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EVALUATION OF STUDENT ABILITY IN DRAWING CONCEPT MAPS: A STUDY OF CONCEPT MAP STRUCTURE AND QUALITY

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ABSTRACT

Concept maps are an effective tool in the learning process, enabling students to organise and structure information into a unified whole. Although there has been much research on concept maps as a learning tool, there is still limited research specifically analysing the structural patterns of concept maps and relating them to students' conceptual understanding or abilities. This study aims to analyse students' abilities in constructing concept maps. This study is a quantitative descriptive. The sample of this study were 16 students who took the basic science education course. The sample was selected using purposive sampling, namely students who had received basic chemistry material. The concept maps that had been made were then analysed based on the structural pattern used (hierarchical, network, linear, mixed) using an assessment rubric. Quantitative descriptive analysis was used to see the distribution of the pattern of students' concept maps in the form of averages, frequencies, percentages and graphic visualisations for each aspect measured in the concept maps. Based on the results of data analysis in this study, it can be concluded that most students use a hierarchical pattern (38%), followed by a network pattern (31%), a mixed pattern (25%), and a linear pattern (6%). The majority of students (62.5%) had an understanding in the very good category, 6.25% in the good category, and 12.5% in the lacking category. No students were in the very lacking category. The findings of this study have significant implications for science education. Understanding the structural patterns of students' concept maps can help educators identify how students process and connect scientific concepts. Moreover, by recognising the types of patterns associated with higher levels of conceptual understanding, educators can design instructional strategies that foster more effective knowledge organisation.

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1. INTRODUCTION

Concept maps are an effective tool in the learning process, enabling students to organise and structure information into a unified whole. In the context of education, concept maps not only function as a teaching method, but also as an evaluation tool that provides a clear picture of students' understanding of the material being taught. Several studies show that the application of concept maps in various disciplines, such as physics, biology, and chemistry, significantly improves students' conceptual understanding (Chandra et al. 2019; Asriani et al. 2020; Rizalia and Munawar 2021). One of the advantages of using concept maps is their ability to encourage student learning activities through visualising the relationships between different concepts. This method helps students not only memorise subject matter, but also understand the relationships between concepts, thus improving their critical and creative thinking skills (Wepe et al. 2016; Hidayah 2019; Yusa 2023). Research by Handayani (2022) notes that concept maps can be used as an evaluation tool, which provides more in-depth insights into student understanding compared to traditional evaluation methods such as written tests. In addition, analysis of the use of concept maps in learning also shows that this strategy can increase students' learning motivation. The application of concept maps provides a more enjoyable and interesting learning experience, thus encouraging students to participate more actively in learning activities (Wepe et al. 2016; Andriani et al. 2023; Mudana et al. 2023). Field observations show that students who learn with concept maps show an increase in motivation and learning outcomes that are more visible in their grades and understanding of the material (Harneli et al. 2019; Rizalia and Munawar 2021).

In practice, the application of concept maps in learning is often done through a collaborative approach, such as group investigation or cooperative learning models. Research by Hidayah (2019) & Uripah (2022) shows that concept maps are very effective when combined with cooperative learning methods, because students are encouraged to learn from each other and discuss, which leads to a better understanding of the material. Concept maps are a tool that allows students to collaborate in structuring their understanding and sharing their knowledge with each other. However, to achieve optimal results, it is important for teachers to design structured learning and integrate concept maps with various teaching techniques that are in line with the characteristics of the material being taught. Errors in the application of concept maps can lead to misunderstandings in student understanding, so training and guidance for teachers is essential (Kusuma 2016; Helda et al. 2022; Setyaputri and Destya 2022). Through concept-oriented education, concept maps can be an essential instrument in shaping students who not only know but also understand and can apply the knowledge they learn in a broader context.

Various studies have been conducted to evaluate students' ability to create concept maps, particularly in terms of mapping structure and quality. One approach used is through analyzing the structure of concept maps such as the density of propositions, as well as the number of initial and final concepts, which are considered important parameters to assess the effectiveness of mapping techniques during training (Correia and Aguiar 2017). Thus, not only the number of concepts or relationships is important, but also their position and interrelationship within the overall structure. Supporting the initial structure in the form of prepared components can help students in developing better concept maps, both in terms of structure and substance (Prasetya et al. 2022).

Recent research continues to show that concept maps are effective tools in evaluating students' ability to understand and organize knowledge, especially in science and engineering. One study in the context of engineering design used graph-based analysis to assess the structure of concept maps. Through this approach, not only can the extent of students' understanding in describing key concepts be seen, but also concepts that are often misunderstood can be identified. These results provide important insights into the effectiveness of concept maps as learning evaluation tools (Patel et al. 2024). Furthermore, the structure of concept maps is also seen as a representation of students' level of conceptual understanding and scientific reasoning ability. One study highlighted that concept map structure correlates with scientific thinking skills, such as the ability to justify, present evidence, and reject irrelevant information. This means that the quality of concept map structure reflects not only how well a concept is understood, but also students' ability to apply scientific reasoning in the learning process (Hardiana and Widoretno 2021). Another study assessed the complexity and structure of concept maps created both individually and in groups. Although students were able to identify main and supporting concepts, many of them had difficulty in mapping complex systems. Interestingly, concept maps created individually tended to be of slightly higher quality than those created in groups. This indicates that individual cognitive processes may play an important role in organizing more structured knowledge (Iriondo-Plaza et al. 2020). These three studies reinforce the view that the evaluation of concept map structure is a relevant and meaningful approach in assessing students' understanding, reasoning and learning difficulties. Thus, the use of concept maps not only as learning tools, but also as diagnostic tools can help educators in designing more effective and targeted learning strategies. Although there has been a lot of research on concept maps as learning tools, research that specifically analyses the structural patterns of concept maps and relates them to students' conceptual understanding is still limited. This is a research gap that needs to be filled with a more in-depth study related to how concept map patterns can reflect students' level of understanding and abstract thinking abilities.

This study aims to analyse students' ability to compile concept maps. This study offers a new approach in analysing students' concept maps, not only in terms of the number of branches or concept relationships, but also in terms of the pattern of the concept map structure used by students. This research is important considering that concept maps are an effective tool in helping students understand the relationship between concepts. However, if students do not understand how to make good concept maps, this tool will not provide optimal benefits in supporting learning. This research is expected to provide a deeper understanding of how students build the structure of their concept maps and how this affects their understanding. In addition, the results of this study can be a reference for lecturers and educators in developing more effective learning strategies, especially in guiding students in compiling concept maps that are more systematic and easy to understand. The results of this study can be used as a basis for developing more interactive learning methods based on conceptual representation and can be a reference in developing concept-based curricula to improve students' understanding in various fields of study.

2. METHOD

This research uses a descriptive quantitative approach. This approach was chosen because it is suitable for describing and analyzing numerical data related to students' ability to construct concept maps, as well as to identify the concept map structure patterns used. This approach also allows researchers to obtain an overview of the level of student understanding based on the results of concept map construction without directly intervening in the variables studied (Woldeamanuel et al. 2020; Barella et al. 2024). This research design uses a quantitative descriptive study design that aims to reveal general patterns of data obtained through observation of student learning products, namely concept maps. The population in this study were all students who took the basic science education course, with a sample of 16 students selected using purposive sampling technique. The criteria for selecting samples are students who have obtained basic chemistry material, so they are considered to have the basic conceptual understanding needed to compile concept maps.

The instrument used in this study is the concept map assessment rubric, which was developed to evaluate several important aspects, namely: (a) the pattern of the concept map structure used (hierarchical, network, linear, mixed), (b) the number of branches that reflect the depth of the concept, (c) the clarity of concept representation, and (d) the relationship between concepts in the hierarchy as well as the relationship between concepts. Data collection was done by giving certain learning materials to students, then asking them to make concept maps based on their understanding. The data analysis technique used in this research is quantitative descriptive statistical analysis, by measuring and presenting the distribution of students' concept map patterns in the form of averages, frequencies, percentages, and graphic visualizations. This analysis is used to describe the tendency of the concept map structure prepared by students and its relationship with the level of concept understanding shown. The results of this analysis are expected to provide a clear picture of the conceptual ability of students in building relationships between concepts systematically.

3. RESULTS AND DISCUSSION

3.1. Structural Pattern of Concept Maps Used by Students

Based on the analysis, students tend to use several patterns in preparing concept maps, with the distribution shown in Figure 1. Based on the visual data in Figure 1, it was found that the most widely used concept map structure pattern by students was the hierarchical pattern (top-bottom) at 38%, followed by the network pattern (network-like) at 31%, mixed pattern at 25%, and linear pattern (sequential) at 6%. Hierarchical pattern is a concept map structure that is arranged from the most general concept to a more specific concept, in accordance with the theory proposed by Novak et al. (1984), where the concept map serves to represent the cognitive structure of the individual. Network patterns or network-like structure displays the relationship between concepts in a more complex and flexible manner, reflecting a deeper relational understanding (Ruiz-Primo and Shavelson 1996). Meanwhile, linear patterns depict a sequential arrangement of concepts without branching, which according to Bahar & Hansell (2000), usually reflects limited conceptual understanding. The mixed pattern is a combination of several basic patterns that show integrative ability in organizing knowledge. The diversity of concept map structures reflects the variation in students' level of conceptual thinking in understanding the material. This finding reinforces the view that the pattern of concept map preparation can be an important indicator in assessing the depth of understanding and critical thinking skills.

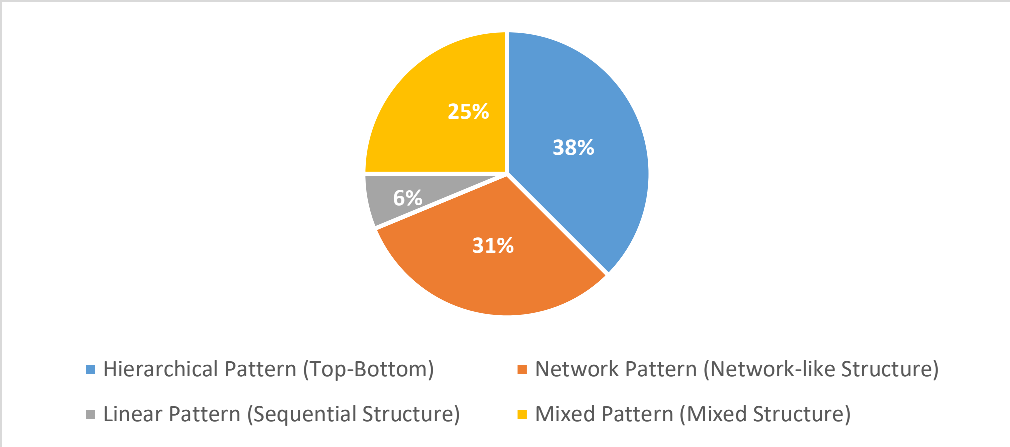

Figure 1. Distribution of percentage of structural patterns used by students in compiling concept maps

In this Figure 1, pie chart illustrates the analysis of concept map structure patterns made by students based on four main types of patterns:

a. Hierarchical Pattern (Top-Bottom)

The majority of students (38%) used the hierarchical pattern seen in Figure 2, where the main concept is placed at the top and the derived concepts are linked gradually downwards. This pattern shows a systematic understanding of the material and is often used in the representation of concepts that have a clear hierarchy, such as classification in chemistry. The hierarchical pattern is the most widely used pattern, indicating that most students have understood the concepts systematically with clear concept relationships from general to more specific.

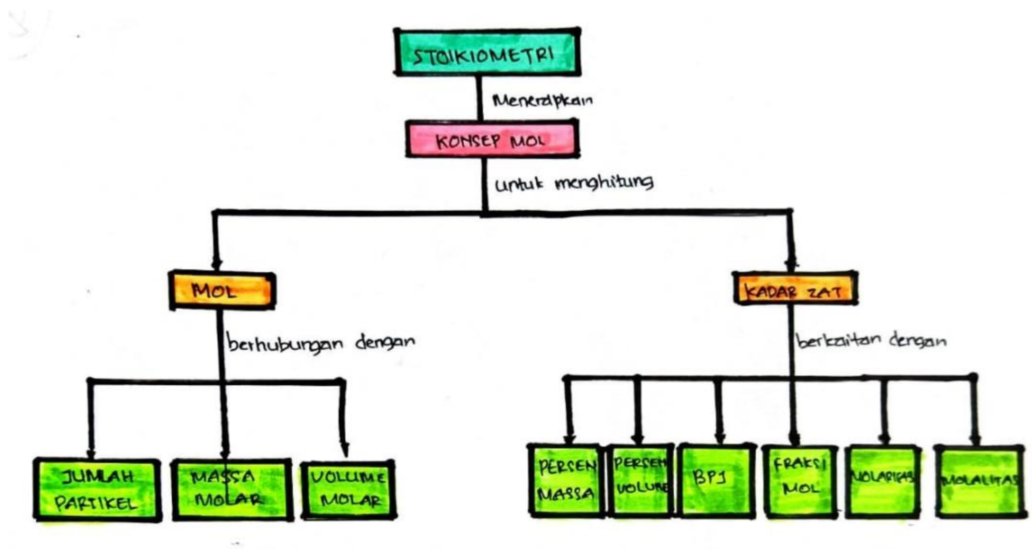

Figure 2. Mind map arranged by students with hierarchical pattern (top-bottom)

In the Figure 2, hierarchical structure is the most common form used in concept mapping. In this approach, concepts are ordered from the most general to the most specific, allowing students to see clear relationships between concepts and how they are interconnected (Al-Dmour et al. 2017; Demirci and Memiş 2021). According to research by Demirci & Memiş (2021), students claim to prefer to use concept maps with a hierarchical structure in the learning process because this structure helps them to better understand the relationship between concepts. The concept of a map with this hierarchical pattern also supports a more systematic acquisition of knowledge and allows students to develop a deeper understanding of the material being studied (Zimmerman et al. 2011).

b. Network Pattern (Network-like Structure)

Some students (31%) chose the network pattern shown in Figure 3, which shows a more flexible relationship between concepts and does not rely on one main flow. This pattern indicates that students understand the relationship between concepts more broadly and have a deeper conceptual understanding. The network pattern is also quite widely used, which indicates that students are able to connect concepts flexibly without a too rigid structure. Students who use the hierarchy and network patterns tend to have a deeper understanding because the concepts used are more structured and interconnected.

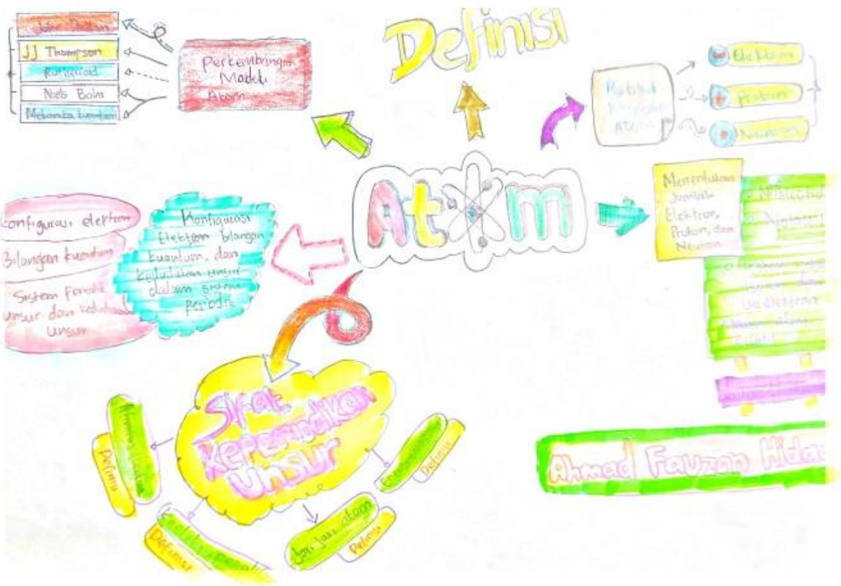

Figure 3. Mind map arranged by students with network pattern (network-like structure)

Meanwhile, in the Figure 3, network structures allow students to see more complex relationships between concepts with interactions between concepts like branches in a network, without limiting these relationships to a linear sequence (Wangila et al. 2020). This structure is often adapted by students who have a good understanding of the material and want to explore more complex relationships. For example, Kinchin et al. (2010) show that concept maps with network structures can illustrate non-linear knowledge development and can form deeper relationships between ideas.

c. Linear Pattern (Sequential Structure)

Only a few students (6%) used a linear pattern. The shape of the pattern can be seen in Figure 4 where the concept is arranged sequentially from one point to another. This shows that a small number of students still understand concepts in the form of a sequence of steps or procedures, not as a more complex conceptual relationship. Linear patterns (6%) are relatively rarely used, students who use linear (sequential) patterns, which show an understanding of concepts that still tend to be sequential without complex relationships.

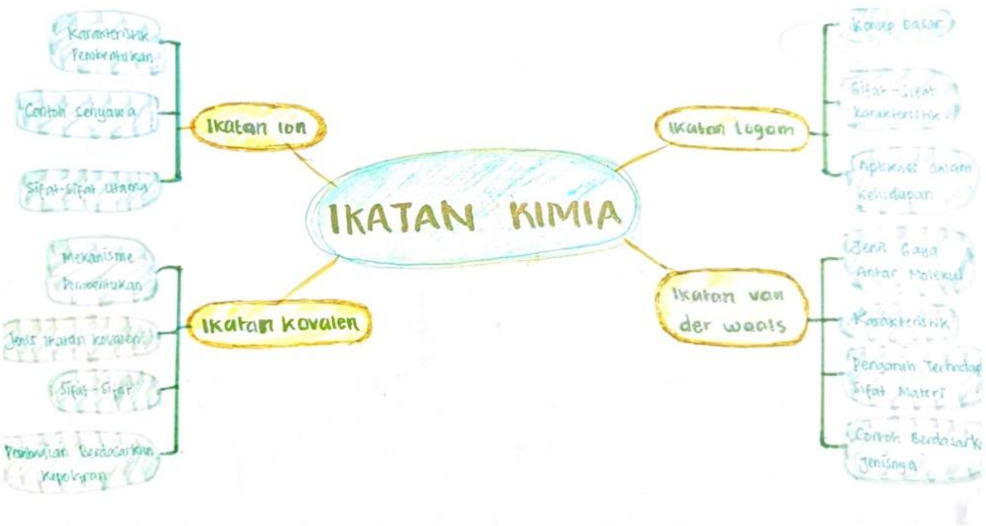

Figure 4. Mind map arranged by students with linear pattern (sequential structure)

In this pattern, it means that most students not only understand concepts procedurally, but also conceptually. In the course of learning, linear structures are often used to guide students through a series of systematic steps. Although not as complex as hierarchical or network structures, this pattern can be useful in contexts where learning sequence is important, such as in the manipulation of procedural steps (Atapattu et al. 2014). For example, when involving processes that require sequential steps for good conceptual understanding, students can more easily follow a linear structure to learn certain skills or concepts.

d. Mixed Pattern (Mixed Structure)

A quarter of the students (25%) used a mixed pattern, combining elements from various other patterns such as the shape of the pattern in Figure 5. This reflects students' creativity in constructing concept maps and shows that they are able to connect concepts more dynamically. The mixed pattern (25%) shows flexibility and creativity in understanding the relationship between concepts. Students with hierarchical and network patterns tend to have stronger conceptual understanding than linear patterns.

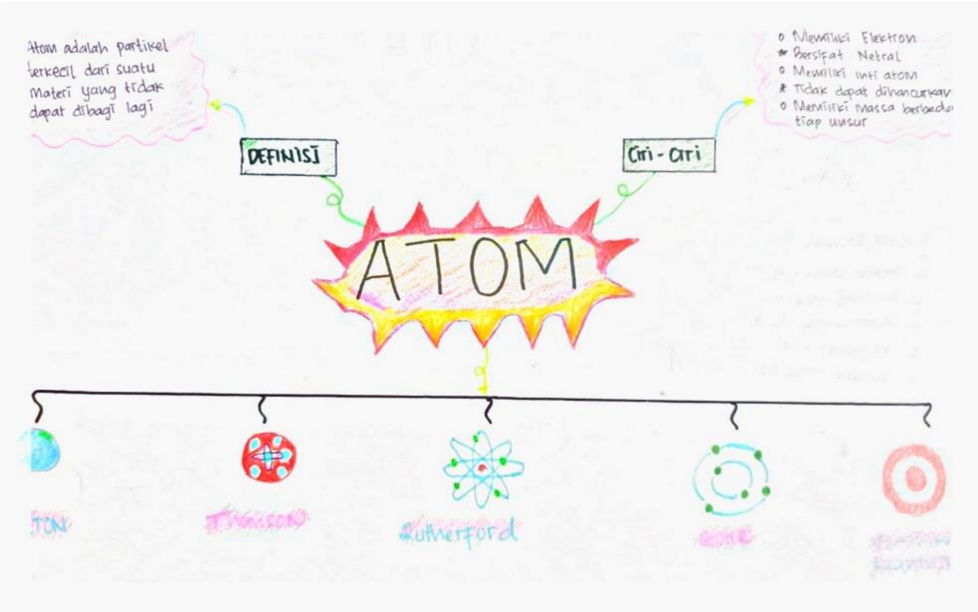

Figure 5. Mind map arranged by students with Mixed Pattern (Mixed Structure)

On the other hand, the adoption of mixed patterns is often seen in students who want to combine the advantages of various structures to create a more comprehensive map. For example, students can use elements from hierarchical and network structures to create concept maps that are more needed in a particular learning context. This shows the flexibility and ability of students to adjust their mapping based on different learning needs and contexts (Lynch and Mallmann-Trenn 2021). Students with hierarchical and network patterns are more likely to have a stronger conceptual understanding than linear patterns. The majority of students choose the hierarchical (38%) and network (31%) patterns, which indicates that they have a good understanding of the relationship between concepts. With these results, the learning approach can be more directed to help students develop a more flexible concept map structure, such as by directing them to the network or mixed pattern, so that they not only understand concepts hierarchically but also understand broader relationships.

3.2. Quality Evaluation of Student Concept Maps

The quality of the student concept map is evaluated based on the following aspects shown in Figure 6. The quality of the student concept maps was evaluated based on four key aspects: concept hierarchy, inter-concept relationships, number of branches, and clarity of representation. As shown in Figure 6, the aspect that scored the highest mean was inter-concept relationships (3.75), indicating that students generally demonstrated a good ability to connect related concepts meaningfully. This was followed by the concept hierarchy aspect with a mean score of 3.56, suggesting a strong ability to organize concepts from general to specific. The clarity of representation scored 3.19, which implies that while most concept maps were legible and understandable, there were some inconsistencies in how ideas were presented. Meanwhile, the number of branches received the lowest mean score (3.00), showing that some students may have had difficulty elaborating sub-concepts in sufficient depth. The overall average score across all aspects was 3.375, indicating that the students' concept maps were of fairly good quality but still had room for improvement, particularly in expanding and detailing concept branches. This analysis underscores the importance of guiding students not only in organizing concepts hierarchically but also in elaborating their understanding through branching and clarity.

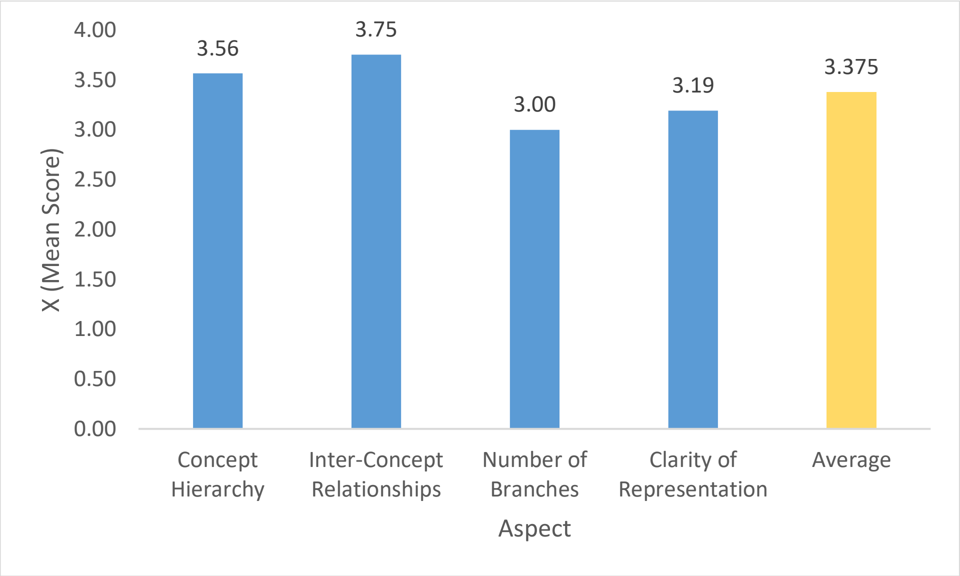

Figure 6. Aspects assessed in the preparation of concept maps

Based on the graph shown, the following is an interpretation of each aspect assessed based on the mean score:

a. Concept Hierarchy (Mean Score: 3.56)

This score shows that most students have been able to properly organise the hierarchy of concepts. The distribution of students in organising the Hierarchy of Concepts can be seen in Table 1 below:

Table 1. Frequency distribution on the concept hierarchy criteria

Score	**Frequency**
4 (Very Good)	11
3 (Good)	3
2 (Less)	2
1 (Very Poor)	0

Based on the Table 1, it can be interpreted that the majority of students (11 students) obtained a score of 4 (very good), which means that they are able to structure the concept hierarchy very clearly, reflecting conceptual relationships well and systematically. A total of 3 students obtained a score of 3 (good), which shows that they already understand the concept hierarchy quite well, although there may still be some aspects that need to be clarified. A total of 2 students scored 2 (poor), which means that they already have a concept hierarchy, but it is still unclear or incomplete. No student scored 1 (very poor), meaning that all students at least have an understanding of the concept of hierarchy, albeit to varying degrees.

Overall, the majority of students have a good understanding of how to structure hierarchical concepts. This can be seen from the dominance of scores 4 and 3 compared to scores 2 and 1. The absence of students who scored 1 indicates that no one has a concept structure that is completely unclear or without differences in concept level. However, there are a small number of students (2 people) who still need guidance to clarify the hierarchical structure they have created.

b. Inter-Concept Relationships (Mean Score: 3.75)

This aspect has the highest score among all categories. The distribution of students in structuring the relationship between concepts can be seen in Table 2 below:

Table 2. Frequency distribution on the inter-concept relationships criteria

Score	Frequency
4 (Very Good)	12
3 (Good)	4
2 (Less)	0
1 (Very Poor)	0

Based on the Table 2, it can be interpreted that: most students (12 students) scored 4 (very good), which indicates that they are able to build relationships between concepts in a logical, relevant, and well-structured manner. A total of 4 students scored 3 (good), which means that the relationships between concepts they made are quite good, but there are still some that need improvement. No student scored 2 (poor) or 1 (very poor), meaning that all students understood the concept of inter-conceptual relationships quite well, with no one having irrelevant relationships or many being inaccurate. Overall, these results show that students' understanding of inter-conceptual relationships is very good. With a total of 16 students, all of them scored 3 or 4, which means that no student had difficulty connecting the concepts. The absence of scores of 1 or 2 also indicates that there were no completely irrelevant or inaccurate relationships. However, some students (4 people) still need a little improvement in building stronger and clearer relationships between concepts.

c. Number of Branches (Average Score: 3.00)

This aspect has the lowest average score compared to other aspects. The distribution of students in structuring number of branches can be seen in Table 3 below:

Table 3. Frequency distribution on the number of branches criteria

Score	Frequency
4 (Very Good)	6
3 (Good)	5
2 (Less)	4
1 (Very Poor)	1

Based on the Table 3, it can be interpreted that a total of 6 students scored 4 (very good), which means that they are able to compile the branches of the concept completely, reflecting various aspects of the concept as a whole. A total of 5 students scored 3 (good), which shows that they have made a significant number of branches and describe the main concept well, although they may not have fully covered all aspects. A total of 4 students scored 2 (poor), which means that they have structured the branches, but still lack in reflecting the complexity of the material. A total of 1 student scored 1 (very poor), which shows that the number of branches created is very small (only 1-2 branches) and is less able to fully describe the concept.

Overall, the majority of students (11 out of 16) have shown a good understanding of concept branching with scores of 3 and 4. This shows that most of them are able to construct branches that are comprehensive enough to illustrate the relationship between concepts. However, there are still 5 students (scores 2 and 1). This shows that there are still students who create a number of branches that do not adequately reflect the complexity of the material. They need to receive further guidance to improve the number and structure of their branches to better reflect the complexity of the material. Especially 1 student with a score of 1 needs to be encouraged to increase the number of branches so that the concepts presented are more comprehensive.

d. Clarity of Representation (Average Score: 3.19)

This aspect relates to creativity in compiling concept maps which are assessed on the basis of neatness, aesthetics, and the use of colours/symbols.

Table 4. Frequency distribution on the clarity of representation criteria

Score	Frequency
4 (Very Good)	3
3 (Good)	13
2 (Less)	0
1 (Very Poor)	0

Based on the Table 4, it can be interpreted that a total of 3 students scored 4 (very good), which means that they were able to present a concept representation that was very neat, easy to understand, aesthetically pleasing, and used colours/symbols to clarify information. A total of 13 students scored 3 (good), which shows that their representation was neat enough and that they had used colours and symbols, but not optimally. These students still have room to improve the quality of their representations, especially in the use of colour, symbols, or other aesthetic aspects to be more optimal and clearer in conveying information. No student scored 2 (poor) or 1 (very poor), meaning that no representation was considered difficult to understand, untidy, or uninteresting. Overall, the majority of students were able to represent the concepts quite well to very well. With a total of 16 students, the majority scored 3 or 4, indicating that there were no representations that were difficult to understand or untidy. The majority of students presented representations that were quite clear and neat.

e. Total Average Score: 3.375

Overall, students' performance in concept mapping is quite good with an average score of close to 3.5. This score shows that most students have a fairly good understanding of the concept, but there are still aspects that need improvement, especially in the number of branches and visual representations. It can be concluded that the main strength in students' concept mapping is the relationship between concepts (inter-concept relationships) with the highest score (3.75). The aspect that needs improvement is the number of branches (number of branches), as it has the lowest score (3.00). In general, the concept mapping is quite good, but there is still room to increase the number of branches and improve the visual representation to make it clearer and more attractive.

3.3. Distribution of Categories of Understanding or Ability in Drawing Up Concept Maps

Through concept mapping, students are able to grasp the relationships between concepts and the parameters involved in a discipline (Rizalia and Munawar 2021; Yusa 2023). To see the extent of students' conceptual understanding of a field of study, their ability to draw up a concept map can be measured against the score obtained, with the results shown in Figure 7. The skill of making a good concept map is closely related to the ability of students to think critically and evaluate the relationship between various concepts systematically (Hidayah 2019).

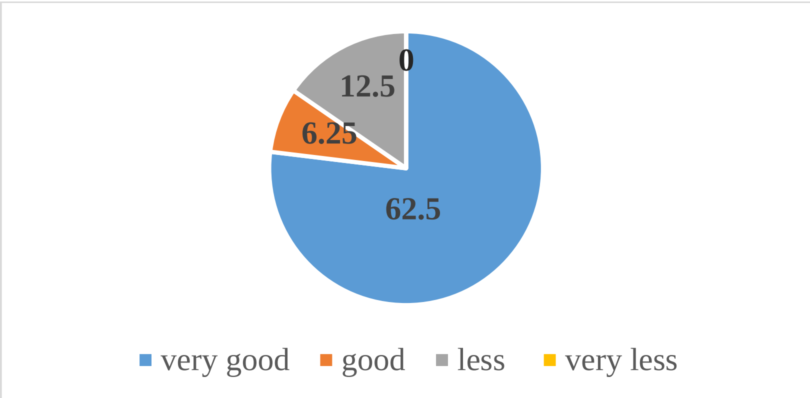

Figure 7. Distribution of percentage of students' ability to make concept maps

In this Figure 7, pie chart shows the percentage distribution of students' ability to create concept maps based on four assessment categories: very good, good, less, and very less. The majority of students (62.5%) have an understanding in the very good category. This shows that the majority of students have demonstrated excellent ability in creating concept maps. Research shows that the majority of students have excellent ability in drawing up concept maps, which include logical structure, clear relationships between concepts, and neat and informative visual representations (Chandra et al. 2019; Asriani et al. 2020). Students who are able to create neat and informative concept maps show good critical thinking skills and creativity in formulating ideas (Uripah 2022; Andriani et al. 2023).

Meanwhile, 6.25% are in the good category, which indicates that there are some students who are already quite good at developing concept maps, but may still need some improvement, such as in the concept hierarchy, number of branches, or clarity of representation. A total of 12.5% are in the poor category, which means that a small number of students have difficulty in making concept maps. They have difficulties in determining the hierarchy of concepts (there is a hierarchy but it is incomplete) and there are very few branches (only 1-2) and the concept is poorly described in terms of the complexity of the material. This problem can arise due to a lack of in-depth understanding of the relationship between concepts, resulting in concept maps that are unrepresentative and ineffective in reflecting students' overall knowledge (Rizalia and Munawar 2021). Concept maps with more branches and relationships can lead to a better understanding, because students are able to explore diverse relationships and strengthen the connections between various relevant pieces of information (Yusa 2023). The next interpretation is that no student has a very poor understanding, which means that no student scored 'very poor', indicating that all students have at least a basic understanding of concept mapping. With this result, the learning approach can be more focused on helping students who are still in the 'less' category to improve the quality of their concept maps, for example with additional exercises, group discussions, or the use of more effective visual aids.

4. CONCLUSION

The findings of this study indicate that students generally demonstrate a good ability to construct concept maps, with hierarchical structures being the most frequently used. The quality of the concept maps shows strength in connecting and organizing concepts, although some students still face challenges in expanding and clearly representing their ideas. These results suggest that concept mapping is an effective tool to support students' conceptual understanding, particularly in subjects requiring deep cognitive processing. The study underscores the importance of integrating concept mapping in instructional strategies and highlights the potential for further development in teaching students to enhance the structural complexity and clarity of their maps.

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