicated "strongly disagree" and a rating of 7 indicated "strongly agree." The data were gathered in collaboration with the coordinators at each institution, and a total of 1250 vocational students participated in the study. The respondents need a maximum of 10 minutes to complete the paper-based questionnaire. Participants were provided with information on the objective of the study and were told of their prerogative to withdraw from the data collection process at any point without being obligated to provide justification.

*Data Analysis*

The data analysis for this study encompassed multiple procedures. Initially, descriptive statistics were calculated to summarize the demographic profile of the participants and were subjected to tests for univariate normality. Furthermore, a structural equation modeling approach (SEM) was utilized to analyze participants' responses to the items measuring five variables. Analysis involved tests of both the measurement model and the structural model. Confirmatory factor analysis (CFA) was done with maximum likelihood estimation and LISREL 8.80 as the analytical tool to look at the factor loadings of the proposed indicators. In addition, the study reported the values of composite reliability (CR) and average variance extracted (AVE) to determine construct reliability and validity, respectively. These indices provided insights into the consistency and accuracy of the measurement model. Finally, tests of the structural model were conducted to examine the hypotheses in this study. Through this comprehensive data analysis process, the study aimed to draw meaningful conclusions and contribute valuable findings to the research field.

## Findings/Results

*The Content Validity of the Innovative Thinking Skills*

Out of the whole pool of 25 items, all five raters unanimously assessed 23 things as "essential" for the purpose of fostering innovative thinking. The content validity ratio (CVR) for these items was determined to be 1.00. According to the finding, four raters assigned a rating of "essential" to two items, resulting in a content validity ratio (CVR) of .80. The mean coefficient of variation was determined to be .98. The items that had a content validity ratio (CVR) value of 1.00 were retained unchanged. However, the experts' recommendations led to the modification of items with a CVR of .80. The objective of these revisions was to enhance the clarity of the items in conveying the concept of innovative thinking within the context of the learning process. For example, the item "I can draw conclusions from observations to make predictions about coming events" was rephrased to read "I can draw conclusions from my observations to forecast future events".

*The Construct Validity of the Innovative Thinking Scale*

The 25 questions of the Innovative Thinking Scale were asked on a Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The participants in this study were vocational students who were asked to complete questionnaires in order to conduct a confirmatory factor analysis. The confirmatory factor analysis consists of five factors, with 25 components having loadings above the critical threshold. These loadings ranged from .83 to.90, consistent with the research conducted by Dyer et al. (2008). The research methodology involved the use of five different approaches: observing, questioning, experimenting, idea networking, and associating. According to Hair et al. (2010), the combined Cronbach's alpha values are higher than the generally accepted threshold of .75. The Pearson correlation analysis conducted on five components or categories demonstrated statistically significant positive connections, with correlation coefficients ranging from .86 to .92. This finding suggests that the five components are interconnected yet may still be differentiated from one another. The associating factor demonstrated the highest score (5.14) in terms of its efficacy in fostering innovative thinking. The category of questioning obtained the lowest grade of 5.10, suggesting that relying just on passive questioning to develop new ideas is inadequate for fostering creativity.
The confirmatory factor analysis performed on a sample of 1250 vocational students supported the five-component model. Based on the empirical data and the confirmatory factor analysis (CFA) results, the five-factor model fit well ($\chi 2/df$ = 2.72, CFI = 1.00, GFI =.96, AGFI =.95, RMSEA =.037). Furthermore, it is worth noting that the correlations among the five latent components exhibited statistical significance, as seen in Figure 1.

*Table 1. Means, Standard Deviations, and Correlations of Innovative Thinking Skills*

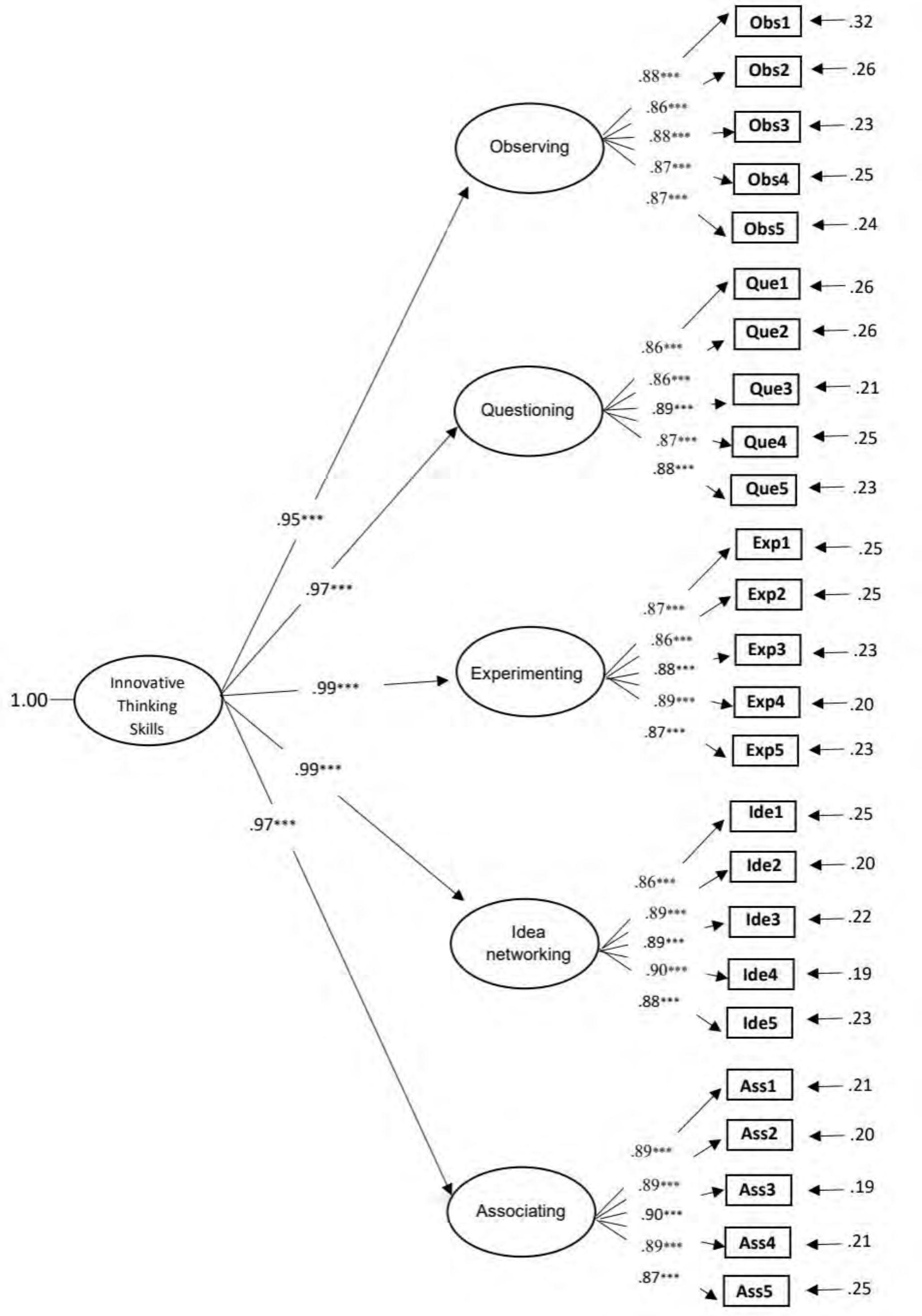
| Category | Mean | SD | Obs | Que | Exp | Ide | Ass |
|---|---|---|---|---|---|---|---|
| Observing | 5.13 | 1.08 | 1 | | | | |
| Questioning | 5.10 | 1.10 | .89** | 1 | | | |
| Experimenting | 5.13 | 1.09 | .87** | .90** | 1 | | |
| Idea networking | 5.13 | 1.11 | .87** | .90** | .92** | 1 | |
| Associating | 5.14 | 1.29 | .86** | .88** | .90** | .92** | 1 |

Obs, observing; Que, questioning; Exp, experimenting; Ide, idea networking; Ass, associating.
N = 1,250, ** $p < .01$
Rang 1-7 (from low to high levels of innovative thinking skills)

*Table 2. Fit Indexes of the Structural Model*

| Fit indexes | Level of acceptable fit | Model | Result |
|---|---|---|---|
| $\chi^2$/df | < 3.00 | 2.72 | Pass |
| CFI | ≥ .95 | 1.00 | Pass |
| GFI | ≥ .95 | .96 | Pass |
| AGFI | ≥ .90 | .95 | Pass |
| RMSEA | < .05 | .037 | Pass |

AGFI, adjusted goodness of fit index; CFI, comparative fit index; GFI, goodness-of-fit indices; RMSEA, root mean square error of approximation.




Chi-Square = 721.96, df = 265, P-value = .00000, RMSEA = .037 *** p < .001

*Figure 1. The Confirmatory Factor Analysis Based on Five Dimensions and 25 Factors With the Hierarchical Model*

## Discussion

Innovation has a pivotal role in driving the development and expansion of the economy. The evaluation of innovative thinking among vocational students is crucial in light of the dynamic nature of our contemporary society (Barak et al., 2020). In order to meet this need, the present study undertook the validation of a modified self-report instrument designed to assess variations in innovative thinking among individuals. The initial investigation focused on establishing the content validity of the scale, specifically assessing the degree to which each item accurately reflects a dispositional inclination towards innovative thinking. Five experts with expertise in the field of education participated in the determination using Lawshe's (1975) proposed Content Validity Ratio (CVR) methodology. The determination of construct validity was subsequently conducted through the utilization of confirmatory factor analysis (Hu & Bentler, 1999; Little, 2013). This research resulted in the identification of a five-factor solution consisting of 25 items that were found to be statistically distributed over five factors. Researchers have identified five main factors that can foster learners' propensity for innovative thinking: observing, questioning, idea networking, experimenting, and associating (Dyer et al., 2008, 2011). From a cognitive standpoint, scholars perceive observation as a cognitive process that involves the generation of novel ideas through the exploration and examination of the surrounding environment. Questioning is defined as the cognitive ability to pose inquiries that challenge preconceived notions and prevailing circumstances. The concept of idea networks pertains to the capacity to generate novel ideas via active engagement in diverse venues and diligent consideration of other views. Experimentation is commonly defined as the cognitive capacity to comprehend the underlying mechanisms of phenomena and to discover novel approaches for accomplishing tasks. Finally, association is the ability to link cross-disciplinary knowledge to create innovation through questioning, observation, experimentation, and the ability to network ideas.

The use of structural equation modeling revealed statistically significant associations among the five parameters. There was a significant correlation between the exchange and interconnection of ideas and the processes of experimentation and association. This observation suggests that learners engage in the exchange of ideas, pose inquiries, and experiment with novel concepts as a means of fostering innovative thinking. The interconnections between the components of innovative thinking may be observed by the application of structural equation modeling, indicating a significant reciprocal relationship among these cognitive structures. The findings presented align with research conducted by Cheung and Rensvold (2002), which demonstrated noteworthy correlations among the four criteria. The act of networking was shown to be closely linked with the practices of experimentation and questioning.

The empirical data was well-fitted by the model derived from the principal component and confirmatory factor analyses (Field, 2013; Little, 2013). The structural equation model (SEM) results supported the validity of the five-part assessment model that already existed. This model includes the linked cognitive structures from the Innovative Thinking Skills Questionnaire. This statement indicates an increasing recognition of the importance of educational programs that cultivate learners' ability to engage in independent and innovative thinking (Cropley, 2015; Tang & Werner, 2017). The findings of this study show that educators and vocational schools can apply a systematic approach to assess their students' innovative thinking abilities before they start learning to adjust instruction to fit each student's abilities. They can achieve this by employing a specific measurement tool. This approach is integrated into the teaching format through design thinking and project-based learning. These teaching methods promote innovative thinking skills and innovation creation in vocational students. Once students have gone through this teaching method, they can self-assess their own innovative thinking skills using a reliable and validated measurement tool. This tool is well-suited for evaluating students' innovative thinking abilities.

## Conclusion

The concept of innovative thinking refers to a cognitive process that encourages the emergence of novel solutions. The objective of this study is to examine the role of innovative thinking in the educational experience of vocational students as well as to create a robust and dependable tool for assessing their capacity for innovative thinking within an educational context (Dyer et al., 2008). Consequently, the development of the Innovative Thinking Scale was undertaken in order to accomplish these objectives. The scale can serve as a reflection instrument for learners to get insight into their own strengths and shortcomings in attaining creative learning outcomes. According to Barak and Usher (2019), individuals who engage in innovation and generate novel concepts have the potential to provide resolutions to challenges that arise as a result of societal or environmental transformations.

## Recommendations

As a result, it is imperative that vocational students possess the capacity to effectively address complex challenges through innovative approaches. It is important for individuals to recognize the significance of engaging in introspective observations and posing inquiries that challenge the prevailing norms. Individuals should be encouraged to utilize social networks as a means of acquiring fresh viewpoints and engaging in the exploration and evaluation of novel ideas. Drawing upon prior research (e.g., Christensen, 1997; Dyer et al., 2008, 2011) and the empirical evidence presented in this study, the present article posits that innovative thinking within the realm of education can be understood as a cognitive ability of elevated complexity. This cognitive ability is predicated upon the foundation of observational skills, operates at an individual level, progresses through collaborative processes such as questioning and networking, and is perpetuated through iterative experimentation whereby novel ideas and outcomes are critically evaluated and refined. In future research, we could employ tools to evaluate the innovative thinking skills of vocational students. We might then create a system that uses machine learning to predict these skills. This system could classify students into three groups: those with high innovative thinking abilities, those with medium abilities, and those with low abilities. Once we have these classifications, we can develop customized learning approaches. These approaches would adjust instruction to fit each student's abilities. This way, we can provide a more effective and tailored education for every student.

## Limitations

This study successfully established the validity and reliability of the Innovative Thinking Scale, but it is important to acknowledge its limits as well. The restriction is on the utilization of a self-report questionnaire that captures the subjective view of the participants, as proposed by Dyer et al. (2008). Nevertheless, it is important to acknowledge that self-report measures are not without their limitations. One such limitation is the potential for memory bias, where individuals may inaccurately recall or remember information. Additionally, social desirability bias can influence self-reported responses, as individuals may be inclined to provide answers that are socially acceptable or desirable. Lastly, self-observation errors can occur, whereby individuals may have difficulty accurately assessing their own thoughts, feelings, or behaviors (Paulhus & Vazire, 2007). Hence, it is advisable to conduct a more comprehensive examination of abilities by augmenting the range of research instruments employed, including observations, interviews, and the execution of activities within the researcher's laboratory over an extended duration (Podsakoff et al., 2003).

### Authorship Contribution Statement

Sukkeewan: Design, conceptualization, deep analysis, writing and reviewing, supervision. Songkram: Data acquisition, conceptualization, analysis and interpretation of data, writing, edition, and final approval. Nasongkhla: Conceptualization, design, analysis, writing.

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