# Scientific Creativity in Chemistry Education: How is it Measured?

**Wimbi Apriwanda Nursiwan*, Chuzairy Hanri, Nor Hasniza Ibrahim**

**Department of Innovative Science and Mathematics, Faculty of Educational Sciences and Technology, University Technology Malaysia**

*** Corresponding Author**

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## ABSTRACT

Scientific creativity is a critical component of 21st-century skills, especially in science education. This study aims to develop a scoring rubric that enables chemistry educators to assess students' scientific creativity effectively. The development process adopted Tessmer's model, consisting of three phases: Preliminary Phase, Self-Evaluation Phase, and Prototyping Phase. To determine the rubric's validity, expert judgment was conducted and analyzed using the Content Validity Index (CVI). The findings showed that the rubric achieved an item-level CVI (I-CVI) of 1.00, indicating excellent content validity. Feedback from the experts was also incorporated to improve the structure, clarity, and applicability of the rubric. The resulting scoring method provides a practical tool to evaluate key aspects of scientific creativity, such as creative traits, product and process within the context of chemistry learning. This study contributes to the advancement of assessment practices by offering a reliable and valid instrument tailored for creative performance in science. The rubric can support educators in identifying and fostering students' creative potential, ultimately enhancing the quality of chemistry instruction.

**Keywords;** Scientific Creativity, Chemistry Education, HOTS, Creative Process, Chemical Representation

## INTRODUCTION

Creativity in science is defined as scientific creativity [1]. Scientific creativity is an overview of an individual's thinking ability to generate several original ideas and hypotheses from various domains in order to solve problem [2]-[3]. Creative potential in science is complicated, as evidenced by the presence of three dimensions of scientific creativity: products, traits, and process [4]. When students are scientifically creative, the ideas they generate are based on science and lead to more applicable solutions [5]-[6].

Unlike general creativity, which may involve more open-ended problem-solving, scientific creativity has a distinct focus and application. For instance, when a teacher provides students with materials such as batteries, wires, and light bulbs and asks them to light the bulb to two classes. In Class A, students are asked to make a model of a house and investigate how illumination (with light coming from the sun) within the house can increase. While students in Class B are asked to investigate and then come up with an explanation, how substances like sugar and salt, affect the evaporation rate of the water in a container. The students in Class A require general creativity in order for students to try possible factors that might affect the illumination in the house (such as the position of windows, the color of curtains, the arrangement of furniture). Meanwhile, students from Class B might be asked to investigate how substances like sugar or salt affect the evaporation rate of water. Here, students must apply their understanding of molecular interactions and hypothesize why adding these substances slows the evaporation process. In this case, with similar materials, the product will be different. In conclusion, scientific creativity requires students to engage deeply with scientific concepts and use imaginative thinking grounded in science to explain [7].

In chemistry education, the studies that reported students' scientific creativity level is relatively small. Unfortunately, those studies also found students' scientific creativity remains low. For example, students in Kenya show a low level of scientific creativity in chemistry class [8] – [9]. A similar conclusion was reported in Malaysia, where students in chemistry demonstrated a low level of scientific creativity [5], [10].

Previous researchers have applied various approaches to measure the level of scientific creativity, [10] tested fluency, flexibility, originality, and elaboration; [8] assessed sensitivity, recognition, and flexibility; while [5] evaluated fluency, flexibility, and originality. [9] added sensitivity to the problem, flexibility, recognition of relationships and planning for investigation. Overall findings from previous studies show that flexibility is the most measured. Those highlight challenges in students' flexibility, a critical aspect of scientific creativity. [8] found that students' flexibility remains poor, similar to their ability to recognize relationships. [9] reported mixed findings, with some students exhibiting better flexibility than planning investigative tasks, yet others struggled to generate diverse responses when required. Similarly, [10] observed that students' flexibility was weak, along with their fluency and originality. [5] also identified flexibility as the most problematic trait for students, followed by fluency, though students performed slightly better in originality. Thus, these findings underscore that students' ability to produce diverse and new ideas is inadequate.

Furthermore, despite the attention to creativity traits, no studies have specifically addressed the creative process, leaving a critical gap in understanding how students develop and refine their creativity in scientific contexts. The creative process is significant in scientific creativity because it involves thinking and imagination, both of which are necessary in generating diverse solutions as well as fresh and original ideas [4], it means that exploring individuals' creative processes provides a deeper understanding of the phases involved in the way of producing ideas.

In addition, the measurement of scientific creativity is limited in terms of how students express creative ideas in chemical representations. In fact, chemical representations are important for understanding chemical concepts and solving problems creatively. In chemistry learning, macroscopic, sub-microscopic, and symbolic representations are crucial [11], and the use of various forms of representation strengthens concept formation [12]. As a result, while research has focused on the ideas generated, it is equally important to explore creative process and examine chemical representation ideas generated by students.

### Objective of Study

This study aims to design and develop a valid rubric of scoring for scientific creativity test in chemistry education.

## LITERATURE REVIEW

### Scientific Creativity

Creativity is generally understood as the ability to produce new ideas or products, as well as to combine existing concepts or objects in novel ways for a specific purpose [13]. However, creativity is not a universal skill that manifests equally across all domains. Individuals who demonstrate creativity in one area, such as the arts, may not necessarily exhibit the same level of creativity in another area, such as science [14]. This perspective highlights the distinction between general creativity and domain-specific creativity. Therefore, scientific creativity is defined by experts based on various perspectives. Scientific creativity is the ability to solve problems by generating ideas and hypotheses, through experimentation, discovery, and problem-solving activities [3]. Then, [15] defined it as individual's ability to generate several original ideas from various domains in order to solve scientific problem. Based on the above definition, it can be concluded that scientific creativity is a thinking ability that involves the creative process of generating new ideas to solve scientific problems, formulate knowledge, and develop innovative experiments. This ability includes the skills to formulate hypotheses, make discoveries, and carry out in-depth problem-solving activities from various fields of science. Overall, scientific creativity helps individuals in finding solutions, designing experiments, and imagining new ways of understanding and solving scientific problems. In the field of chemistry, scientific creativity impacts on students' sensitivity to chemical problems, scientific observations and scientific concepts so that there is flexibility in thinking when solving problems in chemistry [8]. In this case, it is clear that knowledge for domain specialization and domain expertise plays an important role. To put it another way, people must build new ideas on top of subject knowledge such as chemistry. Based on the definitions, it indicates that the criteria for scientific creativity in chemistry are different. Thus, scientific creativity in this study defined as the ability of students producing ideas related to chemistry domain, where the students were not only measured in terms of quantity of ideas, but also quality of ideas.

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**Scientific Structure Creativity Model**

Scientific Structure Creativity Model (SSCM) was developed by [4], it is a test for secondary school students and established and proposed it as dimension. SSCM included of three dimensions namely process, trait, and product as shown in Figure 1.

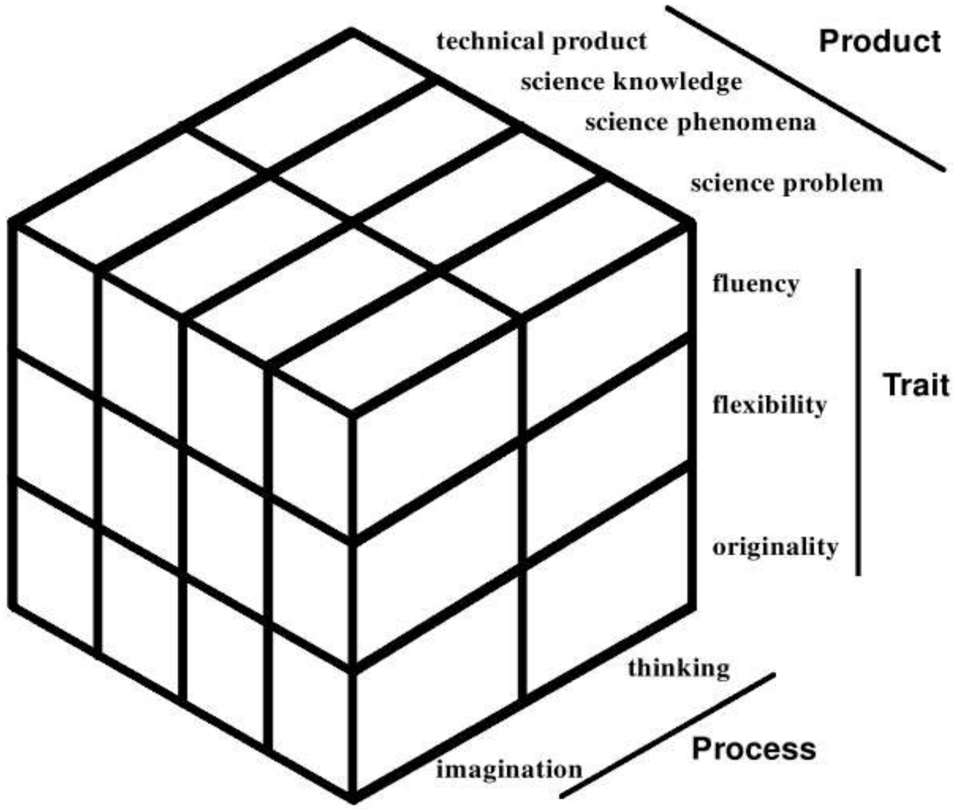


**Fig. 1 Scientific Structure Creativity Model (SSCM)**

**Source: Hu & Adey (2002)**

In creative product, there are 4 components such as technical product, science knowledge, science phenomena, and science problem. Science problems are problems that require scientific knowledge to solve. By presenting scientific problems to students, it is likely that they can come up with creative scientific solutions. Scientific phenomena refer to natural physical events or occurrences that can be scientifically explained. In the concepts of science, the everyday activities are related to the scientific phenomena that individual experience in their world. Scientific knowledge refers to knowledge in science-based fields such as Physics, Biology, Chemistry, Geology, Engineering, and many more. Technical product refers to science-based engineering technologies to perform certain tasks and are subject to innovation. According to [4], technical product must be product with a purpose to come to fruition in the result of creative thinking in science, to expose scientific knowledge, overcome a scientific problem and must be designed to be related to scientific phenomena.

Furthermore, creative process includes of imagination. In this dimension, thinking is good thing to find great solution which is free and can offer various and different solution. [4] stated that creative thinking often emerges with divergent thinking. Next part of process is imagination, in which strong imagination is the best way to be creative individual and it produces new and original product which it is also play important role in creativity.

Next dimension is creative trait includes flexibility, fluency, and originality. Those determine how creative of individual and the ability of individual's creative thinking. Creative people will solve their problem, and they know when they must to make decisions which express though through either writing or verbally. Through their creativity, students demonstrate their fluency, flexibility, and originality while demonstrating their understanding of scientific phenomena and demonstrate scientific knowledge.

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**Scientific Creativity in Chemistry Education**

The following Table 1 is about list of previous studies of scientific creativity in chemistry education, especially using SSCM model.

**Table 1. Chemistry topic in scientific creativity (previous studies):**

| Previous Studies | Dimensions of Scientific Structure Creativity Model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Creative Trait | | | Creative Process | | Creative Product | | | |
| | Fluency | Flexibility | Originality | T | I | SPr | TP | SPh | SK |
| Omar et al. (2017) | √ | √ | √ | | | | | | |
| Alkan & Altundag (2018) | | | √ | | √ | / | | | |
| Jamal et al. (2020) | √ | √ | √ | | | / | | | √ |
| Ramly et al. (2022) | √ | √ | √ | | √ | / | √ | | √ |
| Eroglu & Bektas (2022) | √ | √ | √ | | | | | | |
| Eroglu & Bektas (2022) | √ | √ | √ | | | | | | |

Note: T= Thinking; I= Imagination; SPr= Science Problem; TP = Technical Product; SPh = Science Phenomena; SK= Science Knowledge

Table 1 shows that in chemistry education, the majority of previous studies focused on creative traits (fluency, flexibility, and originality). For creative products, the previous researchers studied technical product and science knowledge mostly. Then, it was limited to measure creative process. The following Table 2 shows the previous studies for creative traits scoring.

**Table 2. Creative Traits - Fluency, Flexibility, Originality (Scoring Criteria) From Previous Studies:**

| Previous Studies | Fluency | Flexibility | Originality |
|---|---|---|---|
| Omar et al. (2017) | **Each question has specific scoring.**<br><br>**0 point =** No idea.<br>**1 point =** 1 –4 ideas. / 1 –6 ideas / 1 –3 ideas.<br>**2 points =** 5 – 8 ideas / 7-12 ideas / 4 – 6 ideas.<br>**3 points =** ≥ 9 ideas / ≥ 13 ideas / ≥ 7 ideas. | **0 point =** All the ideas in same category.<br>**1 point** = 2 categories of idea.<br>**2 points** = 3-5 categories of idea.<br>**3 points =** ≥ 6 categories of idea. | • **0 point =** Idea stated ≥ 50% as compared to overall sample.<br>• **1 point =** One or more idea is 20%-49% from the overall sample.<br>• **2 points =** One or more idea is ≤ 19% from the overall sample.<br>• **3 points =** One or more idea is ≤ 10% from the overall sample. |
| Alkan & Altundag (2018) | N/A | N/A | • **0 point =** Other correct answers.<br>• **1 point =** The students whose answers between 5% and 10% of all correct answers. |

| | | | |
|---|---|---|---|
| | | | • **2 points** = The students who enter the first 5% of all correct answers. |
| Jamal et al. (2020) | • **0 point** = Students cannot provide ideas/answers.<br>• **2 points** = Students can come up with one to two ideas/answers.<br>• **4 points** = Students can come up with three or more ideas/answers. | • **0 point** = Students are not able to provide ideas/methods.<br>• **2 points** = Students can come up with one to two ideas/methods.<br>• **4 points** = Students can come up with three or more ideas/methods. | • **0 point** = Student do not answer/ general ideas / common ideas and no originality.<br>• **2 points** = Students come up with moderate unique ideas.<br>• **4 points** = Students come up with very unique ideas. |
| Ramly et al. (2022) | **1 point** = for each idea.<br>(Max score is 5) | **1 point** = for each category of idea.<br>(Max score is 5) | • **0 point** = The idea is incorrect.<br>• **1 point** = The idea is common and correct.<br>• **2 points** = The idea is unique and correct. |
| Eroglu & Bektas (2022a) | **1 point** = for each idea (codes). | **1 point** = for each category in which their answers (codes). | **0 point** = Answers with a repetition frequency of more than 10%.<br>**1 point** = Answers with a repetition frequency of 5-10%.<br>**2 points** = Answers with a repetition frequency of less than 5%. |
| Eroglu & Bektas (2022b) | **1 point** = for each idea (codes). | **Each question has specific scoring.**<br><br>**1 point** = for each category in which their answers (codes).<br>**3 points** of tool, **3 points** of principles, and **3 points** of the way of followed.<br><br>**3 points** for each function. | **Each question has specific scoring.**<br><br>**0 point** = Answers with a repetition frequency of more than 10%.<br>**1 point** = Answers with a repetition frequency of 5-10% / answers with a repetition frequency of more than 10%.<br>**2 points** = Answers with a repetition frequency of less than 5% / answers with a repetition frequency of 5-10%.<br>**3 points** = Answers with a repetition frequency of less than 5%.<br>**4 points** = Answers with a repetition frequency of less than 5%.<br><br>**Points between 1 and 5 depending on the content of drawings.** |

Based on Table 2, either fluency, flexibility, or originality were measured differently. In terms of fluency, [5] used a range of points that varied depending on the questions asked. The varying scoring criteria indicate the complexity of the assessment, making it too complicated for situations that require rapid assessment. Then, [10] applied more structured scoring criteria because each question has the same maximum score. However, this assessment method equates students who have 1 with 2 ideas with the same level of fluency. The assessment should be made more detailed for each idea put forward so that it is more appreciated as done by [19]-[21], where each idea gets one point. In this study, to determine the fluency of students, sensitivity and flexibility to the number of ideas submitted by students become important points so that every idea submitted by students is considered because that is the result of their thinking. Therefore, the combination of scoring criteria from [10] and [19]-[20] was used in this study to measure the fluency of students.

Considering that chemistry is not a discipline with a scope as broad as art and the depth of chemistry material at the high school level limits the diversity of ideas that students can generate, this study sets a maximum score of 4. The range of scores from 0 to 4 is considered sufficient to distinguish the level of student ability, from those who did not answer to those who were able to produce the most creative ideas. Thus, to determine fluency of students, 0 point is given for students who do not answer the question/no ideas produced, 1 point for one idea produced, 2 points for two ideas produced, 3 points for three ideas produced, and 4 points for more than three ideas produced

Furthermore, similar to fluency, flexibility is measured by giving points based on the number of idea categories produced. Each idea will be given points, but it needs to consider the relevance or accuracy of the chemical concepts included. Of the various scoring criteria used by previous researchers, none specifically emphasize the quality of ideas or ensure that each idea category contains the correct chemical concept. Therefore, the scoring criteria of flexibility of students in this study is to give score of 0 for students who do not answer / the wrong idea, score of 1 for one idea category, score of 2 for two idea categories, score of 3 for three idea categories, and score of 4 for more than three idea categories.

The last is originality, based on the scoring criteria that have been applied by previous studies, scoring from [10],[21]. does not specify the definition of common, moderate unique and very unique ideas so that this assessment seems more subjective. Furthermore, [22] assessed the originality of the truth of chemical concepts without involving the novelty of the ideas. [20] have very detailed scoring criteria, although the assessment is directed at the originality of students' ideas, it is difficult to use in large class conditions. The scoring criteria of [20] and [5] provide clear details for measuring originality. Given that the originality of ideas plays an important role, [19]'s study is stricter in measuring originality because only repetition of ideas with a frequency of less than 5% gets the highest points. However, the maximum points in the study by [19] were only 2. Therefore, the maximum score was equalized to 4 to ensure that fluency, flexibility, and originality were assessed in a balanced manner and to minimize bias. Then, the aspect of the correctness of ideas is also needed, so this study adapts to [5], [10], [19] and adds the aspect of the accuracy of the responses given so that the criteria of originality are obtained: 0 point for student do not answer/ incorrect ideas; 1 point if the probability of correct response is more than 10%; 2 points if the probability of correct response is from 5 to 10%, 3 points if the probability of correct response is smaller than 5%, and 4 points if the ideas produced are very unique (the ideas produced are only one student).

Most researchers used indicators of fluency, flexibility, and originality to describe how well someone can think divergently. However, it is also important to know how the divergent thinking process works so that someone can generate ideas. Based on Table 2, none studies divergent thinking in detail. In fact, divergent thinking is a key component for scientific creativity. The divergent thinking process consists of association, decomposition, and combination with adjustment [23]. Association is the ability to connect concepts, objects, or situations to generate original ideas. The initial thought may be relatively general, but subsequent ideas resulting from associations tend to be more original. By developing the habit of making unexpected correlations or finding new connections from seemingly irrelevant relationships, creative thinking can be enhanced. After the association process, decomposition is the second process by which a concept, object, or situation can be made into a whole with rich information by, among other things, deconstructing it into its component elements or identifying its characteristics. Rich details can offer stimuli that enable a wider range of cognitive associations. The last is combination with adjustment. This process allows for the combining of two or more related elements into a single new element. In order to come up with new ideas, it is also possible to modify one or more of the components or attributes that originate from a concept, object, or situation.

This study combines scientific imagination and divergent thinking into one creative process. This is because there are similarities in the core elements between the scientific imagination [24] and divergent thinking [23],

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especially in the aspects of association and decomposition. In divergent thinking, association plays an important role when someone connects various ideas or concepts that seem unrelated. This process is in line with the dynamic adjustment stage in scientific imagination, which is to link ideas that emerge, expand, and modify to create new solutions. Thus, dynamic adjustment continues the role of association by identifying relationships between ideas and refining them. In addition, the purpose of decomposition in divergent thinking is to break down concepts or situations into more detailed parts to open up new perspectives. The purpose of decomposition in divergent thinking is the same as elaboration in dynamic adjustment where the ideas that have been generated are rearranged, modified, and given new meaning. Therefore, association and decomposition in divergent thinking are combined in dynamic adjustment as shown in Figure 2.

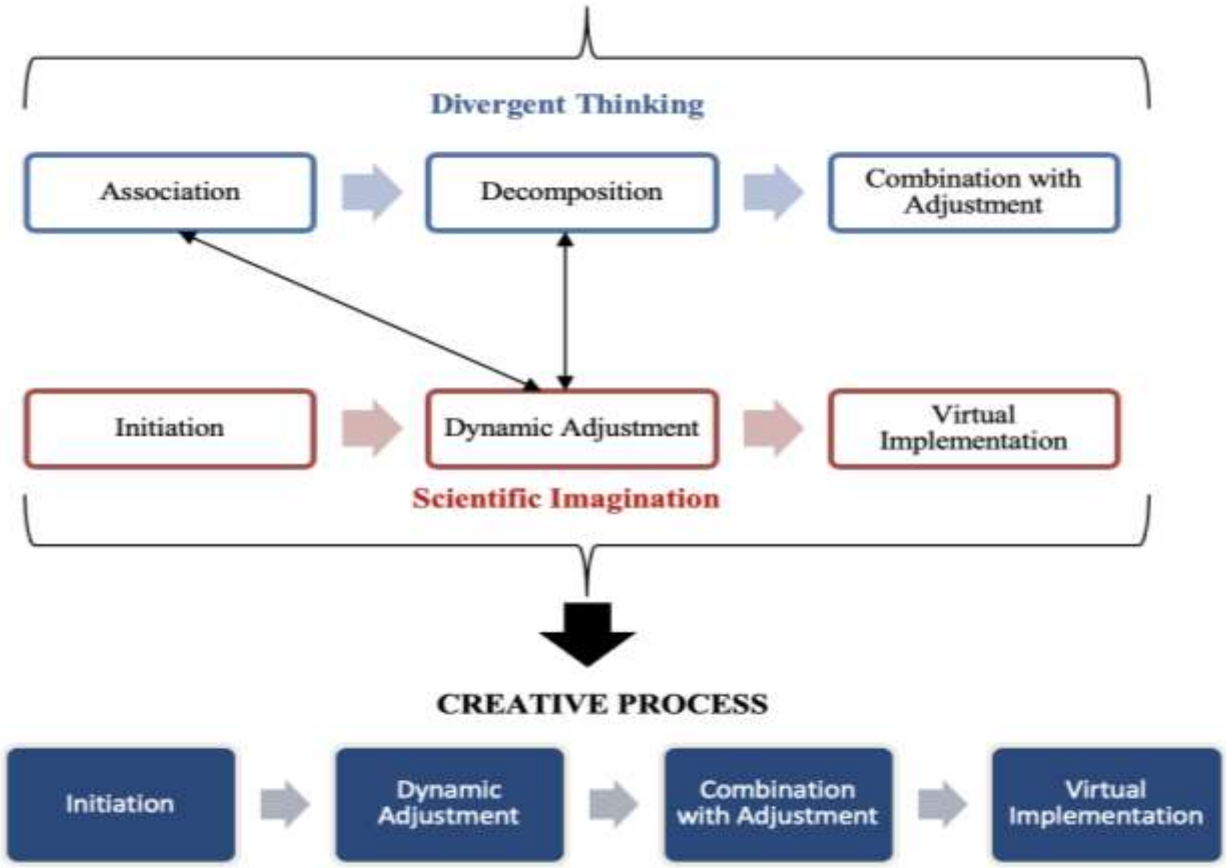


**Fig. 2 Combination of Divergent Thinking & Scientific Imagination into Creative Process**

**Source: Elaborated by the authors**

The creative process begins with initiation, namely students identify problems and begin to explore ideas; dynamic adjustment, namely connecting ideas as many as possible; combination with adjustment, where different ideas are combined and adjusted to create new ideas; to virtual implementation, where these ideas are organized and realized in the form of prototypes or real solutions. Thus, the creative process resulting from this combination becomes a complete and structured process, which encourages scientific creativity from the beginning to the implementation of ideas.

## RESEARCH METHODOLOGY

### Research Procedure

The research employed a Research and Development (R&D) methodology utilizing Tessmer's Development Design, which was adapted from [16]-[17]. Tessmer's model comprises three key phases namely: Preliminary Phase, Self-Evaluation Phase, and Prototyping Phase implemented an iterative cycle of validation, evaluation, and revision. The study was conducted over a period of three months, with the research procedure illustrated in Figure 3.

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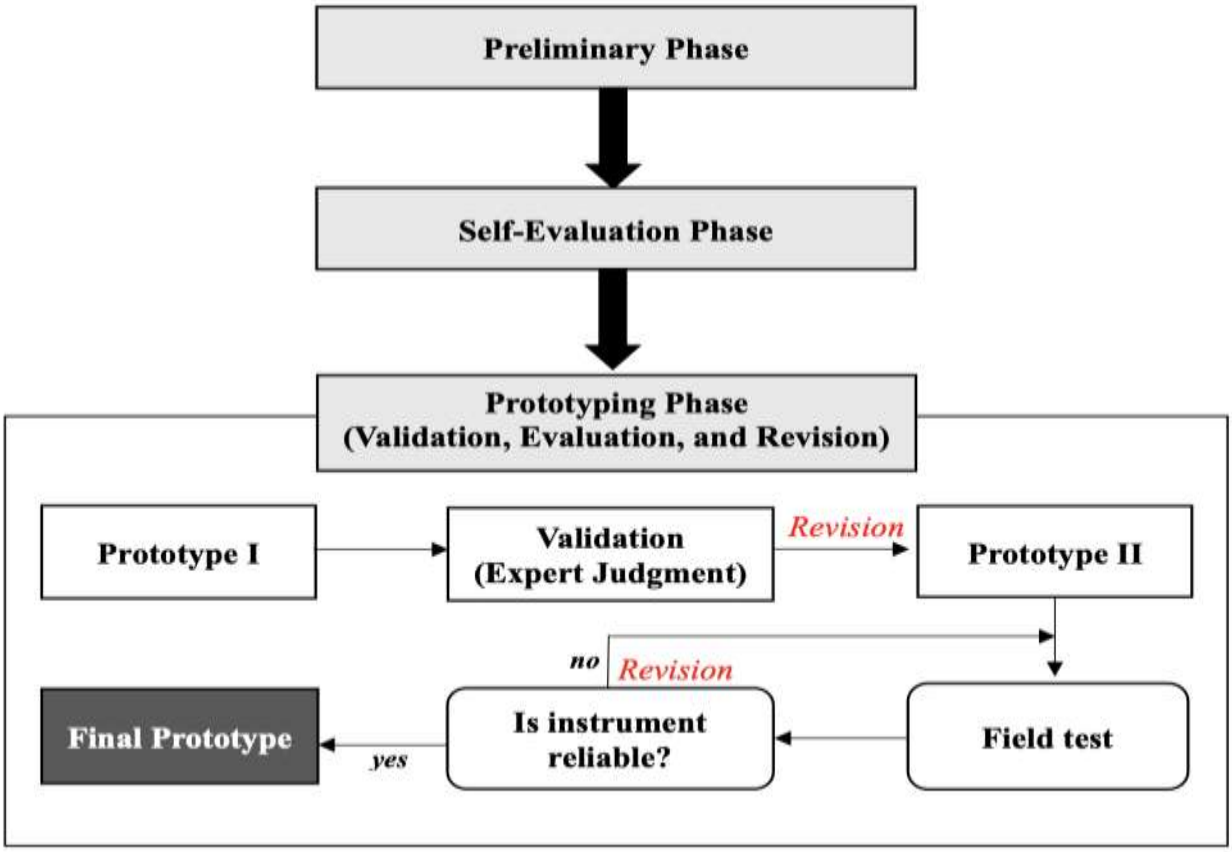


**Fig. 3 Research Procedure**

**Source: Elaborated by the authors**

**Preliminary Phase**

In the preliminary phase, a systematic review was conducted to examine the need for scientific creativity in chemistry education, particularly how previous research has assessed it. This review aimed to identify the indicators and assessment methods used in prior studies, providing a foundation for developing an appropriate instrument.

**Self-Evaluation Phase**

The first designed instrument will be called as prototype 1.

**Prototyping (Validation, Evaluation and Revision)**

The Prototype 1 will be further reviewed and validated by experts (validation process (expert review)). In validation process, the experts will give comments to improve, and score based on instructions provided in validation form. Furthermore, the instrument will be revised based on comments given and it will obtain Prototype 2. In field test, Prototype 2 will be testing reliability of instrument by giving to students. If the instrument is not reliable, the researcher needs to revise. The instrument is considered as final prototype once it has been valid and reliable.

**Validators Criteria**

The validators in this study consisted of five experts carefully selected based on specific criteria to ensure the credibility and reliability of their assessments. These criteria included having an academic background in chemistry education or science education, demonstrating research interest and experience in scientific creativity as evidenced by their publications, and possessing over 10 years of teaching experience. The five experts played a crucial role in evaluating the rubric of scoring developed in this study, which underwent a rigorous assessment

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process through expert judgment. Their extensive experience in chemistry education research related to creativity equipped them to critically evaluate the instrument's quality and relevance. They identified potential weaknesses, such as questions that were overly technical, lacked a focus on creativity, were insufficiently challenging, or were irrelevant to the chemical context. Their expertise also ensured that the rubric of scoring accurately measured students' creativity in relation to chemistry concepts and phenomena. Furthermore, the experts provided detailed feedback and constructive suggestions for improvement, contributing to the refinement of the instrument. This systematic process, supported by insights from all five experts, ensured that the final test was valid, reliable, and appropriately designed for measuring scientific creativity within the context of chemistry.

**Data Analysis**

The Content Validity Index (CVI) was utilized to validate the scoring rubric for assessing students' scientific creativity. As stated by [18], for five validators, each item must achieve a minimum Item-Level CVI (I-CVI) of 0.80 to be considered relevant. Additionally, the Scale-Level CVI (S-CVI/Ave) should be at least 0.90 to ensure strong overall content validity, while an S-CVI/UA (Universal Agreement) of 0.80 is deemed acceptable, indicating a high level of expert consensus. Experts assessed each item's clarity and relevance using a four-point Likert scale, and items that did not meet the 0.80 I-CVI threshold were revised or eliminated based on their feedback. Therefore, to ensure a valid instrument, the S-CVI must meet a minimum value of 0.80.

## RESULTS & DISCUSSION

The following Table 3 is rubric of scoring for creative traits developed. It is followed by Table 4 for creative product.

**Table 3. Creative Traits – Rubric of Scoring:**

| Scientific Creativity Dimension | Sub-Dimension | Indicator | Score |
|---|---|---|---|
| Trait | Fluency | Student cannot provide ideas. | 0 |
| | | Student can come up with one idea/answer. | 1 |
| | | Student can come up with two ideas/answers. | 2 |
| | | Student can come up with three ideas/answers. | 3 |
| | | Student can come up with more than three ideas/answers. | 4 |
| | Flexibility | No ideas / Students are not able to provide correct ideas/methods. | 0 |
| | | Students can come up with one correct category of idea/method | 1 |
| | | Students can come up with two correct categories of ideas/methods. | 2 |
| | | Students can come up with three correct categories ideas/methods. | 3 |
| | | Students can come up with more than three correct categories of ideas. | 4 |
| | Originality | Student do not answer/ideas are wrong/incomplete answer. | 0 |
| | | If the ideas produced are general/common ideas/no originality (ideas produced by students are more than 10% of similar to each other). | 1 |
| | | If the ideas produced by students are 5 to 10% of similar to each other. | 2 |
| | | If the ideas produced are smaller than 5% of similar to each other. | 3 |
| | | If the ideas produced are very unique (the ideas produced are only one student). | 4 |

**Table 4. Creative Product -Rubric of Scoring**

| Scientific Creativity Dimension | Sub-Dimension | Indicator | Score |
|---|---|---|---|
| Creative Product | Chemical Knowledge | **No Understanding**<br>Unanswered/ Misunderstanding/Misconception. | 0 |
| | | **Low understanding**<br>Answers are correct and contain one chemical representation. | 1 |
| | | **Moderate understanding**<br>Answers are correct and contain two chemical representations. | 2 |
| | | **High Understanding**<br>Answers are correct and contains all chemical representations. | 3 |

In term of creative process, this study only used one question namely: How could you solve the questions presented in the test? This is because by using one question, students could be asked to describe their stages, from understanding the problem to finding a solution where this indirectly covers all processes of creative process. In addition, the flexibility of answers can be achieved in which one open question will give students space and freedom to describe how they explore various ideas and approaches in solving problems, including creative solutions.

To analyse the qualitative data, this study used thematic analysis by [25]. Thematic analysis technique has been used by previous researchers to understand the process (though process and cognitive process) [26]-[27]. Thematic analysis was used to analyse data from Think Aloud Protocol and Interview Protocol because both produce qualitative data. In Think Aloud Protocol, thematic analysis helps identify themes in the creative process of students. While in Interview Protocol, this analysis was used to find the main themes in the participants' responses that describe scientific creativity process after using the module. Both types of protocols can provide in-depth insights through the identification of recurring codes and themes, making thematic analysis very suitable for analyzing qualitative data. Thematic analysis consists of 5 phases namely: Phase1: Familiarizing Yourself with the Data, Phase 2: Generating Initial Codes, Phase 3: Searching for Themes, Phase 4: Reviewing Potential Themes, Phase 5: Defining and Naming Themes, and Phase 6: Producing the Report. The following is example of how thematic analysis was conducted.

**Phase1: Familiarizing Yourself with the Data**

In this phase, the teacher could ask the question with "How do you develop ideas to be able to solve it?"

**Phase 2: Generating Initial Codes**

| Responses | Codes |
|---|---|
| R32: The first thing to do is read the question | Reading the problem |
| R16: I first find out what the main problem is by reading | Finding the main problem by reading |
| R36: I look for several points that have been explained in the problem.... | Looking for several points in problem explained |

**Phase 3: Searching for Themes**

| Codes | Sub-Themes |
|---|---|
| Reading the problem | Reading the problem |
| Finding the main problem by reading | Identifying the main problem by reading |
| Looking for several points in problem explained | Highlighting the problem |

**Phase 4: Reviewing Potential Themes**

| Sub-Themes | Themes |
|---|---|
| Reading the problem | Initial exploration of problem |
| Identifying the main problem by reading | |
| Highlighting the problem | |

In this phase, the codes, sub-themes, and themes obtained were reviewed by expert to ensure that potential themes were appropriate.

**Phase 5: Defining and Naming Themes**

According to Braun & Clarke (2012), to define and name the themes, the themes should ideally have a singular focus, not overlap, and directly address the research question. Thus, the comments from expert were useful to obtain appropriate themes.

**Phase 6: Producing the Report**

The codes, sub-themes, and themes obtained in this study were reported in form of table and further was represented into framework.

| Students | Responses | Codes | Sub-Themes | Themes |
|---|---|---|---|---|
| | | | | |

**Fig. 4 Thematic Analysis for Creative Process**

**Source: Elaborated by the authors**

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The prototype 1 was reviewed and validated by experts in term of construct, content and language aspect. It is further continued by revision process and reliability test. Rubric of scoring is used to analyze students' answers on chemistry scientific creativity test. It was developed together with the test and validated based on content, construct and criterion adapted from [28]. Therefore, the following Table 5 reveals the validation result for rubric of scoring.

**Table 5. Validation Results:**

| Aspects | Items | I-CVI |
|---|---|---|
| Content | Evaluation criteria address relevant content. | 1.00 |
| | Evaluation criteria of the scoring rubric address all aspects of scientific creativity. | 1.00 |
| | The rubric of scoring address content appropriately. | 1.00 |
| Construct | Scoring criteria consists of all important facets of construct evaluated. | 1.00 |
| | The evaluation criteria are relevant to the construct evaluated. | 1.00 |
| Criterion | Scoring criteria reflect competencies that related performances (scientific creativity). | 1.00 |
| | Rubric of scoring in accordance with the use of the assessment instrument related performance that will be evaluated. | 1.00 |
| | Scoring criteria measure the important components of scientific creativity. | 1.00 |
| | Scoring criteria reflects whole objectives in the research. | 1.00 |
| S-CVI = 1.00 | | |

Based on Table 5, S-CVI for rubric of scoring is 1.00, meaning that the validators agreed the rubric of scoring was valid in term of content, construct and criterion. In term of content, each item obtained I-CVI of 1.00, meaning that evaluation criteria address the relevant content, the scoring rubric address all aspects of scientific creativity, and the rubric of scoring address the content appropriately. Moreover, the validation result also shows that scoring criteria consist of all important facets or construct evaluated and the evaluation criteria are relevant to the construct evaluated. The result indicates that the rubric of scoring is also valid in term of construct with I-CVI for each item is 1.00. Lastly, the validation results show that the rubric of scoring is also valid in term of criterion with I-CVI of 1.00. It means that the experts agreed that scoring criteria reflect competencies that related to scientific creativity, and the rubric of scoring in accordance with the use of the assessment instrument related to performance that will be evaluated. In addition, the scoring criteria was believed to be able to measure the important components of scientific creativity and reflect to whole objectives in the research. Even though the experts agreed that the rubric of scoring has been valid in term of I-CVI value obtained, there were comments given by the experts to improvements as showed in Table 6.

**Table 6. Validation-Informed Comments:**

| No | Comments |
|---|---|
| 1 | A score of 0 on the assessment rubric should be avoided for indicators where students answer incorrectly (because, even if they are wrong, students have answered the question according to their abilities, especially for fluency in creative traits). For originality, a score of 0 is permissible if there is no answer. |
| 2 | Scoring between creative traits and creativity products usually uses a Likert scale, namely Likert scale of 1, 2, 3, 4 or 1, 2, 3, 4, 5. |
| 3 | Make sure that on the partial understanding and understanding indicators, the answers do not only cover various macro, sub-micro, and symbolic aspects, but also must have the correct concept. |
| 4 | In the think aloud protocol, the number column is removed because all questions are the same for each question |

Based on comments in Table 6, in term of creative trait, the validator suggested to score of 0 was only for students who could not give any ideas. The students who answered the question incorrectly should be given score of 1 because the incorrect ideas indicate their abilities. However, for flexibility and originality, score of 0 was acceptable. Furthermore, the score criteria should be in line with Likert scale, which is 1, 2, 3, and 4 instead of 0, 2, and 4. In addition, in term of creative product (chemical knowledge), answers should not only address chemical representation aspects but also contain the correct concept. Lastly, in term of creative process, it should be one question to be asked with the aim of giving the flexibility of students to express the ideas. The responses from the students were analyzed using thematic analysis and further suited to creative process.

## CONCLUSION

A rubric to assess scientific creativity in the context of chemistry learning was developed in this study. The rubric demonstrated excellent content validity, as evidenced by an item-level Content Validity Index (I-CVI) of 1.00. Revisions based on expert feedback further enhanced the rubric's structure, clarity, and practical applicability. The resulting scoring tool provides a systematic approach to evaluate students' creative traits, products, and processes, aligning with the multidimensional nature of scientific creativity. By offering a valid and reliable assessment instrument, this study contributes to the improvement of creativity-focused evaluation practices in science education. The rubric has the potential to assist educators in recognizing and nurturing students' creative potential, thereby promoting more engaging and innovative chemistry instruction.

## RECOMMENDATIONS

Given the excellent content validity achieved, it is recommended that the developed scientific creativity scoring rubric be applied in senior high school chemistry classrooms, especially when evaluating students' responses to open-ended or inquiry-based tasks. The rubric provides a structured and multi-dimensional approach to assess students' scientific creativity.

Future research should expand the validation of the rubric across different chemistry topics and student populations with higher level of education. In addition, longitudinal studies could examine how the use of this rubric impact to students' scientific creativity over time.

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## REFERENCES

1. Aktamıs, H., Şahin-Pekmez, E., Can, B. T., & Ergin, O. (2005). Developing scientific creativity test. University of Dokuz Eylul. Retrieved October 2, 2016.
2. Antink-Meyer, A., & Lederman, N. G. (2015). Creative cognition in secondary science: An exploration of divergent thinking in science among adolescents. International Journal of Science Education, 37(10), 1547–1563. https://doi.org/10.1080/09500693.2015.1043599.
3. Kirimi, D. O., Wanja, M., Barchok, H., & Jagero, N. (2017). Effectiveness of integrating science process-skills in teaching mathematics on students' achievement in secondary schools in tharaka-nithi county, kenya. International Journal of Academic Research in Progressive Education and Development, 6(4), 111–121. https://doi.org/10.6007/ijarped/v6-i4/3533.
4. Hu, W., & Adey, P. (2002). A scientific creativity test for secondary school students. International Journal of Science Education, 24(4), 389–403. https://doi.org/10.1080/09500690110098912.
5. Omar, S.S., Harun, J., Halim, N. D. A., Surif, J., & Muhammad, S. (2017). Investigating the level of scientific creativity of science students. Advanced Science Letters, 23(9), 8247–8250. https://doi.org/10.1166/asl.2017.9870.
6. Overton, T., Potter, N., & Leng, C. (2013). A study of approaches to solving open-ended problems in

chemistry. Chemistry Education Research and Practice, 14(4), 468–475. https://doi.org/10.1039/c3rp00028a.

7. Hadzigeorgiou, Y., Fokialis, P., & Kabouropoulou, M. (2012). Thinking about creativity in science education. Creative Education, 3(5), 603.
8. Ikiao, E. K. K. (2019). Effect of discovery teaching approach on scientific creativity amongst students of chemistry in public secondary schools in Imenti North Sub-County, Kenya (Doctoral dissertation, Chuka University).
9. Kamonjo, F. & Wachanga. (2019). Creativity level in chemistry education by gender among secondary school students in Kenya. Journal of Education and Practice, 10(20), 50–60. https://doi.org/10.7176/jep/10-20-07.
10. Jamal, S. N. B., Ibrahim, N. H. B., Halim, N. D. B. A., & Alias, M. I. Bin. (2020). A preliminary study on the level of creativity among chemistry students in district of melaka tengah. Journal of Critical Reviews, 7(16), 752–761. https://doi.org/10.31838/jcr.07.16.88.
11. Ibrahim, M., & Jamaludin, K. A. (2019). The roles of teacher and students via blended problem-based learning: Improving students' mastery of three representation levels of chemistry. EDUCATUM Journal of Science, Mathematics and Technology, 6(2), 9-21.)
12. Lansangan, R. V., Orleans, A. V., & Camacho, V. M. I. (2018). assessing conceptual understanding in chemistry using representation. Advanced Science Letters, 24(11), 7930-7934.
13. Ozdemir, G., & Dikici, A. (2016). Relationships between scientific process skills and scientific creativity: mediating role of nature of science knowledge. Journal of Education in Science, Environment and Health, 3(1), 52–52. https://doi.org/10.21891/jeseh.275696.
14. Liang, J. C. (2002). Exploring scientific creativity of eleventh-grade students in Taiwan. The University of Texas at Austin.
15. Obote, D. K. (2016). Effectiveness of integrating science process skills in teaching mathematics on students‟ scientific creativity in secondary schools in Tharaka Nithi County, Kenya. International Journal of Academic Research in Progressive Education and Development, 5 (4), 111, 121.
16. Apriwanda, W., & Hanri, Chuzairy. (2021). Development of instrument to assess chemistry prospective teachers' scientific creativity development of instrument to assess prospective teachers' scientific creativity. Journal Penelitian Antarabangsa, 1(1).
17. Sagala, P. N., & Andriani, A. (2019). Development of Higher-Order Thinking Skills (HOTS) Questions of Probability Theory Subject Based on Bloom's Taxonomy. Journal of Physics: Conference Series, 1188(1). https://doi.org/10.1088/1742-6596/1188/1/012025.
18. Polit, D. F., & Beck, C. T. (2006). The content validity index: Are you sure you know what's being reported? Critique and recommendations. Research in Nursing & Health, 29(5), 489-497. https://doi.org/10.1002/nur.20147.
19. Eroglu, S. & Bektas, O. (2022). The effect of STEM applications on the scientific creativity of 9th-grade students. Journal of Education in Science, Environment and Health (JESEH), 8(1), 17-36. https://doi.org/10.21891/jeseh.1059124.
20. Eroglu S., & Bektas, O. (2022). The Effect of STEM applications on the scientific creativity of 9th-grade students. Journal of Education in Science, Environment and Health. https://doi.org/10.21891/jeseh.1059124.
21. Ramly, S. N. F., Ahmad, N. J., & Yakob, N. (2022). Development, validity, and reliability of chemistry scientific creativity test for pre-university students. International Journal of Science Education, 44(14), 1-16.
22. Alkan, F., & Altundag, C. K. (2018). The effect of inquiry-based chemistry experiments practices on inquiry skills and scientific creativity. The Eurasia Proceedings of Educational and Social Sciences, 9, 36-41.
23. Sun, M., Wang, M., & Wegerif, R. (2020). Effects of divergent thinking training on students' scientific creativity: The impact of individual creative potential and domain knowledge. Thinking Skills and Creativity, 37, 1–10.
24. Ho, H. C., Wang, C. C., & Cheng, Y. Y. (2013). Analysis of the scientific imagination process. Thinking Skills and Creativity, 10, 68–78. https://doi.org/10.1016/j.tsc.2013.04.003.
25. Braun, V., & Clarke, V. (2012). Thematic analysis. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), APA handbook of research methods in psychology: Vol. 2. Research

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designs (pp. 57–71). American Psychological Association. https://doi.org/10.1037/13620-004.

26. Noushad, B., Van Gerven, P. W., & De Bruin, A. B. (2024). Twelve tips for applying the think-aloud method to capture cognitive processes. Medical Teacher, 46(7), 892-897.
27. Wolcott, M. D., & Lobczowski, N. G. (2021). Using cognitive interviews and think-aloud protocols to understand thought processes. Currents in Pharmacy Teaching and Learning, 13(2), 181-188.
28. Moskal, B. M., & Leydens, J. A. (2001). Scoring rubric development: validity and reliability. Practical Assessment, Research and Evaluation, 7(10), 2000–2001.