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# Development and Validation of an Assessment Tool for Measuring Innovative Thinking in STEM Students

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## Abstract

The researchers conducted this study to develop and validate instrument an assessment tool for measuring innovative thinking in STEM students of Hilongos National Vocational School, Hilongos, Leyte, in 2024. It was done in three-phases: (1) Construct Specification and Item Creation; (2) Content Validation; and (3) Internal Consistency Assessment. Figure 1 shows the overview of the instrument development and validation process adopted from Bazhan et al. (2023) with modifications. As to content validity, the expert panel members evaluated the 150 items based on the four-point scale. Then, CVI for each item was calculated. Items are retained if they have a Content Validity Ratio (CVR) of 0.60 or higher and a Content Validity Index (CVI) of 0.80 or higher, while items are eliminated if they fall below either criterion, with a CVR of less than 0.60 or a CVI of less than 0.80. The remaining items were revised to satisfy the recommendations of the experts in terms of the consistency of statements' verb tenses as well as the points of view utilized. As to internal consistency, it revealed that the reliability of the five constructs is greater than 0.90, indicating that the reliability is acceptable. This implies that all items demonstrated a valid internal consistency. Cronbach's α between 0.8 to 1 shows good reliability, between 0.6 to 0.79 indicates the reliability is acceptable, and less than 0.6 indicates poor reliability. The developed questionnaire for measuring innovative thinking in STEM students exhibited strong reliability and content validity. The instrument effectively captured the core dimensions of innovative thinking, such as observing, questioning, experimenting, idea networking, and associating. The factor analysis results supported the instrument's underlying structure, and Cronbach's alpha values indicated high internal consistency. These findings suggest that the questionnaire is a reliable and valid tool for assessing innovative thinking in STEM students.

## Introduction

Innovative thinking is the cognitive competency to define a need or a problem, generate new or changed ideas, develop an outcome in accordance with new or changed ideas, implement a new or improved outcome for the addressee, and adopt a new or improved outcome with added value (Baregheh et al., 2009; Crossan & Apaydin, 2010).For assessing and encouraging creativity in STEM domains, a valid and effective evaluation method for measuring innovative thinking in students must be developed (Peeraya Sukkeewan et al., 2024). The goal of creating a complete instrument that accurately assesses students' creativity, problem-solving skills, and innovative thought processes is to build and validate an assessment tool that is valid and reliable for assessing innovative thinking in STEM students. To guarantee a comprehensive evaluation of creative thinking, this tool will incorporate both quantitative and qualitative components, such as scenario-based questions and introspective prompts. To guarantee the tool's psychometric robustness and reliability, the validation procedure will include thorough statistical analysis, expert reviews, and pilot testing. This tool will help the educational system by giving STEM students a way to develop and evaluate crucial 21st-century abilities. (Plucker, Beghetto, & Dow, 2004; Sternberg, 2006).

However, there is a notable gap in existing assessment tools that comprehensively measure these skills in a STEM context (Pellegrino, 2013; Penuel et al., 2014). Current tools often lack the depth and breadth required to evaluate the multifaceted nature of innovative thinking (Cropley, 2006; Kaufman & Sternberg, 2019). This new instrument aims to fill this gap by incorporating a variety of assessment methods, including scenario-based questions and reflective prompts, thus providing a more nuanced and accurate measurement. This tool assesses some significant ideas that are important for creative thinking in the fields of technology, engineering, and science which include originality, or the capability to produce unconventional but helpful concepts; problem-solving skills as a means of dealing with entirely new and complicated problems; analytical thinking hence involves evaluating data and information systematically; flexibility thus implies openness to change and adaptability when one is faced with novel challenges or knowledge; collaboration denotes teamwork where one has to give opinions as well as others.

The introduction of this assessment tool represents a significant advancement in the field of STEM education. By providing educators with a reliable and valid means to measure innovative thinking, this tool will enable more targeted and effective teaching strategies (Morad et al., 2021). It will help identify students' strengths and areas for improvement, fostering a more individualized approach to education (Stenberg, 2006). Moreover, it will contribute to the broader goal of preparing students for the demands of the 21st-century workforce, where innovative thinking is increasingly valued (Amabile, 1996).

The purpose of this study is to develop and validate an assessment tool that accurately measures innovative thinking in STEM students. The objectives include:

- Identifying key components of innovative thinking through a review of existing literature.
- Designing an assessment tool that incorporates these components into measurable indicators.
- Conducting expert reviews and pilot testing to refine the tool.
- Validating the tool through statistical analyses to ensure reliability and psychometric robustness.

The aim is to create a comprehensive, reliable, and valid instrument that educators can use to assess and enhance innovative thinking in STEM students. This tool will not only aid in the academic development of students but also better prepare them for the innovative demands of modern careers.

## Method

This study was conducted in Hilongos National Vocational School SHS Department, Hilongos, Leyte. Research participants were Grade 12 STEM students for the school year 2024-2025.Purposive random sampling was used in this study. The main goal of purposive sampling is to focus on particular characteristics of a population that are of interest, which will best enable the researcher to answer their research questions (Kassiani Nikolopoulou, 2022). Cochran's sample size formula will be used for sample size calculation to ensure a given level of confidence and margin of error (*Sample Size in Statistics (How to Find It): Excel, Cochran's Formula, General Tips*, 2024). This study was done in three phases: (1) Construct specification and item creation (2) Content Validation and (3) Internal Consistency Assessment. Figure 1 shows the adopted from Bazhan et al. (2023) with modification the overview of the instrument development and validation process.

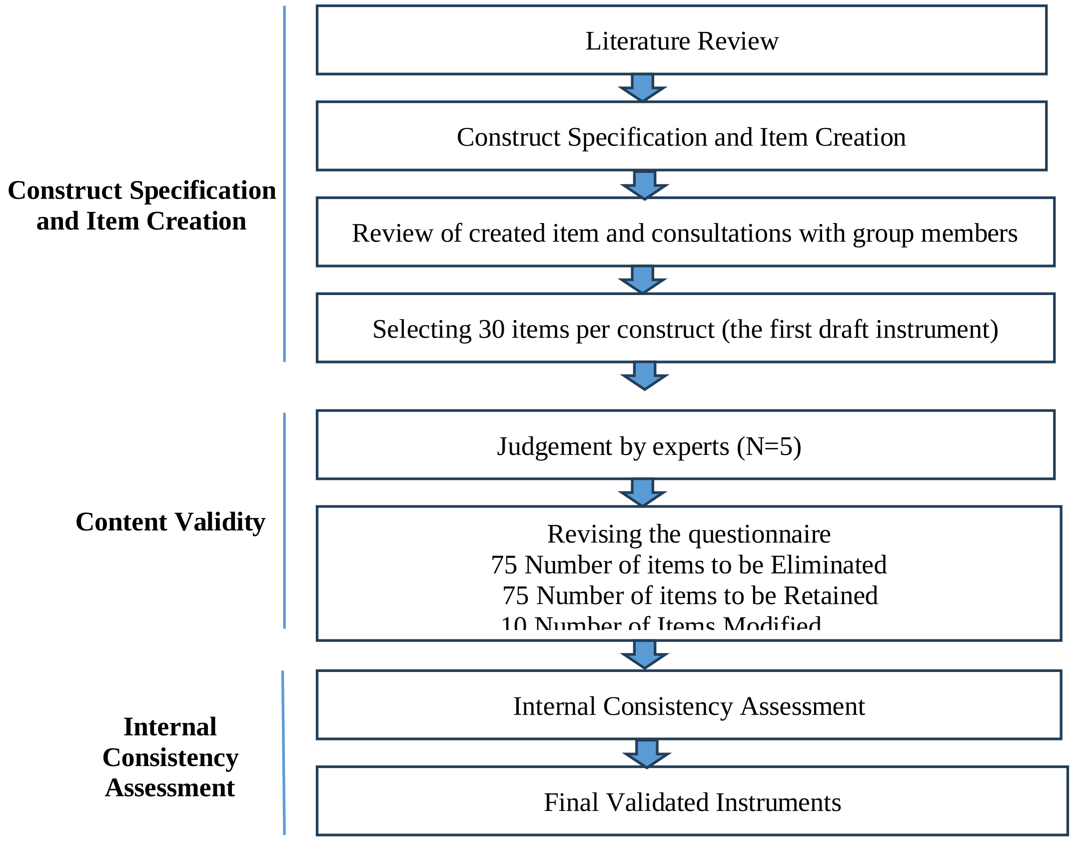


Figure 1. Three-Step Instrument Development Procedure

### Phase 1 Construct Specification and Item Creation

The first step in developing a reliable and valid assessment tool for measuring innovative thinking in STEM students is to conduct a thorough literature review (*The Construct Specification Is the Blueprint for a Survey*, 2024). This involves mastering the empirical literature related to the constructs of interest, such as creative thinking, problem-solving, and critical analysis.) The research team must identify and represent the key content areas that constitute the overall construct, supported by citations from the most current published evidence

According to Barak et al, (2020), New thinking is a behavior that incorporates elements of innovative thinking, consisting of five aspects: associating, questioning, observing, experimenting and idea networking. Associating involves making connections between seemingly unrelated things or experiences. Questioning entails asking thought-provoking questions to stimulate the thinking process, especially when seeking specific answers. Observation is the skill of watching people's behavior and asking why they act in certain ways to generate new possibilities. Experimenting involves trial and error to learn and correct mistakes. Idea networking emphasizes the importance of collaboration in exchanging knowledge to create and develop new ideas (Barak et al., 2020; Dyer et al., 2009; Schar et al., 2017; Strange, 2012; Tobar-Muñoz et al., 2020)

Based on the literature review, the research team can then develop a construct specification that provides a clear operational definition of the construct and its content areas. This construct specification serves as a blueprint for creating the survey instrument. The team can then begin the process of item formulation, ensuring that the items accurately reflect the intended constructs and content area. After the initial items are created, the research team should engage in a review process, where the items are evaluated for content validity by a group of educational experts. This step allows for feedback and refinement to ensure the items accurately measure the intended constructs. A series of statements was formulated for each construct: Associating, Questioning, Observing, Experimenting and Idea Networking. The instrument will be consisted of 150 items on a 5 Likert Scale varying from 1- Strongly Disagree and 5- Strongly Agree.

**Phase 2 Content Validation**

Three experts from Leyte Division Department of Education with backgrounds in educational research and expertise in instrument design and item development, along with two experts from the Visayas State University with extensive experience in measurement constructs, were chosen to validate the questionnaire contents. They provided their professional judgment on the semantics and content of the scale using the Content Validity Index (CVI) on a four-point scale, adopted from Elangovan & Sundaravel (2021). The scale categories included: 1-non-equivalent item (requiring significant revision), 2-extensive revision needed (showing potential but needing extensive refinement),3- minor adjustments required (generally equivalent but needing minor modifications), and 4- totally equivalent item (completely equivalent as is). Items are retained if they have a Content Validity Ratio (CVR) of 0.60 or higher and a Content Validity Index (CVI) of 0.80 or higher, while items are eliminated if they fall below either criterion, with a CVR of less than 0.60 or a CVI of less than 0.80 ("(PDF) Psychometric Properties in Instruments Evaluation of Reliability and Validity," 2017).

**Phase 3 Internal Consistency Assessment**

The validated instrument will be pretested to (251) Two Hundred Fifty One Grade 12 STEM learners of Hilongos National Vocational School. Factor Analysis was done using SPSS to confirm the structure and how items were grouped. The reliability of the validated instrument will be assessed using Cronbach's Alpha (α). According to Mat Nawi et al., (2020) it is used by researchers to assess the interrelation between items of an instrument and the consistency of the tool in measuring variables.

### Statistical Analysis

Reliability analysis using Cronbach's Alpha was conducted using SPSS as well as Confirmatory Factor Analysis while Content Validity will be assessed using Microsoft Excel.

### Ethical Considerations

When developing an assessment tool to measure innovative thinking in STEM students, several important ethical considerations must be kept in mind. First, ensure all student participants (or their legal guardians) provide informed consent, clearly explaining the study's purpose, procedures, risks, and benefits, and emphasizing that participation is voluntary and can be withdrawn at any time without penalty. Second, protect the confidentiality and privacy of student participants by de-identifying data, securely storing personal information, and obtaining permission before sharing or publishing any student data. Third, minimize risks such as stress or loss of instructional time while maximizing benefits like improved learning experiences or self-awareness of innovative thinking skills. Fourth, select participants equitably, avoiding discrimination based on race, gender, socioeconomic status, or other characteristics, ensuring the sample represents the target STEM student population. Fifth, disclose and manage any conflicts of interest to maintain objectivity and integrity throughout the research process. Lastly, follow established research protocols and guidelines from organizations like the American Educational Research Association (AERA) or the National Institutes of Health (NIH), ensuring responsible data management, analysis, and reporting practices while adhering to ethical principles to guarantee the study's scientific soundness.

## Results & Discussion

This part discusses the results of the study on the development and validation of an Assessment Tool for Measuring Innovative Thinking in STEM Students. A total of five (5) experts participated in the content validity and (251) students participated in the reliability assessment.

### Content Validation

Content validation plays a crucial role in the development of instruments designed to assess their validity before they are implemented in practical settings. The findings from the content validation of an Assessment Tool for Measuring Innovative Thinking in STEM Students are presented in Table 1.

Table 1. Results of the Content Validation by Five

| Constructs and Items | | CVR | CVI | Decision |
|---|---|---|---|---|
| OBSERVATION | | | | |
| 1 | I frequently notice patterns in data or phenomena in my STEM classes. | 1 | 1 | Retained |

| | | | | |
|---|---|---|---|---|
| 2 | Small details often lead me to significant discoveries or ideas. | 1 | 1 | Retained |
| 3 | I approach tasks requiring close observation with enthusiasm. | -0.2 | 0.4 | Eliminated |
| 4 | I use specific techniques to enhance my observational skills during experiments. | 0.6 | 0.8 | Retained |
| 5 | Careful observation often leads me to innovative solutions in my projects. | 1 | 1 | Retained |
| 6 | My observation skills help me identify problems before they become apparent to others. | -1 | 0 | Eliminated |
| 7 | I consistently record and reflect on my observations during STEM activities. | -1 | 0 | Eliminated |
| 8 | I actively seek opportunities to observe new technologies or scientific advancements. | 0.6 | 0.8 | Retained |
| 9 | I incorporate observations from various sources into my learning process. | 1 | 1 | Retained |
| 10 | I believe that observation is crucial in the process of innovation. | 1 | 1 | Retained |
| 11 | I enjoy observing natural phenomena to gain insights. | 0.6 | 0.8 | Retained |
| 12 | My ability to observe small changes helps in troubleshooting. | -1 | 0 | Eliminated |
| 13 | I prefer to observe before taking action in experiments. | -1 | 0 | Eliminated |
| 14 | I often notice details that others overlook. | -1 | 0 | Eliminated |
| 15 | Observation is a key part of my problem-solving process. | 1 | 1 | Retained |
| 16 | I use visual aids to enhance my observation skills. | -1 | 0 | Eliminated |
| 17 | My observations often lead to new hypotheses. | 1 | 1 | Retained |
| 18 | I find that my observational skills improve with practice | -0.2 | 0.4 | Eliminated |
| 19 | I rely on my observations to guide my learning. | -0.2 | 0.4 | Eliminated |
| 20 | I enjoy activities that require careful observation. | 0.6 | 0.8 | Retained |
| 21 | My observations help me understand complex concepts. | 1 | 1 | Retained |
| 22 | I use my observations to improve my work continuously. | -1 | 0 | Eliminated |
| 23 | I often reflect on my observations to gain deeper insights. | -0.2 | 0.4 | Eliminated |
| 24 | Observation is an essential skill for innovation in STEM | 1 | 1 | Retained |
| 25 | I document my observations thoroughly | 1 | 1 | Retained |
| 26 | I am confident in my ability to make accurate observations. | -1 | 0 | Eliminated |
| 27 | My observations often lead to creative ideas. | -1 | 0 | Eliminated |
| 28 | I enjoy observing the details of how things work. | 0.6 | 0.8 | Retained |
| 29 | I often notice patterns that others miss. | -1 | 0 | Eliminated |
| 30 | My observational skills help me excel in STEM activities. | -1 | 0 | Eliminated |

| Constructs and Items | | CVR | CVI | Decision |
|---|---|---|---|---|
| QUESTIONING | | | | |
| 1 | I frequently ask questions that challenge existing norms in my STEM classes. | 1 | 1 | Retained |
| 2 | My questioning often leads to breakthroughs in projects or experiments. | 1 | 1 | Retained |

| | | | | |
|---|---|---|---|---|
| 3 | I enjoy asking probing questions to deepen my understanding of STEM topics. | 0 | 0.4 | Eliminated |
| 4 | I believe that questioning is a critical part of the scientific process. | 0.6 | 0.8 | Retained |
| 5 | I feel comfortable asking questions that others might consider difficult | 0.4 | 0.4 | Eliminated |
| 6 | My questions often lead to new insights or perspectives. | 1 | 1 | Retained |
| 7 | I actively seek feedback on the questions I ask in class. | 0.4 | 0.4 | Eliminated |
| 8 | I believe that asking the right questions is essential for innovation | 1 | 1 | Retained |
| 9 | I often question the validity of existing solutions or theories | 0.2 | 0.2 | Eliminated |
| 10 | I find that my questions often lead to productive discussions in class | 1 | 1 | Retained |
| 11 | I am curious and often ask questions to learn more. | 0.2 | 0.2 | Eliminated |
| 12 | My questions help clarify complex concepts. | 0.2 | 0.2 | Eliminated |
| 13 | I encourage others to ask questions during group activities. | 0.2 | 0.2 | Eliminated |
| 14 | I enjoy discussions that involve deep questioning. | 1 | 1 | Retained |
| 15 | I ask questions to explore different possibilities. | -0.2 | 0.4 | Eliminated |
| 16 | Questioning helps me understand the root cause of problems. | -1 | 0 | Eliminated |
| 17 | I use questioning to evaluate the effectiveness of solutions. | 1 | 1 | Retained |
| 18 | I believe that good questions can lead to significant discoveries. | 1 | 1 | Retained |
| 19 | I am confident in my ability to ask meaningful questions. | -1 | 0 | Eliminated |
| 20 | I ask questions to explore new ideas. | 0.2 | 0.2 | Eliminated |
| 21 | My questions often lead to further research. | 1 | 1 | Retained |
| 22 | I enjoy asking questions that make others think deeply. | 0.2 | 0.2 | Eliminated |
| 23 | I use questioning to challenge assumptions. | 1 | 1 | Retained |
| 24 | I find that questioning helps me learn more effectively. | 1 | 1 | Retained |
| 25 | I ask questions to connect different concepts. | 1 | 1 | Retained |
| 26 | My questions often spark interesting discussions. | 0.2 | 0.2 | Eliminated |
| 27 | I use questioning to test my understanding. | 1 | 1 | Retained |
| 28 | I believe that asking questions is a sign of intelligence. | 1 | 1 | Retained |
| 29 | My questions often lead to new ways of thinking. | 0.2 | 0.2 | Eliminated |
| 30 | I enjoy the process of questioning and discovery | 0.2 | 0.2 | Eliminated |

| Constructs and Items | | CVR | CVI | Decision |
|---|---|---|---|---|
| EXPERIMENTING | | | | |
| 1 | I enjoy designing and conducting experiments to test my ideas. | 1 | 1 | Retained |
| 2 | I am not afraid to take risks when experimenting with new concepts. | 1 | 1 | Retained |
| 3 | I frequently learn from failed experiments. | 1 | 1 | Retained |
| 4 | I regularly modify my experiments based on initial results. | 1 | 1 | Retained |
| 5 | Experimentation helps me develop innovative solutions in STEM. | 1 | 1 | Retained |
| 6 | I often use experiments to explore unconventional ideas. | 0.4 | 0.4 | Eliminated |
| 7 | I feel confident in my ability to conduct successful experiments. | 0.2 | 0.4 | Eliminated |

| | | | | |
|---|---|---|---|---|
| 8 | I actively seek out new methods and techniques for experimenting. | 1 | 1 | Retained |
| 9 | I believe that experimentation is essential for scientific progress. | -0.2 | .4 | Eliminated |
| 10 | My experiments often lead to unexpected but valuable outcomes. | 1 | 1 | Retained |
| 11 | I enjoy hands-on activities that involve experimenting. | -0.2 | 0.4 | Eliminated |
| 12 | Experimenting helps me understand how things work. | -1 | 0 | Eliminated |
| 13 | I often experiment to find the best solution to a problem. | 1 | 1 | Retained |
| 14 | I use experiments to test my hypotheses. | -0.2 | 0.4 | Eliminated |
| 15 | I am creative in designing experiments. | 1 | 1 | Retained |
| 16 | I enjoy the process of trial and error in experiments. | 1 | 1 | Retained |
| 17 | I document my experiments thoroughly. | -0.2 | 0.4 | Eliminated |
| 18 | I use the results of my experiments to improve my work. | 1 | 1 | Retained |
| 19 | I believe that experimenting is a fun way to learn. | -0.2 | 0.4 | Eliminated |
| 20 | I often experiment with different approaches to solve a problem. | 1 | 1 | Retained |
| 21 | Experimenting helps me think outside the box | -0.2 | 0.4 | Eliminated |
| 22 | I am open to experimenting with new ideas. | 1 | 1 | Retained |
| 23 | I use experiments to verify the accuracy of information. | -0.2 | 0.4 | Eliminated |
| 24 | I enjoy collaborating with others on experiments. | -0.2 | 0.4 | Eliminated |
| 25 | I believe that failure is a part of the experimentation process. | 1 | 1 | Retained |
| 26 | I learn valuable lessons from my experiments. | -0.2 | 0.4 | Eliminated |
| 27 | I enjoy experimenting with new technologies. | -0.2 | 0.4 | Eliminated |
| 28 | I use experiments to test the feasibility of my ideas. | 1 | 1 | Retained |
| 29 | I believe that experimenting is essential for innovation. | -0.4 | 0.4 | Eliminated |
| 30 | I am confident in my ability to design effective experiments. | -0.2 | 0 | Eliminated |

| Constructs and Items | | CVR | CVI | Decision |
|---|---|---|---|---|
| IDEA NETWORKING | | | | |
| 1 | I regularly share my ideas with peers to get their feedback. | 1 | 1 | Retained |
| 2 | Collaborating with others helps me refine and improve my ideas. | 1 | 1 | Retained |
| 3 | I actively seek out people with different perspectives to discuss STEM topics. | -1 | 0 | Eliminated |
| 4 | Networking with others often leads to new and innovative ideas. | 1 | 1 | Retained |
| 5 | I find that group discussions help me generate better solutions. | 1 | 1 | Retained |
| 6 | I am open to incorporating ideas from others into my work. | 1 | 1 | Retained |
| 7 | I frequently participate in STEM-related group activities or projects. | -1 | 0 | Eliminated |
| 8 | I believe that diverse viewpoints are crucial for innovation. | -1 | 0 | Eliminated |
| 9 | I use social networks or online communities to discuss STEM ideas. | 1 | 1 | Retained |
| 10 | I am proactive in seeking mentorship or advice from experts in STEM fields. | 1 | 1 | Retained |
| 11 | I enjoy brainstorming sessions with others. | -1 | 0 | Eliminated |

| | | | | |
|---|---|---|---|---|
| 12 | Networking helps me stay updated with the latest advancements | 1 | 1 | Retained |
| 13 | I value the input of others in developing my ideas. | -1 | 0 | Eliminated |
| 14 | I am good at building relationships with peers in STEM. | -1 | 0 | Eliminated |
| 15 | I use feedback from others to improve my projects. | -1 | 0 | Eliminated |
| 16 | Networking helps me find solutions to challenging problems. | -1 | 0 | Eliminated |
| 17 | I believe that collaboration is key to innovation. | -1 | 0 | Eliminated |
| 18 | I actively seek opportunities to network with professionals. | 1 | 1 | Retained |
| 19 | I enjoy discussing my ideas with others. | 1 | 1 | Retained |
| 20 | I am open to new ideas from my network. | -1 | 0 | Eliminated |
| 21 | Networking helps me discover new resources. | -1 | 0 | Eliminated |
| 22 | I believe that sharing ideas leads to better outcomes. | 1 | 1 | Retained |
| 23 | I use my network to get diverse perspectives. | 1 | 1 | Retained |
| 24 | I am confident in my ability to network effectively. | -1 | 0 | Eliminated |
| 25 | Networking helps me gain new insights. | 1 | 1 | Retained |
| 26 | I value the connections I make in the STEM community | 1 | 1 | Retained |
| 27 | I use networking to expand my knowledge. | -1 | 0 | Eliminated |
| 28 | I believe that idea networking fosters creativity. | -1 | 0 | Eliminated |
| 29 | I enjoy learning from others in my network. | 1 | 1 | Retained |
| 30 | Networking helps me achieve my goals. | -1 | 0 | Eliminated |

| Constructs and Items | | CVR | CVI | Decision |
|---|---|---|---|---|
| ASSOCIATING | | | | |
| 1 | I often connect ideas from different fields to develop new solutions. | 1 | 1 | Retained |
| 2 | Associating unrelated concepts helps me generate innovative ideas. | 1 | 1 | Retained |
| 3 | I am good at seeing connections between seemingly unrelated topics. | -1 | 0 | Eliminated |
| 4 | I use analogies to understand complex STEM concepts better. | -1 | 0 | Eliminated |
| 5 | I enjoy finding ways to apply knowledge from one area to another. | 1 | 1 | Retained |
| 6 | I believe that interdisciplinary thinking is crucial for innovation. | 1 | 1 | Retained |
| 7 | I regularly draw on experiences from outside STEM to solve problems. | 1 | 1 | Retained |
| 8 | Associating different ideas helps me think more creatively. | -1 | 0 | Eliminated |
| 9 | I often combine elements from various sources to create something new. | 1 | 1 | Retained |
| 10 | I believe that making connections between different concepts is essential for innovation. | -1 | 0 | Eliminated |
| 11 | I use metaphors to explain my ideas. | 1 | 1 | Retained |
| 12 | Associating ideas helps me simplify complex problems. | -1 | 0 | Eliminated |
| 13 | I enjoy synthesizing information from different disciplines. | 1 | 1 | Retained |
| 14 | I often find inspiration from unrelated fields. | 1 | 1 | Retained |
| 15 | I use my knowledge from different subjects to innovate. | 1 | 1 | Retained |
| 16 | Associating ideas helps me see the bigger picture. | -1 | 0 | Eliminated |

| | | | | |
|---|---|---|---|---|
| 17 | I enjoy creating new concepts by combining existing ones. | 1 | 1 | Retained |
| 18 | I believe that cross-disciplinary thinking enhances creativity. | 1 | 1 | Retained |
| 19 | I often apply lessons from one field to another. | -1 | 0 | Eliminated |
| 20 | Associating ideas helps me come up with unique solutions. | 1 | 1 | Retained |
| 21 | I use examples from different areas to illustrate my points. | -1 | 0 | Eliminated |
| 22 | I am skilled at integrating knowledge from various fields. | -1 | 0 | Eliminated |
| 23 | Associating ideas helps me think more deeply. | -1 | 0 | Eliminated |
| 24 | I enjoy exploring connections between different subjects. | 1 | 1 | Retained |
| 25 | I believe that associating ideas leads to breakthrough innovations. | -1 | 0 | Eliminated |
| 26 | I often use my diverse interests to innovate. | -1 | 0 | Eliminated |
| 27 | Associating ideas helps me generate novel concepts. | -1 | 0 | Eliminated |
| 28 | I enjoy drawing parallels between different fields. | 1 | 1 | Retained |
| 29 | I believe that thinking across disciplines is essential for innovation. | -1 | 0 | Eliminated |
| 30 | Associating ideas helps me solve complex problems. | -1 | 0 | Eliminated |

The expert panel looked at 150 items using a four-point scale. The Content Validity Ratio (CVR) shows the percentage of experts who rated an item as either 4 or 5, adjusted for those who rated it as 3 or lower, reflecting how many experts consider the item essential. The Content Validity Index (CVI) measures the proportion of experts who rated the item as 4 , indicating its perceived importance. Items are retained if both CVR and CVI scores meet or exceed the threshold of 0.80, showing strong expert agreement; otherwise, they are eliminated. Items with a low content validity ratio (CVR) were removed: 15 items for the first group, 15 for the second, 15 for the third, 15 for the fourth and 15 for the fifth group. The remaining items were revised based on expert feedback to fix issues with the consistency of wording and perspectives. According to Polit et al, (2017), for three to five experts, a CVI value of 1 is considered acceptable. Items are retained if they have a Content Validity Ratio (CVR) of 0.60 or higher and a Content Validity Index (CVI) of 0.80 or higher, while items are eliminated if they fall below either criterion, with a CVR of less than 0.60 or a CVI of less than 0.80 ("(PDF) Psychometric Properties in Instruments Evaluation of Reliability and Validity," 2017).

Table 2 shows the principal component analysis (PCA) that was conducted on the 75 items with orthogonal rotation (varimax). It was found out that items are group into five components that confirmed the five constructs. 15 items are under each constructs the Observing, Questioning, Experimenting, Idea Net Working and Associating. All individual items were greater than .5 which were well above the acceptable limit of .5 (Field, 2009).

Table 2. Rotated Component Matrix[a]

| | Component | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| My observations often lead to new hypotheses. | .661 | | | | |
| I enjoy observing the details of how things work. | .647 | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Observation is an essential skill for innovation in STEM. | .642 | | | | |
| I use specific techniques to enhance my observational skills during experiments. | .640 | | | | |
| Small details often lead me to significant discoveries or ideas. | .577 | | | | |
| Careful observation often leads me to innovative solutions in my projects. | .613 | | | | |
| My observations help me understand complex concepts. | .612 | | | | |
| Observation is a key part of my problem-solving process. | .636 | | | | |
| I actively seek opportunities to observe new technologies or scientific advancements. | 0.52 | | | | |
| I document my observations thoroughly. | 0.51 | | | | |
| I believe that observation is crucial in the process of innovation. | 0.53 | | | | |
| I enjoy activities that require careful observation. | .572 | | | | |
| I frequently notice patterns in data or phenomena in my STEM classes. | .553 | | | | |
| I enjoy observing natural phenomena to gain insights. | .587 | | | | |
| I incorporate observations from various sources into my learning process | .555 | | | | |
| I believe that good questions can lead to significant discoveries. | | .707 | | | |
| My questions often lead to new insights or perspectives. | | .706 | | | |
| I use questioning to evaluate the effectiveness of solutions. | | .686 | | | |
| I ask questions to connect different concepts | | .682 | | | |
| I believe that asking questions is a sign of intelligence. | | .675 | | | |
| I find that questioning helps me learn more effectively. | | .670 | | | |
| My questions often lead to further research | | .676 | | | |
| I use questioning to test my understanding. | | .624 | | | |
| I use questioning to challenge assumptions. | | .621 | | | |
| I find that my questions often lead to productive discussions in class. | | .601 | | | |
| I frequently ask questions that challenge existing norms in my STEM classes. | | .615 | | | |
| I believe that asking the right questions is essential for innovation. | | 0.58 | | | |
| I enjoy discussions that involve deep questioning. | | .569 | | | |
| I believe that questioning is a critical part of the scientific process. | | .563 | | | |
| My questioning often leads to breakthroughs in projects or experiments. | | 0.51 | | | |
| I enjoy designing and conducting experiments to test my ideas | | | .713 | | |
| I actively seek out new methods and techniques for experimenting | | | .566 | | |
| I use the results of my experiments to improve my work. | | | .661 | | |
| I use experiments to test the feasibility of my ideas. | | | .649 | | |
| I believe that failure is a part of the experimentation process. | | | .642 | | |
| I enjoy the process of trial and error in experiments. | | | .636 | | |
| I am open to experimenting with new ideas | | | .612 | | |
| I frequently learn from failed experiments | | | .577 | | |

| | | | | | |
|---|---|---|---|---|---|
| My experiments often lead to unexpected but valuable outcomes. | | | .555 | | |
| I regularly modify my experiments based on initial results | | | .545 | | |
| I often experiment with different approaches to solve a problem. | | | .526 | | |
| I am creative in designing experiments | | | .511 | | |
| I often experiment to find the best solution to a problem | | | 0.53 | | |
| I am not afraid to take risks when experimenting with new concepts. | | | 0.553 | | |
| I actively seek opportunities to network with professionals | | | | .686 | |
| I enjoy discussing my ideas with others. | | | | .707 | |
| I regularly share my ideas with peers to get their feedback. | | | | .691 | |
| I value the connections I make in the STEM community | | | | .682 | |
| I believe that sharing ideas leads to better outcomes | | | | .676 | |
| Networking helps me gain new insights | | | | .670 | |
| Networking with others often leads to new and innovative ideas. | | | | .660 | |
| I often find inspiration from unrelated fields | | | | .615 | |
| Collaborating with others helps me refine and improve my ideas. | | | | .615 | |
| Networking helps me stay updated with the latest advancements | | | | .606 | |
| I use my network to get diverse perspectives | | | | .599 | |
| I am proactive in seeking mentorship or advice from experts in STEM fields | | | | .565 | |
| I find that group discussions help me generate better solutions. | | | | .563 | |
| I use social networks or online communities o discuss STEM ideas. | | | | .577 | |
| I am open to incorporating ideas from others into my work. | | | | 0.53 | |
| I believe that cross-disciplinary thinking enhances creativity | | | | | .652 |
| I enjoy synthesizing information from different disciplines | | | | | .639 |
| I regularly draw on experiences from outside STEM to solve problems | | | | | .629 |
| I often connect ideas from different fields to develop new solutions | | | | | .731 |
| I enjoy creating new concepts by combining existing ones. | | | | | .719 |
| I often combine elements from various sources to create something new. | | | | | .690 |
| I enjoy exploring connections between different subjects | | | | | .689 |
| I enjoy learning from others in my network. | | | | | .675 |
| I believe that interdisciplinary thinking is crucial for innovation | | | | | .667 |
| I use metaphors to explain my ideas. | | | | | .632 |
| Associating ideas helps me come up with unique solutions. | | | | | .617 |
| Associating unrelated concepts helps me generate innovative ideas | | | | | .609 |
| I enjoy drawing parallels between different fields. | | | | | .582 |
| I enjoy finding ways to apply knowledge from one area to another. | | | | | .571 |
| I use my knowledge from different subjects to innovate. | | | | | .563 |
| Extraction Method: Principal Component Analysis. | | | | | |
| a. 5 components extracted. | | | | | |

**Internal Consistency**

Table 3 shows that the reliability of all constructs is greater than 0.90, indicating that the reliability is acceptable.

Table 3. Internal Consistency of all Constructs

| **Reliability Statistics** | | |
|---|---|---|
| Cronbach's Alpha | Cronbach's Alpha Based on Standardized Items | N of Items |
| 0.975 | 0.975 | 75 |

Table 4 shows that the reliability of the five constructs is greater than .8, this implies that all items demonstrated a valid internal consistency. According to Taber (2018), Cronbach's alpha between 0.8 to 1 shows good reliability, between 0.6 to 0.79 indicates the reliability is acceptable, and less than 0.6 indicates poor reliability.

Table 4. Internal Consistency of the Instrument

| Constructs and Items | Cronbach's Alpha | Mean Score |
|---|---|---|
| OBSERVATION | 0.897 | |
| I frequently notice patterns in data or phenomena in my STEM classes. | | 3.43 |
| Small details often lead me to significant discoveries or ideas. | | 3.92 |
| I use specific techniques to enhance my observational skills during experiments. | | 3.87 |
| Careful observation often leads me to innovative solutions in my projects. | | 4.07 |
| I actively seek opportunities to observe new technologies or scientific advancements. | | 3.61 |
| I incorporate observations from various sources into my learning process. | | 3.61 |
| I believe that observation is crucial in the process of innovation. | | 4.12 |
| I enjoy observing natural phenomena to gain insights. | | 3.92 |
| Observation is a key part of my problem-solving process. | | 4.16 |
| My observations often lead to new hypotheses. | | 3.57 |
| I enjoy activities that require careful observation. | | 3.80 |
| My observations help me understand complex concepts. | | 3.92 |
| Observation is an essential skill for innovation in STEM | | 4.26 |
| I document my observations thoroughly | | 3.34 |
| I enjoy observing the details of how things work. | | 4.12 |

| Constructs and Items | Cronbach's Alpha | Mean Score |
|---|---|---|
| QUESTIONING | 0.916 | |
| I frequently ask questions that challenge existing norms in my STEM classes. | | 3.51 |
| My questioning often leads to breakthroughs in projects or experiments. | | 3.38 |

| | | | |
|---|---|---|---|
| | I believe that questioning is a critical part of the scientific process. | | 4.10 |
| | My questions often lead to new insights or perspectives. | | 4.14 |
| | I believe that asking the right questions is essential for innovation | | 3.46 |
| | I find that my questions often lead to productive discussions in class | | 3.64 |
| | I enjoy discussions that involve deep questioning. | | 3.93 |
| | I use questioning to evaluate the effectiveness of solutions. | | 4.11 |
| | I believe that good questions can lead to significant discoveries. | | 3.90 |
| | My questions often lead to further research. | | 4.07 |
| | I use questioning to challenge assumptions. | | 3.55 |
| | I find that questioning helps me learn more effectively. | | 3.50 |
| | I ask questions to connect different concepts. | | 4.01 |
| | I use questioning to test my understanding. | | 3.44 |
| | I believe that asking questions is a sign of intelligence. | | 4.03 |

| Constructs and Items | | Cronbach's Alpha | Mean Score |
|---|---|---|---|
| EXPERIMENTING | | 0.895 | |
| | I enjoy designing and conducting experiments to test my ideas. | | 4.04 |
| | I am not afraid to take risks when experimenting with new concepts. | | 3.42 |
| | I frequently learn from failed experiments. | | 3.90 |
| | I regularly modify my experiments based on initial results. | | 3.64 |
| | Experimentation helps me develop innovative solutions in STEM. | | 3.92 |
| | I actively seek out new methods and techniques for experimenting. | | 3.56 |
| | My experiments often lead to unexpected but valuable outcomes. | | 3.58 |
| | I often experiment to find the best solution to a problem. | | 3.56 |
| | I am creative in designing experiments. | | 3.49 |
| | I enjoy the process of trial and error in experiments. | | 4.21 |
| | I use the results of my experiments to improve my work. | | 3.60 |
| | I often experiment with different approaches to solve a problem. | | 3.92 |
| | I am open to experimenting with new ideas. | | 3.92 |
| | I believe that failure is a part of the experimentation process. | | 4.30 |
| | I use experiments to test the feasibility of my ideas. | | 3.74 |

| Constructs and Items | | Cronbach's Alpha | Mean Score |
|---|---|---|---|
| IDEA NETWORKING | | 0.915 | |
| | I regularly share my ideas with peers to get their feedback. | | 3.75 |
| | Collaborating with others helps me refine and improve my ideas. | | 3.51 |
| | Networking with others often leads to new and innovative ideas. | | 3.60 |

| | | | |
|---|---|---|---|
| | I find that group discussions help me generate better solutions. | | 4.10 |
| | I am open to incorporating ideas from others into my work. | | 3.40 |
| | I use social networks or online communities to discuss STEM ideas. | | 3.46 |
| | I am proactive in seeking mentorship or advice from experts in STEM fields. | | 4.18 |
| | Networking helps me stay updated with the latest advancements | | 3.38 |
| | I actively seek opportunities to network with professionals. | | 4.11 |
| | I enjoy discussing my ideas with others. | | 3.90 |
| | I believe that sharing ideas leads to better outcomes. | | 4.07 |
| | I use my network to get diverse perspectives. | | 3.44 |
| | Networking helps me gain new insights. | | 3.50 |
| | I value the connections I make in the STEM community | | 4.03 |
| | I enjoy learning from others in my network. | | 4.01 |

| Constructs and Items | | Cronbach's Alpha | Mean Score |
|---|---|---|---|
| ASSOCIATING | | 0.934 | |
| | I often connect ideas from different fields to develop new solutions. | | 3.59 |
| | Associating unrelated concepts helps me generate innovative ideas. | | 3.72 |
| | I enjoy finding ways to apply knowledge from one area to another. | | 3.49 |
| | I believe that interdisciplinary thinking is crucial for innovation. | | 3.69 |
| | I regularly draw on experiences from outside STEM to solve problems. | | 3.69 |
| | I often combine elements from various sources to create something new. | | 3.91 |
| | I use metaphors to explain my ideas. | | 3.87 |
| | I enjoy synthesizing information from different disciplines. | | 3.66 |
| | I often find inspiration from unrelated fields. | | 3.55 |
| | I use my knowledge from different subjects to innovate. | | 3.53 |
| | I enjoy creating new concepts by combining existing ones. | | 3.92 |
| | I believe that cross-disciplinary thinking enhances creativity. | | 3.76 |
| | Associating ideas helps me come up with unique solutions. | | 3.70 |
| | I enjoy exploring connections between different subjects. | | 3.78 |
| | I enjoy drawing parallels between different fields. | | 3.48 |

The present study aimed to develop a reliable and valid instrument for assessing innovative thinking in STEM students. This research employed a three-phase methodology that included the creation of the assessment tool through a comprehensive review of existing literature, followed by an evaluation of its psychometric properties, such as content validity and internal consistency.

Several studies have focused on creating and testing tools to measure innovative thinking in STEM students. For instance, Lee and Kim (2019) developed and tested a new assessment tool for innovative thinking specifically in

STEM education (Lee & Kim, 2019). Nguyen and Nguyen (2020) examined how effective these assessment tools are in improving STEM learning outcomes (Nguyen & Nguyen, 2020). Gordon and Smith (2018) designed a tool to measure creativity in STEM students and validated its effectiveness (Gordon & Smith, 2018). Choi and Lee (2021) worked on validating an assessment tool aimed at measuring innovative thinking among engineering students (Choi & Lee, 2021). Finally, Miller and Johnson (2022) developed and validated a tool to assess both innovation and critical thinking in STEM students (Miller & Johnson, 2022).

This study successfully developed and validated a robust instrument for assessing innovative thinking in STEM students by employing a rigorous three-phase approach. The research demonstrated the tool's reliability and validity through careful psychometric evaluation, including content validity and internal consistency. Building on previous work, such as the efforts by Lee and Kim (2019) and Nguyen and Nguyen (2020), which provided foundational insights into the development and effectiveness of such tools, this study contributes to the ongoing enhancement of assessment methods in STEM education. By incorporating elements from Gordon and Smith (2018), Choi and Lee (2021), and Miller and Johnson (2022), this tool offers a comprehensive framework for measuring innovative and critical thinking skills. Ultimately, this advancement supports educators and researchers in fostering and evaluating creativity and innovation in STEM students, paving the way for more effective educational strategies and interventions.

## Conclusion

To give resolutions to the objectives of this research, the study was able to establish 75 item questions 15 each construct the Observing, Questioning, Experimenting, Idea Networking and Associating. Items were primarily developed from the intensive review of related literature. 75 were retained after expert validation and after pilot testing tested for the reliability of internal consistency resulting in excellent reliability. The developed questionnaire for measuring innovative thinking in STEM students exhibited strong reliability and content validity. The instrument effectively captured the core dimensions of innovative thinking, such as observing, questioning, experimenting, idea networking, and associating. The factor analysis results supported the instrument's underlying structure, and Cronbach's alpha values indicated high internal consistency. These findings suggest that the questionnaire is a reliable and valid tool for assessing innovative thinking in STEM students.

## Recommendations

Even with promising results, this assessment tool may use for measuring innovative thinking skills among STEM students, yet it is recommended that a supplementary Confirmatory Factory Analysis (CFA) using AMOS be performed to further strengthen the construct validity, future research could explore the instrument's predictive validity to strengthen its utility.

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