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DEVELOPMENT OF STUDENT ACTIVITY SHEET (SAS) USING MIND MAPPING STRATEGIES TO IMPROVE CREATIVE THINKING SKILLS ON ATOMIC MATERIALS AND NANOTECHNOLOGY

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Abstract

This study aims to obtain a suitable SAS to improve students' creative thinking skills. This type of research includes research and development. The development of the model used refers to the 4-D model but is only limited to the stages of determination, design, and development. Trial activities were carried out on 34 students of class XE-3. The feasibility of the developed SAS is guided by validity, practicality, and effectiveness. Validation was carried out by expert validators with scores determined based on the mode value. The results of the study showed the feasibility of the teaching module in terms of content validity and construct validity which obtained modes 4 and 5 in each aspect with valid and very valid categories so that overall the teaching module obtained a mode ≥4 and was declared valid. The results of the practicality analysis were seen from the student response questionnaire and observations of student activities. The percentage of practicality based on the student response questionnaire and student observations was obtained at 92.01% with a very practical category. Meanwhile, the observation results of student activities obtained relevant activities at meeting 1 of 97.62% and meeting 2 97.37%. From the three percentages obtained the percentage of relevant participant activities was increased by 97.5% so that it can be said that the SAS was developed very practically. The results of the analysis of the effectiveness of SAS were measured based on the increase in students' creative thinking skills through the pretest and posttest mind map as well as questions about understanding creative thinking skills on chemical bonding material with N-gain values obtained respectively of 0.73 and 0.72 with a high category. Based on the results of validity, practicality and effectiveness, the mind map strategy teaching module is suitable for use as a learning tool to improve creative thinking skills on atomic and nanotechnology materials.

Key words: SAS, mind mapping, creative thinking skills, atoms and nanotechnology

INTRODUCTION

Science and technology are developing very rapidly in the 21st century. This era is also called the era of the industrial revolution 4.0. The development of science and technology has had a major impact on various aspects of life, one of which is education. Education is the most important thing for the progress of a country in the future. Human resources in a country need to have global competence in terms of thinking, expertise, and skills in order to compete in the era of globalization. Equipping students with the ability to face the industrial revolution 4.0 is a must, one way is by preparing more innovative learning and improving the competence of graduates by equipping them with 2nd-century skills [1]. The 21st-century skills in question include critical thinking skills, creative thinking skills, communication skills, and collaboration skills.

In line with the demands of the Industrial Revolution 4.0 era and the need for 21st-century skills, the Merdeka Curriculum is the latest curriculum implemented since the 2021/2022 academic year by the Ministry of Education and Culture to meet the demands of the education system in the Industrial Revolution 4.0 era. The Merdeka Curriculum centers on guidelines for freedom in implementing basic and flexible materials according to the interests, needs, and character of students. In this case, it sets students as the primary goal [2].

In the context of education that continues to evolve and adapt to the Independent Curriculum, chemistry learning is characterized by problems that involve theories, concepts, laws, and facts. Special skills are required to solve these problems. The ability to interpret data and analyze theories, concepts, and laws to relate them to existing facts is essential to solving these problems.

Atomic and nanotechnology topics in chemistry learning encompass various interrelated basic and advanced concepts, such as atomic structure, electron configuration, elemental periodicity, chemical bonding, and the application of technology at the nanoscale. The complexity of this material often makes it difficult for students to understand the interrelationships between concepts [3]. Students are not only required to memorize chemical terms but also to understand the logical relationships between these concepts. The use of mind mapping strategies in chemistry learning can improve students' understanding of the relationships between concepts, especially in topics that have broad material content such as atomic structure and nanotechnology. [4] With mind mapping, students can see the big picture of the overall concept while simultaneously exploring its details in a coherent manner.

The independent curriculum prioritizes character development, embedded in learning content and Pancasila student profile indicators, which include noble character, independence, critical thinking, creativity, mutual cooperation, and global diversity. It is hoped that it can become an alternative education system in Indonesia to equip students to master various necessary skills, one of which is creative thinking [5].

The creative thinking skills mentioned above are the ability to produce something new, diverse, and unique. Creative thinking enables one to see various possible solutions to existing problems. Students must be able to think, generate new methods, or modify existing ones to produce something useful creatively, reflected through aspects of fluency, flexibility, originality, and elaboration [6].

Despite its importance, the creative thinking skills of Indonesian students remain a challenge. This is indicated by the results of the 2011 TIMSS study, which showed that the percentage of students engaged in higher-order thinking, including creative thinking, is still low. Students lack the ability to think creatively because they are not accustomed to answering questions that can teach them creative thinking. Typical tests used in schools often incorporate tasks that require searching for a single correct response (convergent thinking), making creative thinking capacity essentially impossible to assess [7].

One possible solution to this problem is to develop effective teaching materials to enhance students' creative thinking skills. The majority of students are bored with monotonous textbooks. Student worksheets with a mind mapping strategy are effective for training students' creative thinking skills [8]. The term "SAS" has been changed to "Student Activity Sheet" (SAS), which is integrated with the teaching module, previously known as the Learning Implementation Plan (RPP). The teaching module contains learning activities, teaching materials, and student activity sheets.

Learning strategies are learning activities that must be carried out by teachers and students to achieve learning objectives effectively and efficiently [9]. Learning strategies are a key factor that must be considered in improving the quality of learning and student skills. Therefore, teachers need to prepare appropriate, well-planned, and easy-to-implement strategies [10]. Students' creative thinking skills can be enhanced using mind mapping strategies in learning. This is because this strategy uses visual and sensory symbols in a pattern of related ideas.

SAS with mind mapping strategies can facilitate student learning because students are interested in the mind mapping used in SAS. Teachers can use mind mapping strategies to practice creative thinking skills [11]. When students create mind maps, they develop a variety of concepts and generate new ideas that can foster their creativity. Students can also be trained to connect concepts to the subject matter.

Based on data obtained from a pre-research questionnaire distributed to 34 10th-grade students at a private high school in Sidoarjo Regency, 67.5% of students found chemistry difficult to understand, and 80% struggled with atoms and nanotechnology. Students stated that atoms and nanotechnology require extensive

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memorization, making them difficult to retain long-term.

The aim of this research is to obtain a suitable Student Activity Sheet based on its validity, practicality and effectiveness.

METHOD

The 4D model is the research approach used in this development study, which includes four main stages: definition, design, development, and disseminate. However, this research is limited to the development stage. The flow diagram of the device development stages is presented in Figure 1 as follows:

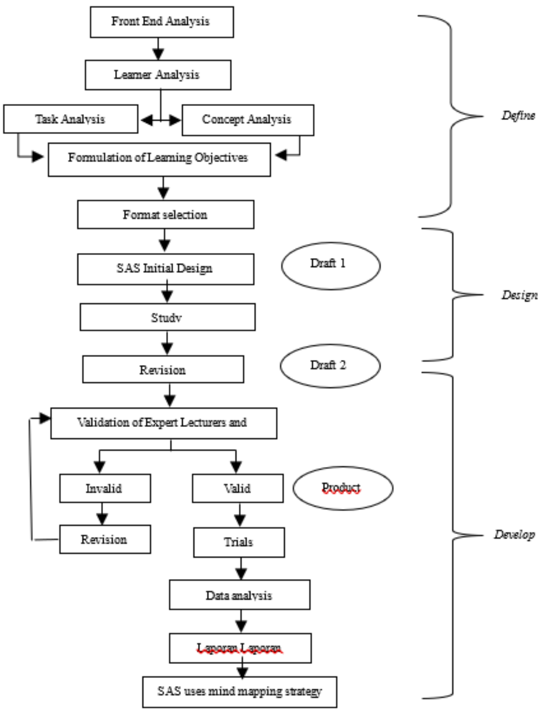

Figure 1. 4-D Research Stages

The SAS development research with a mind mapping strategy, namely the review and validation stages, was conducted in November, while the SAS trial with a mind mapping strategy was conducted in December 2024 at a private high school in Sidoarjo Regency. This study involved 34 10th grade students.

The *One Group Pretest-Posttest* design was employed for the trials in this study. The following presents an overview of the research design that was implemented.

$$O_1 \text{ - X - } O_2$$

Description:

O_1: Pretest, which is the initial measurement of creative thinking ability before treatment is given.

X: Treatment, which is the application of the SAS trial using the mind mapping strategy on the atom and nanotechnology material to research subjects during the learning process.

O_2: Posttest, which is the measurement of creative thinking ability after subjects receive treatment.

Based on the One-Group Pretest-Posttest Design trial design, the pretest (O_1) and posttest (O_2) results were obtained which were then analyzed using the N-gain score [12].

To illustrate the feasibility of using a mind mapping strategy for SAS, an appropriate data collection method is required. This study utilized various data collection techniques, such as questionnaires, observations, and tests.

The feasibility of the SAS with the developed mind mapping strategy was evaluated based on three aspects: validity, practicality, and effectiveness. This study used several instruments, including a validation sheet, a student activity observation sheet, and a creative thinking skills test sheet. Expert assessment of the content and construct aspects of the SAS was carried out using the validation sheet instrument. To assess the practicality aspect, a student response questionnaire was used, supplemented by a student activity observation sheet. Meanwhile, to measure the effectiveness of using SAS in improving creative thinking skills, a test instrument was used that included pretest, posttest, and pretest and posttest questions on mind mapping of atomic and nanotechnology materials.

Data analysis in this study was conducted to assess the feasibility of the Student Activity Sheet (SAS) using the mind mapping strategy in terms of validity, practicality, and effectiveness. The data analysis techniques used included:

1. Review Data Analysis

Review data, consisting of suggestions and comments from expert lecturers and education practitioners regarding the SAS, were analyzed descriptively and qualitatively. Aspects included content, language, presentation, and graphics. The results of the analysis were used to refine and improve the SAS to ensure its suitability for use in learning.

2. Data Validation Analysis

Data validation was obtained from the validator's assessment using a five-point Likert scale for aspects of content, language, presentation, and graphics. The data were analyzed descriptively and quantitatively using a mode to determine the level of validity [13].

Table 1. Likert Scale Validation Assessment

Score	Category
5	Very good
4	Good
3	Fairly Good
2	Less Good
1	Not Good

The interpretation criteria for validation are based on the mode score obtained from expert assessments. An aspect is considered valid if it receives a mode score of 4 or higher. Conversely, if the mode score is less than 4, the aspect is categorized as not valid. In cases where one or more aspects do not meet the validity threshold, the Students Activity Sheet (SAS) must undergo revisions and be subjected to a revalidation process until it fulfills the established standards [14].

3. Practicality Analysis (Student Response Questionnaire)

Practicality data were obtained from student responses after the implementation of the SAS. The questionnaire used a Guttman scale, with scoring criteria as follows:

Table 2. Guttman Scale for Positive and Negative Questions

Question Type	Response	Score
Positive	Yes	1
	No	0
Negative	Yes	0
	No	1

The percentage of practicality was calculated using the following formula:

$$P(\%) = \frac{F}{N} \times 100\%$$

Where:
P = Percentage of student responses
F = Frequency of "Yes" or "No" responses (as appropriate)
N = Number of respondents

Table 3. Interpretation of Student Response Scores

Percentage (%)	Category
81-100	Very Good
61-80	Good
41-60	Fairly Good
21-40	Less Good
0-20	Not Good

SAS is considered practical if it achieves a student response percentage of ≥ 61% with a minimum good category [13].

4. Creative Thinking Skills Test Analysis

The effectiveness of SAS through analysis of pretest and posttest scores on creative thinking skills, which include aspects of fluency, elaboration, flexibility, and originality. Scores are calculated using the formula:

$$Score = \frac{Obtained\ Score}{Maximum\ Score} \times 100\%$$

Table 4. Interpretation of Creative Thinking Skills Score

Percentage (%)	Category
81-100	Very Creative
61-80	Creative
41-60	Fairly Creative
21-40	Less Creative
0-20	Not Creative

Based on these criteria, creative thinking skills are said to have been successfully trained if a percentage of ≥61% is obtained or in the creative category [13] .To measure the improvement in creative thinking skills, the normalized gain (N-gain) was calculated using the following formula:

$$< g >= \frac{S_{posttest} - S_{pretest}}{S_{max} - S_{pretest}}$$

Where:
<g> = Normalized gain score
$S_{posttest}$= Posttest score
$S_{pretest}$= Pretest score
S_{max}= Maximum possible score

Table 5. N-Gain Score Interpretation

N-Gain Value <g>	Category
$\geq 0{,}7$	Very Creative
$0{,}7 >< g > \geq 0{,}3$	Creative
$< g > < 0{,}3$	Fairly Creative

The SAS is considered effective if it produces an N-gain score of ≥ 0.3, categorized as medium or high [15].

RESULTS AND DISCUSSION

The result of this development research is a Student Activity Sheet (SAS) incorporating a mind mapping strategy on Atom and Nanotechnology material. The SAS with the mind mapping strategy can be used in the learning process to help enhance students' creative thinking skills. The development of the SAS was carried out using the 4D research model, which consists of four main stages, but was limited to the development stage.

1. Definition Stage (Define)

The first stage in the 4D model is the Definition (Define) stage, which aims to identify existing problems in schools, establish the research objectives, and formulate the needs for developing the Student Activity Sheet (SAS). At this stage, it is important to understand the current educational context and the characteristics of the students who are the target of the development. Therefore, the define stage is carried out through five types of analysis, namely: preliminary analysis, learner analysis, task analysis, concept analysis, and learning objective analysis.

This is the initial stage aimed at identifying the main problems faced in the chemistry learning process, particularly in the topic of atoms and nanotechnology, and gathering initial information about students’ interest in this topic. Preliminary analysis is conducted by observing the ongoing learning process and collecting data through interviews with chemistry teachers to identify the challenges and difficulties students face in understanding the material on atoms and nanotechnology.

The information obtained by the researcher indicates that 90% of students experience difficulties with chemistry material that involves multiple interconnected concepts. Additionally, the learning process in the school still heavily relies on printed textbooks or packages as both teaching materials and primary learning sources. From interviews with the teacher, it was also found that students generally lack strong interest in chemistry lessons, especially those involving many concepts or memorization.

In this stage, an analysis is conducted on the characteristics of the students, focusing on their prior understanding of the topic atoms and nanotechnology, learning styles, challenges faced, and their motivation to learn. The aim is to ensure that the Student Activity Sheet (SAS) developed aligns with the students’ needs and abilities, and can help enhance their engagement and creativity in the learning process.

Based on the preliminary research results, 83% of students need learning media that can help them better understand and organize the material. Additionally, 80% of students show greater interest when learning activities involve drawing and coloring. In line with this, 90.96% of students expressed the need for varied learning strategies to help them better remember and understand the material, one of which is by using the mind mapping strategy.

Task analysis, this stage aims to understand the types of tasks or activities that will be included in the Student Activity Sheet (SAS). It involves identifying the kinds of assignments that will be given to students. The tasks are designed within the SAS using the mind mapping strategy, so that they can encourage creative thinking and integrate the concepts of atoms and nanotechnology in a fun and easily understandable way.

Concept analysis, this stage involves analyzing the content of atoms and nanotechnology that will be delivered. Fundamental concepts such as atomic structure, the development of atomic theory, and nanotechnology must be identified and classified to ensure that the material presented through the SAS helps students build a deep understanding. These concepts are arranged systematically to match a structure of thinking that supports the development of students' creative thinking skills.

Learning objective analysis, the final step is to define specific and measurable learning objectives. These objectives relate to the competencies that students are expected to achieve through the use of the developed SAS.

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Based on the analysis conducted during the define stage, the researcher developed a Student Activity Sheet (SAS) for the topic of atoms and nanotechnology using the mind mapping strategy. This SAS is expected to serve as an alternative learning medium that can enhance students' conceptual understanding of atoms and nanotechnology, improve their creative thinking skills, and strengthen their ability to organize information using the mind mapping technique.

2. Design Stage (Design)

Based on the analysis conducted during the Design stage, a Student Activity Sheet (SAS) was produced, consisting of three sections, each designed to enhance students' creative thinking skills in the topic of atoms and nanotechnology. These three SAS are integrated with a main SAS, which includes a general description, prerequisites, learning instructions, learning objectives, and supporting information. The design of the SAS on atoms and nanotechnology using the mind mapping strategy is shown in Figure 2 and Figure 3.

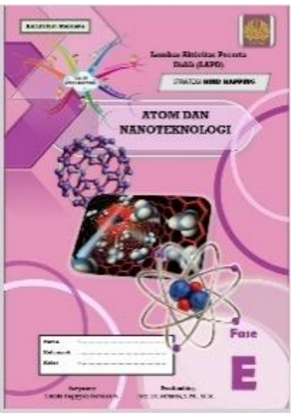
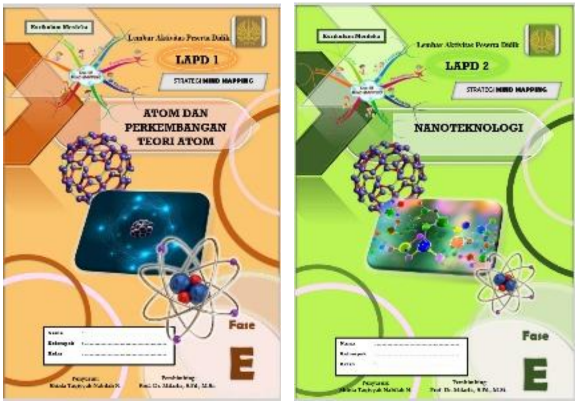


Figure 2. Cover Page SAS



(a) (b)

Figure 3. Cover SAS : (a) SAS 1 (b) SAS 2

The SAS is structured into two sections with one main component. The division of materials in the SAS is adapted to the characteristics of the content and the logical sequence of subtopics within the subject of atoms and nanotechnology. SAS 1 includes content on atoms and the development of atomic theory, while SAS 2 focuses on nanotechnology. Each section of the SAS is designed using the mind mapping strategy, aiming to assist students in organizing and connecting various interrelated chemistry concepts effectively.

3. Development Stage (Develop)

The development stage in this study consists of three key phases aimed at testing the feasibility, practicality, and effectiveness of the product. Each phase is conducted to ensure that the developed Student Activity Sheet (SAS) can achieve its primary goal, which is to enhance students' creative thinking skills in understanding the topic of atoms and nanotechnology.

a. Feasibility

The first phase in the development of the SAS is the validation process, conducted by two expert lecturers and a chemistry teacher. During the validation stage, the developed SAS is assessed for its feasibility through two main indicators: content validity and construct validity. Content validity aims to evaluate the extent to which the material within the SAS covers all necessary aspects required to achieve the predetermined learning objectives, particularly in improving students' creative thinking in the topic of atoms and nanotechnology. The results of the content validity assessment showed mode scores of 4 and 5, indicating that the SAS on atoms and nanotechnology using the mind mapping strategy is categorized as good in terms of content validity.

Construct validity evaluates the developed SAS in terms of language use, presentation, and graphical aspects. The mode scores obtained for construct validity were 4 and 5, indicating that the SAS is categorized as good in terms of construct validity.

The results of the validation process show that the mode scores obtained for both indicators fall into the good category, with mode values of 4 and 5. This indicates that the developed SAS has a high level of validity, both in terms of content and construct, and is therefore considered suitable for use in the learning process.

b. Practicality

The practicality of the developed Student Activity Sheet (SAS) was measured through students' responses regarding the practical aspects of using the SAS in the learning process. The practicality assessment was conducted using the Guttman scale, which provides "yes" or "no" options for each question. The questions were presented in a questionnaire that focused on the ease and effectiveness of using the SAS during teaching and learning activities. A summary of the student response data regarding the use of the SAS is presented in Table 6.

Table 6. Student Response Questionnaire Results

No	Criteria	Average (%)
1	Content	92,16
2	Presentation	93,63
3	Language	95,59
4	Creative Thinking Skills	90,44
5	Mind Mapping	88,24
	Average	92,01
	Category	Very Practice

The research results show that an average of 92.01% of students gave positive responses to each item in the response questionnaire. A positive response percentage of ≥ 61% indicates that the developed SAS is categorized as good in terms of practicality [13]. The SAS was considered practical, easy to use, and helpful for students in understanding the topic of atoms and nanotechnology. The majority of students stated that the SAS could be effectively applied in classroom learning activities.

Students' responses reflect that the SAS, designed using the mind mapping approach, not only makes it easier to understand complex concepts in atoms and nanotechnology, but also helps students organize information more systematically.

In addition to the questionnaire responses, practicality was also measured through classroom observations conducted during two different sessions. The observation results showed a very high level of student engagement in each session. The percentage of relevant activities is presented in Table 7. In the first session, activities relevant to the SAS reached 97.62%, and in the second session 97.37%. The average percentage from both sessions was 97.35%, which falls into the category of high practicality.

Table 7. Observation Results of Student Activities

Pertemuan ke-	Percentage (%)	Category
1	97,62	Very Practice
2	97,37	Very Practice
Rata-rata	97,5	Very Practice

The average percentage obtained is ≥ 61%, indicating that students consistently participated in learning activities focused on the use of the Student Activity Sheet (SAS) and were able to actively and effectively apply the concepts of atoms and nanotechnology. This percentage also shows that the SAS on atoms and nanotechnology using the mind mapping strategy is practical for use in the learning process.

c. Effectiveness

The effectiveness of the developed Student Activity Sheet (SAS) was also measured through the improvement in students' learning outcomes, as indicated by the difference between pretest and posttest scores. One key indicator is how effectively the SAS enhances students' understanding of the topic of atoms and nanotechnology. To measure this effectiveness, the results of the pretest and posttest assessments were obtained, then N-gain analysis was used to assess the extent of student improvement after participating in the learning process using SAS. The following are the results of the increase in students' pretest and posttest scores.

The average pretest and posttest score analysis results were 40,22 categorized as less creative, and 82,42 categorized as highly creative. The pretest and posttest results were analyzed using the N-gain score and showed that the N-gain score for all students in the trial was ≥ 0.7, which is included in the high category. These N-gain scores indicate that the developed SAS is effective. The scores reflect a significant improvement and demonstrate a substantial impact on students' understanding. The SAS was found to significantly enhance students' comprehension, particularly in mastering the concepts of atoms and nanotechnology.

This significant improvement reinforces that the SAS designed with the mind mapping strategy is not only relevant and practical to use, but also effective in enhancing student learning outcomes. The effectiveness of the learning method in improving outcomes can be measured by a high N-gain score, which indicates that students are able to better understand the material and connect more complex concepts. Thus, this SAS not only facilitates better comprehension of the subject matter but also enhances students' creative thinking skills, particularly in the topic of atoms and nanotechnology.

In addition to the pretest and posttest, students' creative thinking skills were also assessed through the evaluation of the mind mapping work they produced during the learning process. This assessment was conducted using a predetermined rubric, aiming to measure the level of students' creativity based on four indicators of creative thinking: fluency, flexibility, elaboration, and originality.

The assessment results showed that most students were able to create well-structured mind maps, effectively connecting key concepts such as atomic structure, the development of atomic theory, and nanotechnology. Figure 2 presents examples of student work categorized as good and very good.

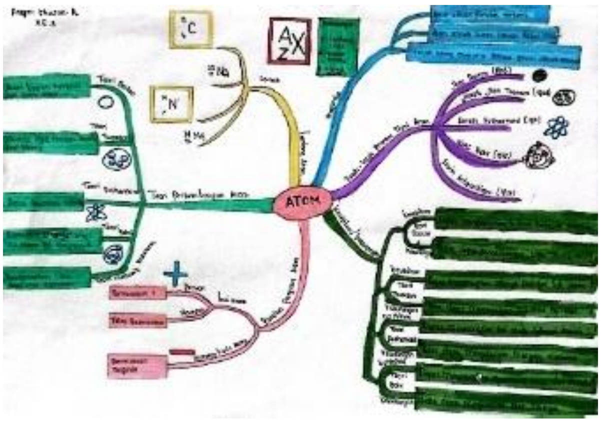


Figure 4 Mind Map Category Creative

Figure 4. shows a student's mind map categorized as creative. The mind map meets the four aspects of creative thinking: fluency, flexibility, elaboration, and originality. The fluency aspect is evident from the student's ability to elaborate on more than five keywords from the entire topic of atoms and nanotechnology, which are broken down into themes, sub-themes, branches, and sub-branches. The flexibility aspect is shown through the use of different colors for each branch representing various sub-themes. However, some branches were colored differently from the main branches, which slightly reduced the flexibility score.

The elaboration aspect is demonstrated by the student's detailed development of each keyword into several branches and sub-branches, with more than four branches for each main keyword. The originality of the mind map is reflected in the uniqueness of the work, which includes imaginative illustrations that distinguish it from others and serve as the student's creative signature.

Overall, the mind map in Figure 4. is rated as creative, mainly due to minor imperfections in the flexibility aspect.

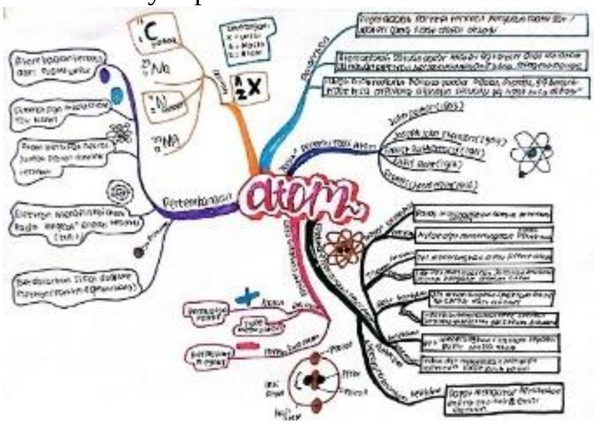


Figure 5 Mind Map Category Very Creative

Figure 5 displays a student's mind map categorized as *very* creative. The mind map fully meets all four aspects of creative thinking. The fluency aspect is evident in the number of keywords used more than five which are clearly broken down into themes, sub-themes, branches, and sub-branches. The flexibility aspect is shown through the use of different colors for each branch, variations in branch shapes, and differences in thickness between main branches and sub-branches.

The elaboration aspect is reflected in the student's ability to expand each keyword into numerous branches, with more than four branches in total. Each sub-branch contains detailed explanations of the main keyword and is placed appropriately. The originality of the mind map is visible in its unique structure, which differs from other mind maps and clearly demonstrates the student's imagination. Based on these criteria, the mind map shown in Figure 5 is assessed as *very creative*.

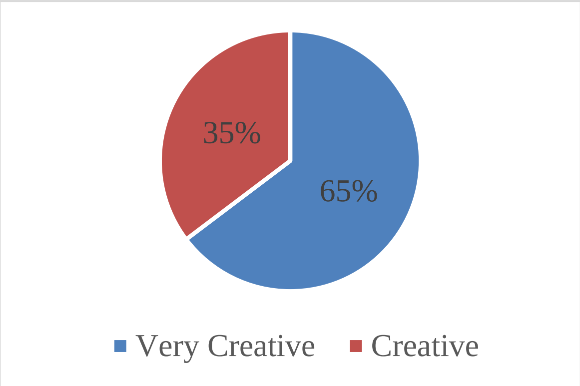


Figure 6 Mind Map Assessment Presentation

Based on Figure 1, 65% of students fall into the Very Creative category, while 35% fall into the Creative category. Of the 34 students, 22 are classified as Very Creative and 12 are classified as Creative.

These results indicate that the mind mapping-based learning strategy is effective in improving students' creative thinking skills. This improvement is evident in students' ability to develop ideas fluently (fluency), flexibly (flexibility), and originally (originality), as well as elaborate on their ideas during the lesson. No students fell into the less or no creative category, indicating that this strategy reaches all students equally and provides an effective stimulus for developing creative thinking**.**

CONCLUSION

This study produced a Student Activity Sheet (SAS) using a mind mapping strategy, which is deemed suitable as a learning medium to enhance creative thinking skills in the topic of atoms and nanotechnology. The feasibility of the SAS is supported by three aspects: (1) it is valid, based on expert evaluations showing that both content and construct validity fall into the *very valid* category; (2) it is practical, as indicated by student responses and observations of learning activities with percentages of 92.01% and 97.35%, respectively; and (3) it is effective, as shown by the improvement in learning outcomes with N-gain scores of 0.73 for creative thinking skills and 0.72 for conceptual understanding, both categorized as *high*.

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