

Examining mathematics teachers' perceptions of concept mapping to facilitate meaningful learning

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Abstract

Concept maps enhance the quality of learning, as they can promote meaningful learning. However, teachers rarely integrate concept maps into their instructional practices. This study aims to explore teachers' perceptions of using concept maps to support meaningful learning. This study employed a qualitative research design to examine teachers' perceptions of the use of concept maps in facilitating students' meaningful learning. The study involved 16 teachers who participated in a three-day professional training program (120 minutes each day) focused on the use of concept maps in teaching quadratic function graphs. Data were collected through concept map documentation and semi-structured interviews. The findings revealed differences between teachers' self-assessment scores and the researchers' assessments, particularly in the cross-link aspect indicating that these discrepancies were caused by teachers' limited understanding of the concept map assessment rubric criteria. Teachers demonstrated positive attitudes towards using concept maps as tools to assess students' conceptual understanding. They used concept maps to connect new material with prior knowledge and to assign students tasks that summarize learning content. The implications of this study highlight the need for professional training that emphasizes the consistent use of concept map rubrics to support teachers' professional reflection and potentially enhance students' conceptual understanding.

Keywords:

Concept mapping, Mathematics teachers' perception, Meaningful learning

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1. INTRODUCTION

The development of 21st-century educational paradigms highlights the importance of deep learning for fostering conceptual understanding, critical thinking skills, and the ability to connect knowledge with real-world contexts (Fullan & Langworthy, 2014; Jiang, 2022; Kovač et al., 2023; Pan et al., 2023). Deep learning centres on an in-depth exploration of meaningful

issues, fundamentally transforming the roles of students, teachers, families, and other stakeholders in education (Fullan et al., 2018). Instead of focusing solely on information acquisition, deep learning encourages learners to link new knowledge with existing understanding and to apply it across various settings (Hussain et al., 2021). This approach has been widely recommended for classroom implementation as a means to enhance learning outcomes (Zhang et al., 2019). In Indonesia, the curriculum mandates the application of deep learning approaches; therefore, teachers are expected to design learning strategies aligned with deep learning principles.

The concept of deep learning highlights the importance of deep and meaningful understanding, connections between concepts, and the ability to apply knowledge across different contexts (Biggs & Tang, 2011). This idea aligns with the principles of mindful learning (Fan & Cui, 2024), meaningful learning (Bryce & Blown, 2024), and joyful learning (Cronqvist, 2024), which are believed to promote inclusive and sustainable learning environments. Ausubel (1968) argued that learning becomes meaningful when individuals understand the relationships between new information and their existing knowledge. Meaningful learning can transform students' cognitive structures, refine prior concepts, and establish new connections among ideas. This can be achieved through the use of concept maps as evaluation tools (Daley et al., 2016; Nesbit & Adesope, 2006; Novak & Cañas, 2007; Tseng et al., 2013), as concept mapping encourages students to link and apply knowledge more deeply. Consequently, concept maps serve as effective tools to support meaningful learning.

Concept maps are among the simplest ways to understand the material being learned (Kinchin et al., 2019; Plotz, 2020). They can serve as both instructional tools and assessment instruments (Bolte, 1999), as well as aid in identifying misconceptions in mathematics (Huerta et al., 2003). Concept maps are believed to enhance learning efficiency because they foster meaningful learning (Machado & Carvalho, 2020). They also have the potential to improve the overall quality of the learning process (Canas et al., 2017; Kinchin, 2019). Although the benefits of concept maps in supporting meaningful learning have been widely examined, their use in practice remains largely limited to classroom instruction. This gap indicates that the challenges lie not only in the availability of instructional media and strategies, but also in teachers' understanding of how to design, assess, and reflect on the quality of concept maps used in learning. This finding is consistent with Kilic et al. (2012), who found that teachers generally perceive concept maps as effective tools but have not yet integrated them consistently into their teaching practices. Similarly, Alenezi (2023) reported that teachers are aware of the pedagogical benefits of using concept maps but face difficulties in implementing them due to a lack of training and institutional support, which constrains their classroom application. The use of concept maps in the context of meaningful learning largely depends on how teachers understand, and interpret their potential. Therefore, it is essential to explore teachers' perceptions of concept map use in order to support the realization of meaningful learning.

Teachers' perceptions play a vital role in implementing concept maps. These perceptions include teachers' views, beliefs, and attitudes towards instructional strategies, which affect how much they adopt and use them in teaching (Marks Krpan, 2004). A positive view of the benefits of concept maps can boost teachers' motivation to use them to improve

students' understanding and retention of content (Alenezi, 2023), while negative perceptions or low self-confidence may prevent their classroom use. Proper professional training has been shown to enhance teachers' perceptions and skills, making them more capable in designing, integrating, and assessing concept maps effectively (Kilic, 2023). Although concept maps are suggested as assessment tools, their use involves several challenges, including difficulties in designing maps, reliably assessing them, and interpreting their meanings (Ruiz-Primo & Shavelson, 1996). Additionally, curriculum demands and time limitations often cause teachers to stick to structured, teacher-centred methods, as these are seen as more efficient for covering content (Leek et al., 2024).

Previous studies have emphasised the importance of concept maps as tools for implementing meaningful learning and have examined teachers' perceptions of their use. Nesbit and Adesope (2006) demonstrated that concept maps consistently improve students' conceptual understanding and knowledge retention. Urhahne (2021) highlighted that the effectiveness of concept maps depends on teacher guidance and the support provided, underlining the importance of teachers' pedagogical skills in maximising their implementation. Widoretno et al. (2023) showed that the success of concept map application is affected by teachers' strategies in questioning and providing feedback during the learning process. Meanwhile, Nipyraakis (2024) found that teachers who used concept maps viewed them positively for designing more structured learning, but faced challenges in assessing the quality of the maps. Although numerous studies have examined teachers' perceptions and strategies in using concept maps, research that specifically investigates teachers' understanding and accuracy in applying assessment rubrics to evaluate their own concept maps remains limited. Therefore, there is a need to examine the accuracy of teachers' application of concept map assessment rubrics, as well as their views and strategies in implementing concept maps as a meaningful learning strategy. Accordingly, the research questions of this study are as follows:

RQ1 : What are teachers' understanding and accuracy in using rubrics to assess their own concept maps?

RQ2 : What are teachers' view on the use of concept maps in teaching and learning?

RQ3 : What strategies do teachers employ to assist students in constructing concept maps?

2. METHOD

2.1. Research Design

This study used a descriptive qualitative research design. This approach was chosen to explore in depth teachers' perceptions of their understanding and accuracy in using rubrics to assess concept maps, their views on concept maps, and the strategies they use to help students construct concept maps. A qualitative approach allows researchers to capture the perspectives, experiences, and subjective meanings created by teachers in real classroom settings (Creswell & Poth, 2018). Therefore, a qualitative design was considered the most appropriate for addressing the research questions, which aim to examine teachers' perceptions in facilitating meaningful learning for students.

2.2. Research Subject

The participants of this study included 16 high school mathematics teachers from Banda Aceh, Indonesia, selected through purposive sampling techniques (Creswell & Poth, 2018; Patton, 2014). Among them, three were male and thirteen were female. The imbalance in the proportion of male and female teachers reflects the demographic characteristics of mathematics teachers in the participating schools. As gender was not used as a comparative variable in this study, this imbalance is not expected to influence the interpretation of the research findings. Their ages ranged from 25 to 50 years, with teaching experience spanning two to thirty years. Regarding academic qualifications, two teachers had completed a master's degree, one was pursuing a master's degree, and the remaining teachers held a bachelor's degree. Teachers with diverse academic qualifications and teaching experiences were included to obtain a more comprehensive perspective on the use of concept maps in instructional practices. In addition, this diversity was considered important, as it enriched the data, enhanced the transferability of the findings, and allowed the researchers to examine how differences in teachers' backgrounds influenced their understanding and perceptions of using concept map assessment rubrics to support meaningful learning.

This research topic was chosen due to the limited number of studies that specifically examine teachers' perceptions of assessing their own concept maps using a rubric, as well as their views and strategies for helping students construct concept maps. Although the study was conducted within a limited timeframe, it did not aim to test the long-term effectiveness of concept maps on students' learning outcomes, but rather focused on exploring teachers' perceptions, understanding, and reflections after participating in a structured training program. Therefore, the duration of the study was considered adequate and relevant in accordance with the descriptive qualitative and exploratory nature of the research objectives. The teachers participated in a three-day deep learning training program, lasting 120 minutes each day, aimed at improving their ability to design and implement meaningful learning when teaching the topic of Quadratic Function Graphs. One of the modules in this training addressed using concept maps as tools to develop conceptual understanding and support reflective teaching practices.

2.3. Instrument

The instruments used in this study included concept map documentation and a semi-structured interview guide. The concept map documentation was collected from the set of concept maps created by teachers after completing a concept map construction exercise. Both the researchers and the teachers assessed the concept maps using a rubric, as shown in Table 1.

Table 1. Concept map assessment rubric (Novak & Gowin, 1984)

Criteria	Descriptions	Points
Proposition	Are the relationships between two concepts represented by connecting lines?	1/each

Criteria	Descriptions	Points
Hierarchical organization	The concept map demonstrates a hierarchical structure, with subordinate concepts that are more specific than the superordinate concepts above them.	6/each
Cross links	Does the concept map demonstrate meaningful connections between different levels of the concept hierarchy?	10/each
Examples	Specific examples or instances that accurately correspond to the assigned concept labels.	1/each

Semi-structured interviews were conducted to explore teachers’ perceptions of using concept map assessment rubrics, views, and strategies in using concept maps in teaching and learning. The interview questions were designed to elicit information about teachers’ experiences, beliefs, and challenges in applying concept maps to the topic of quadratic functions. The interview guide consisted of six questions, covering teachers’ experiences in constructing concept maps, their understanding of the criteria in the assessment rubric, the challenges encountered during self-assessment, and teachers’ views on the use of concept maps as tools for learning and assessment. The interview data served as a form of triangulation to enhance the concept map documentation data, thereby offering a more comprehensive understanding of teachers’ assessments and perceptions.

2.4. Data Collection

Data collection in this study was conducted through two main stages: documentation of concept maps during a three-day training programme, and semi-structured interviews. On the first day, teachers received material on the theory of deep learning, along with examples of its application in classroom instruction. The second day focused on designing student worksheets on quadratic functions and creating concept maps. The teachers received explanations about concept maps, examples of concept maps, and the concept map assessment criteria, which included propositions, hierarchical organization, cross-links, and examples. On the third day, the activities continued with the exploration of GeoGebra to visualize quadratic function graphs and their characteristics based on the values of a , b , c , and the discriminant. Afterwards, teachers were asked to redesign a concept map of quadratic functions. This final concept map was used to assess teachers’ conceptual understanding after the training. Following the training, teachers were asked to evaluate their own concept maps using the assessment rubric, which was distributed via Google Form. The form included the concept map rubric along with an example demonstrating how to apply the rubric for evaluating a concept map, as shown in [Figure 1](#).

WhatsApp to gain a deeper understanding of teachers' comprehension of using the concept map assessment rubric. Teachers' views and strategies in using concept maps to support meaningful learning were obtained based on questions 3–6.

2.5. Data Analysis

Data analysis in this study was conducted qualitatively, involving three main stages: data reduction, data display, and conclusion drawing (Miles & Huberman, 1994). The analysis of the concept map documentation aimed to examine both the consistency and development of teachers' conceptual structures following the training. This process focused on the interconnections of concept, hierarchy, and the consistency of teachers' understanding before and after the training process, particularly when teachers constructed and revised concept maps on the topic of quadratic function graphs. Subsequently, teachers' concept maps were evaluated using the concept map assessment rubric (see Table 1). This stage aimed to assess how well teachers understood the evaluation tool and how they reflected on the quality of the concept maps they had produced.

The semi-structured interview data were analyzed through transcription, coding based on the concept map assessment rubric, and thematic categorization. The coding process was conducted based on patterns emerging from the interview data and aligned with the research focus. Through this process, the researchers interpreted teachers' perceptions of the use of the concept map assessment rubric, their experiences in constructing concept maps, and the strategies they employed to assist students in designing concept maps. The resulting main themes included teachers' understanding of the concept map assessment rubric, difficulties in assessing the cross-link aspect, and instructional strategies applied by teachers in the use of concept maps. Subsequently, triangulation was carried out between the interview findings and the concept map analysis, providing a more comprehensive and in-depth understanding of both teachers' assessments and perceptions. The teachers' strategies reported in this study represent general patterns emerging from interviews with all participants, while the dialogue excerpts are used solely as illustrations to clarify the findings.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Teachers' Understanding and Accuracy in Using Rubrics to Assess Their Own Concept Maps

The researchers assessed the teachers' concept maps using the concept map assessment rubric. Additionally, the teachers evaluated their own concept maps with the same rubric. The scores from both the researchers' and the teachers' assessments of the concept maps are shown in Table 2. Score calculations were conducted based on the concept map assessment rubric (see Table 1).

Table 2. Concept map scores based on researchers' and teachers' assessments

T	Researchers' Scores				Teachers' Scores				Description
	P	HO	CL	E	P	HO	CL	E	
NR	27	4x6=24	0	0	27	5x6=30	3x10=30	0	There are differences in the scores for HO and CL
RM	18	3x6=18	0	0	18	3x6=18	3 x 10= 30	1	There are differences in the scores for CL and E.
HD	24	3x6=18	0	0	10	3x6=18	1 x 10 = 10	4	The scores for HO are the same
MD	21	3x6=18	0	0	3	3x6=18	3 x 10 = 30	10	The scores for HO are the same
RA	15	3x6=18	1x10=10	0	15	3x6=18	3 x 10 = 30	4	There are differences in the scores for CL and E.
HZ	23	3x6=18	0	0	10	3x6=18	2 x 10 = 20	3	The scores for HO are the same
IW	20	4x6=24	1x10=10	0	16	4x6=24	2 x 10 = 20	3	There are differences in the scores for P, CL, and E.
EM	33	4x6=24	0	1	33	4x6=24	12x10=120	10	The scores for HO are the same
SY	30	6x6=36	0	0	6	1x6=6	3	3	There are differences in all aspects.
SB	3	3x6=18	1x10=10	1	1	5	2	3	There are differences in all aspects.
CH	28	3x6=18	1x10=10	14	0	3x6=18	16	42	There are differences in the scores for P and CL.
NH	27	4x6=24	0	12	4	4x6=24	0	12	The scores for HO and E are the same.
TF	21	3x6=18	0	0	18	3x6=18	2x10=20	0	The scores for HO and E are the same.
ID	25	3x6=18	2x10=20	0	16	2x6=12	2x10=20	0	There are differences in the scores for P and HO.
MY	31	3x6=16	0	18	12	3x6=18	0	1	Only the scores for HO and CL are the same.
CF	21	3x6=18	1x10=10	6	20	5x6=30	2x10=20	3	None of the aspects have the same scores.

T = Teacher, P = Proposition, HO = Hierarchical Organization, CL = Cross Link, E = Examples

Based on [Table 2](#), the numerical scores presented were used descriptively to support qualitative interpretation and to identify differences between teachers' assessments and researchers' assessments across each aspect, namely propositions, hierarchical organization, cross-links, and examples. The analysis results indicate score discrepancies, particularly in the

cross-link and example aspects. Subsequently, the score data served as a basis for qualitative analysis through interviews.

Propositions

There was one teacher, CH, who struggled to understand propositions. CH's concept map is shown in Figure 2.

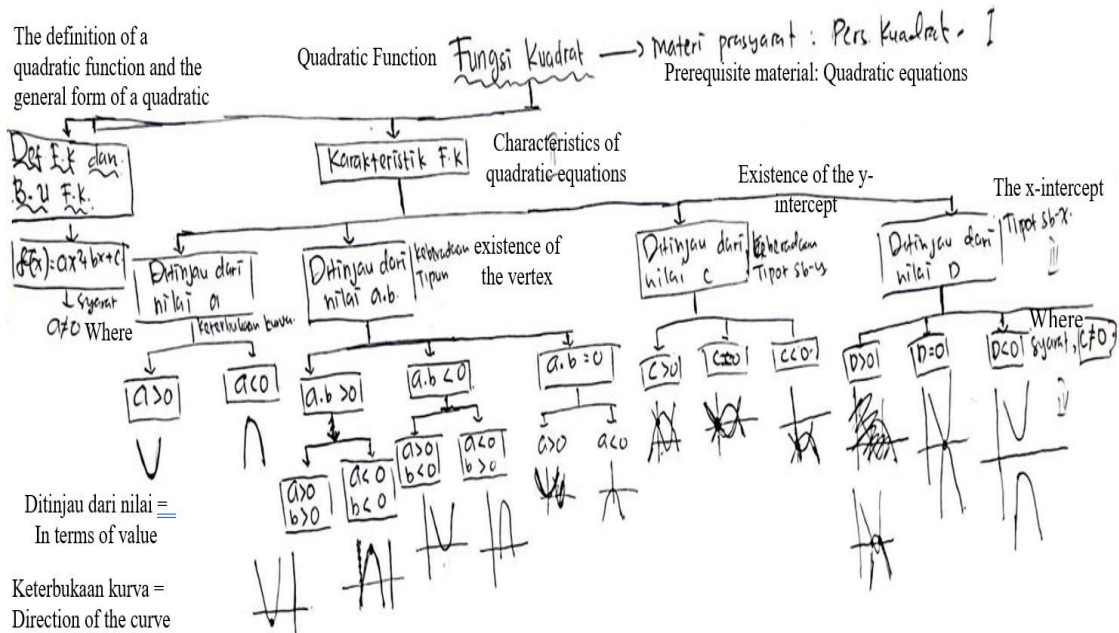
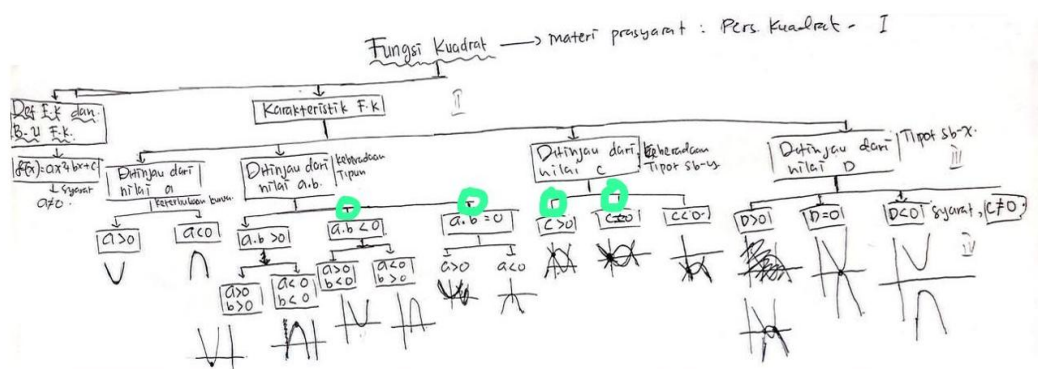


Figure 2. CH's concept map

According to Figure 2, CH rated the propositions in the concept map as 0, while the researcher gave a score of 28. Afterwards, the researcher carried out a detailed interview with teacher CH via WhatsApp, as shown in the following dialogue.

P : How did you determine the number of propositions in your concept map?

CH : This, ma'am. The green circles represent the propositions.



P : Why do you consider that as a proposition?

CH : Because the line is related to the part above it. For example, $c > 0$ shows how the curve refers to c . That's what I understood from the Google Drive file you sent, ma'am. I could be wrong.

P : Oh, I see. So anything meaningful is considered a proposition?

CH : Yes, ma'am. That's why I initially marked it is zero, because not everything can be a proposition. Since I didn't understand, I assigned zero.

P : According to this rubric, a proposition is a link between two concepts. How many links between concepts are in your concept map?

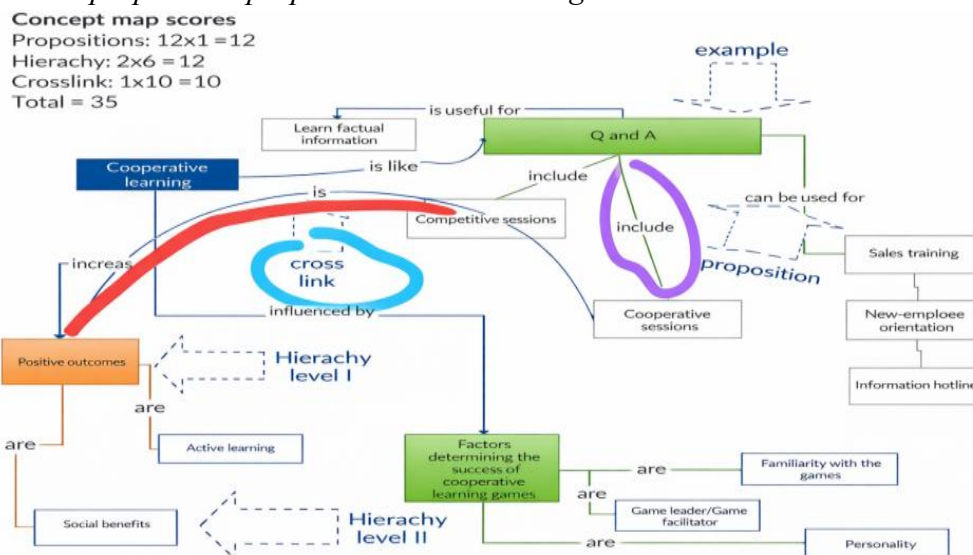
CH : Maybe two, ma'am. 1) The line connecting the concepts of definition and general form of a quadratic function with the concept of quadratic function characteristics. 2) The line connecting the characteristics of the quadratic function to the values of a , b , c , and d .

P : If you count every connecting line between concepts, there are only two?

P : According to this rubric, if a proposition is interpreted as a connecting line, how many connecting lines are there in your concept map?

CH : That means there are none, ma'am.

P : Please look at the lines in the following concept map provided in the Google Form. Are the purple lines propositions or connecting lines?



CH : If propositions are considered as connecting lines, then there are about 20, ma'am.

P : Yes, thank you. Connecting lines can be straight or curved. So, there are more than 20 in your concept map. Thank you.

CH : Yes, ma'am.

Teachers' perceptions of the propositions aspect suggest that CH had not fully grasped the meaning of propositions. This is evident from the discrepancy between the teacher's and the researcher's assessments. The teacher regarded a proposition as a part that is "meaningful in relation to the part above it," rather than a connecting line between two concepts as defined in the assessment rubric. After receiving an explanation, the teacher realised that there were more than 20 connecting lines that should have been counted as propositions. This indicates that the teacher's initial perception of the propositions aspect was inaccurate; however, their understanding improved through guidance.

Hierarchical Organization

There was one teacher, CF, whose concept map hierarchy was less organized. CF's concept map is presented in Figure 3.

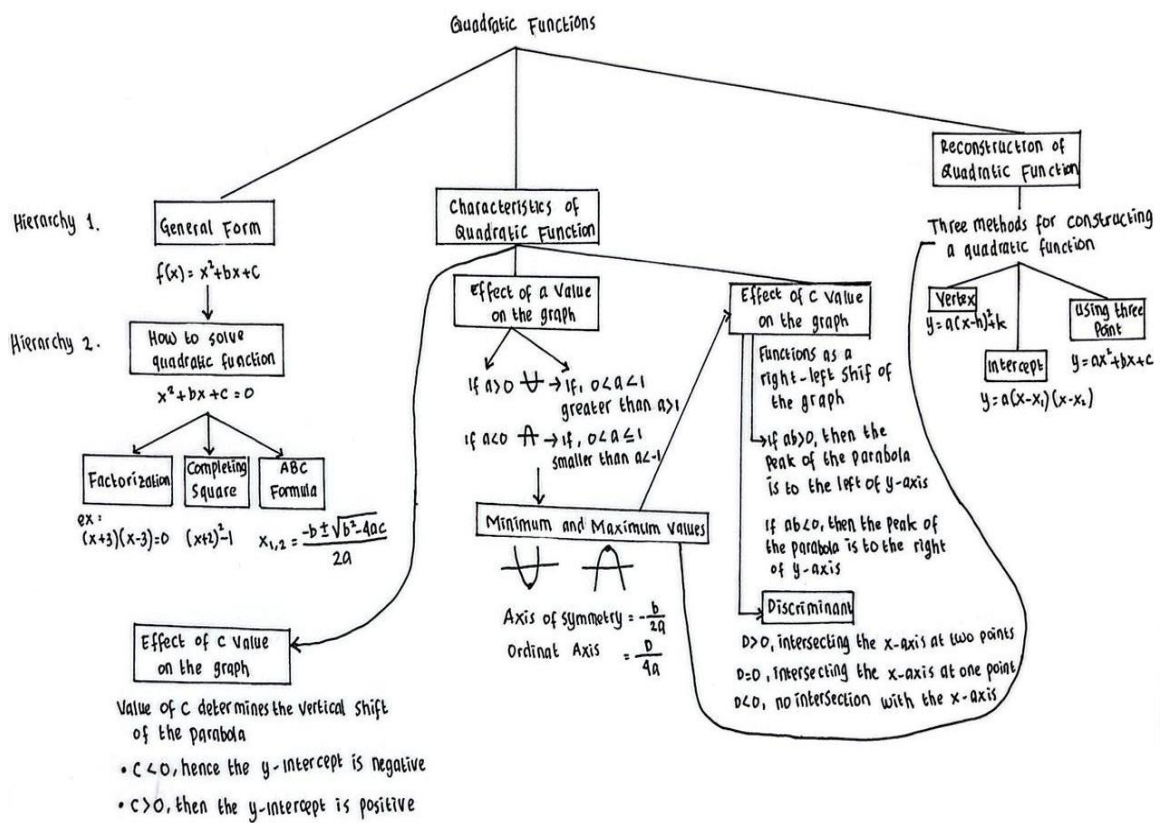


Figure 3. CF's concept map

- R : How did you calculate 20 propositions, a hierarchy of $5 \times 6 = 30$, and $2 \times 10 = 10$ cross-links?
- CF : The propositions are the lines, ma'am; the hierarchy is the lower level, but the second one; and the cross-links are two. But I'm not very sure.
- R : Why is the hierarchy two?
- CF : Because the branches go from the first row to the second row, then from the second row to the third row.
- R : What about from the second row to the third row? Try drawing the concept map so that the hierarchy is clearly visible.
- CF : (The teacher redraws the concept map) Oh yes, there is one, so the hierarchy is 3×6 .
- R : Correct. Now, which ones are the cross-links?
- CF : $ab < 0$ and $ab > 0$, and then the value of a with the discriminant.
- R : Very good.

The interaction between the researcher and CF demonstrates the teacher's reflective thinking in understanding and evaluating her own concept map. However, she still encountered difficulties in applying the rubric criteria precisely. Through questioning, CF recognised her mistakes and revised her calculations.

Crosslink

Regarding the four aspects of the concept map assessment rubric, teachers generally did not fully understand the cross-link aspect. Out of 16 teachers, only two were managed to grasp the meaning of cross-links, and both had relatively longer teaching experience compared to the other teachers, although their examples were still limited; one of whom was ID. ID's concept map is shown in Figure 4.

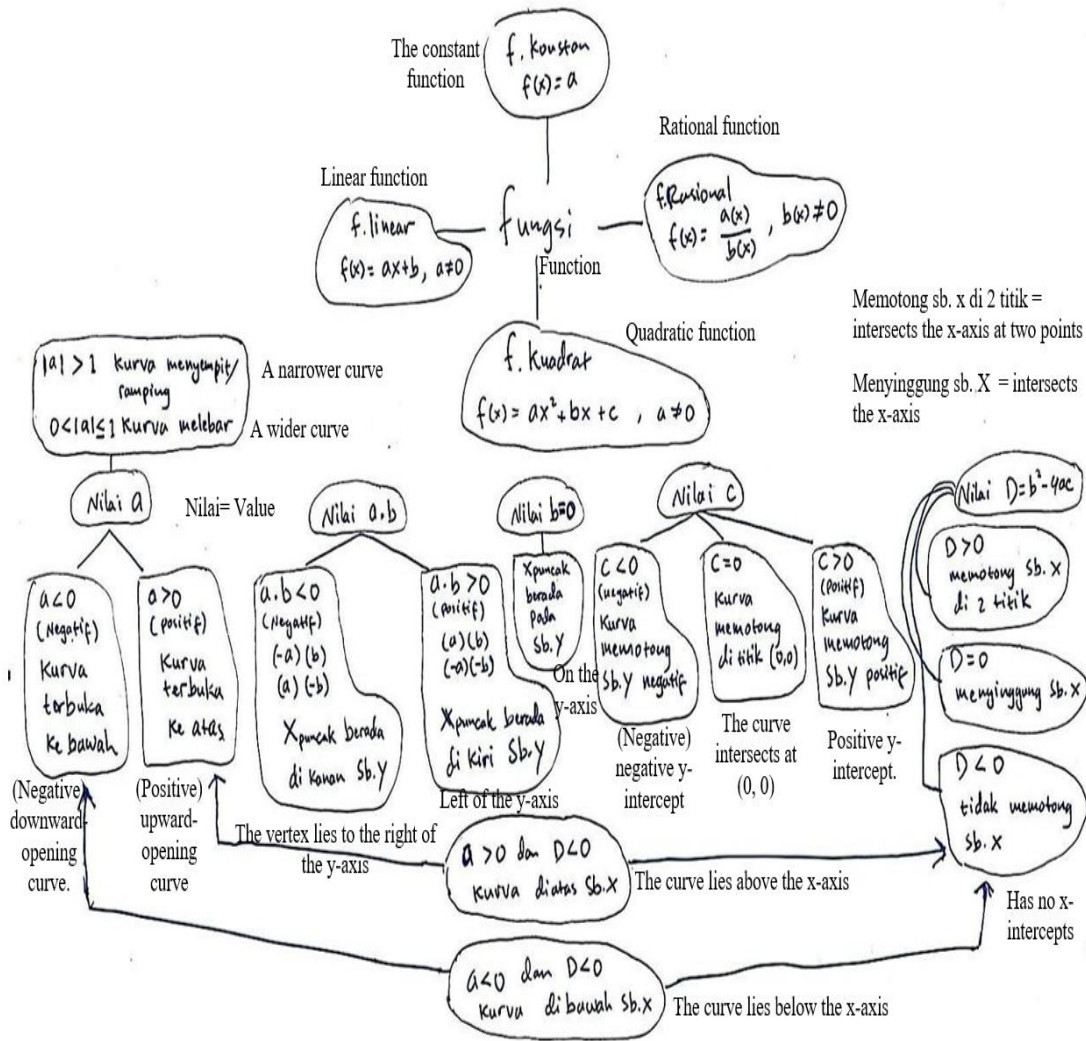


Figure 4. ID's concept map

The ID clearly indicated the presence of two cross-links, connecting the discriminant value and the value of a. The ID assigned a score of 2×10 for the cross-links, which matched the score given by the researcher. In fact, there were additional cross-links in the concept map, specifically the relationship between a and b, which resulted in $ab < 0$ and $ab > 0$. However, based on the interview, the teacher stated that there were no other cross-links. This is evident from the interview excerpt: "Are there any other cross-links besides a and D?" Teacher: "No, ma'am." To clarify the presence of cross-links, the teacher should have separated a and b and then connected them as ab.

Furthermore, there was a teacher who did not understand cross-links, namely NR. The researcher assigned a score of 0×10 because there were no cross-links in NR's concept map, whereas NR gave a score of 3×10 for cross-links. NR's concept map is shown in Figure 5.

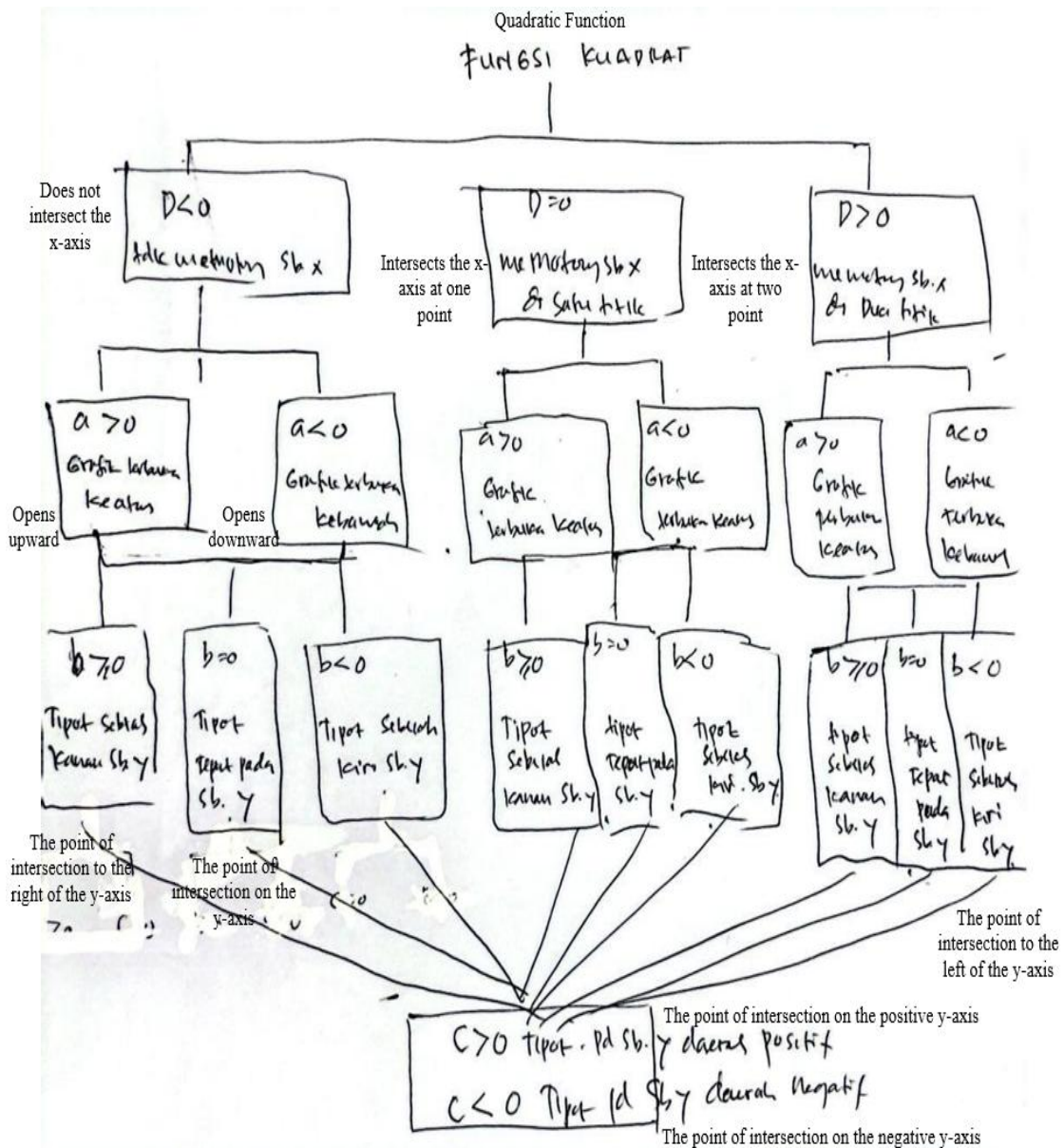


Figure 5. NR's concept map

Subsequently, the researcher conducted an interview with the teacher via WhatsApp, as illustrated in the following dialogue.

- P : How did you determine the cross-links?
- NR : I was a bit confused earlier because I was asked about the relationships between branches. Since the branches at each level differ, I chose the one with the most, which is three, located at level 1 and level 3.
- P : Oh, I understand. Please examine the following concept map. The red lines represent cross-links, which connect two concepts. How about in your concept map—are there any lines linking two different concepts? Cross-links refer to lines that intersect, as

demonstrated in the example provided through the Google Form. These connect two concepts from different hierarchies or branches.

NR : I'm sorry, ma'am. After reviewing it again, I conclude that there are no cross-links in my concept map because the lines are only vertical. There are no horizontal lines like in the example you sent. Please advise if I am still incorrect.

Based on the explanation above, it can be concluded that NR cognised there were no cross-links in her concept map. Subsequently, the researcher asked NR to create cross-links in her concept map, as illustrated in the following dialogue:

P : Thank you, ma'am. If you were to include a cross-link in your quadratic function concept map, how would you do it? Please provide just one example of a cross-link.

NR : In my opinion, for the cross-links in the quadratic function concept map I created, a line could connect $D > 0$ and $C > 0$, or I could add a column explaining the minimum and maximum turning points.

P : Thank you, ma'am. If arranged like this, could you indicate which lines might cross as cross-links in the quadratic function graph?

NR : I think it would be like this, ma'am, please guide me.

P : Yes. Do you think that is all, or are there others?

NR : For now, that's all.

From the interview above, it can be concluded that the teacher was able to create one cross-link, although many more could have been made. ID understood cross-links as relationships between concepts from different branches, yet there were still other relationships that ID did not recognise. In contrast, NR interpreted cross-links as the number of branches at different levels, rather than relationships between concepts from different hierarchies. After the interview, NR realised her mistake and was able to provide a correct example of a cross-link. This indicates that most teachers' perceptions of the cross-link aspect still require proper guidance.

Example

Teachers' perceptions of the example aspect indicate that NH understood the meaning and assessment criteria well. The matching scores of 12 between NH's self-assessment and the researcher's assessment indicate that NH accurately evaluate accurately the relevant examples illustrating relationships between concepts in her concept map. This reflects that NH possesses adequate conceptual understanding of the example aspect as a connector between concepts. These findings suggest that the training provided was effective in helping teachers understand how to identify and assess examples correctly, and thus NH's perception of the example aspect can be categorized as positive and aligned with the rubric criteria.

Teachers' View on the Use of Concept Maps in Learning

Teachers' views on the use of concept maps are presented in [Table 3](#).

Table 3. Teachers’ views on the use of concept maps

No	Question	Teachers’ Responses
1.	How do you plan to use the concept map you have created in classroom learning? Will it be shown to students at the beginning of the lesson, or in another way? Please explain.	<p>a. 11 teachers stated it would be used or shown at the beginning to make the learning material more focused.</p> <p>b. Two teachers stated at the beginning, middle, and end, depending on the learning objective.</p> <p>c. Three teachers stated at the end to summarize understanding.</p>
2.	Will you assign students to create concept maps in learning mathematics? For which topics? Please explain your reasons.	All teachers stated that they would ask students to create concept maps to assess students’ understanding and summarization of the material studied.
3.	Will you use a concept map assessment rubric to evaluate the concept maps created by students? Please explain.	Most teachers stated that using a rubric to assess concept maps is important for more accurate evaluation.
4.	If you assign students to create concept maps, when would you give the task: at the beginning, middle, or end of the chapter? Please explain.	Most teachers stated they would assign concept maps at the end of the lesson, while others would assign them in the middle of the lesson.

Based on [Table 3](#), teachers’ views on the use of concept maps indicate that most teachers understand the function of concept maps as tools to summarize learning material. Eleven teachers stated that concept maps are used at the beginning of the lesson to help students understand the direction and objectives of the material, while others use them in the middle or at the end of the lesson to conclude the concepts that have been learned. Teachers also reported assigning students to create concept maps as part of mathematics learning, aiming to assess students’ understanding of the material studied. This suggests that teachers use concept maps not only as a medium to clarify concepts but also as a formative assessment tool that can reflect students’ cognitive structures.

Teachers recognized that using a rubric is important for producing more objective and accurate evaluations. Overall, these findings indicate that teachers hold a positive attitude toward the use of concept maps as both a learning and assessment tool; however, further strengthening of teachers’ skills in applying the assessment rubric is needed to ensure accurate evaluation of concept maps.

Teachers’ Strategies for Assisting Students in Creating Concept Maps

Based on the interview results, teachers reported that after participating in the training, they assisted students in constructing concept maps through systematic instructional stages in

the topic of quadratic functions. These findings reflect patterns of strategies reported consistently by multiple teachers. Teachers explained that instruction on quadratic functions was conducted over four sessions, which were designed to gradually build students' conceptual understanding through concept maps. In the first session, students were guided to present and identify various forms of equations they already knew. The second and third sessions focused on understanding the characteristics of quadratic functions, including the effects of coefficients and discriminants on quadratic function graphs using GeoGebra, as well as solving contextual problems. In the fourth session, students were asked to design a concept map based on the understanding they had developed in the previous sessions.

Teachers reported that during this process, they employed questioning strategies to activate students' prior knowledge and help them connect relevant concepts. These strategies included: (1) asking students about the types of equations they were familiar with, (2) guiding students to identify the general forms of equations, (3) asking students to provide examples of equations, (4) guiding students to draw function graphs, and (5) directing students to construct concept maps based on the interrelationships among the concepts they had understood. These questioning strategies emerged as a recurring pedagogical approach described by teachers during the interviews. To illustrate these strategies, teachers provided examples of question-and-answer dialogues commonly used in their instructional practices, as shown in the following excerpt. T : What kinds of equations are you familiar with?

S : *Linear equations, ma'am.*

T : *What is the form of a linear equation?*

S : *For example, $x + y = 4$.*

T : *What is the general form of a linear equation?*

The student seems confused, and the teacher offers guidance

T : *The general form is $ax + b = c$. Now, what other equations do you know?*

S : *Quadratic equations, ma'am.*

T : *What is the general form of a quadratic equation?*

S : *(Student provides an example) $x^2 + 3x = 4$*

T : *Correct, but that is not the general form. The general form of a quadratic equation is $ax^2 + bx + c = 0$. Now, what is the graph of a quadratic function like?*

S : *Like this, ma'am, curved (while demonstrating with hand gestures).*

Then the teacher and students collaboratively draw the quadratic function graph

T : *From the two types of equations you mentioned, what is the difference between them?*

S : *The graph of a quadratic function is curved, whereas the graph of a linear function is straight.*

T : *Good, can you explain the difference between them?*

S : *The difference is in the power, ma'am; linear equations are first-degree, whereas quadratic equations are second-degree.*

T : *Exactly. Who can create a concept map based on the knowledge gained?*

A student draws the concept map, as shown in [Figure 6](#).

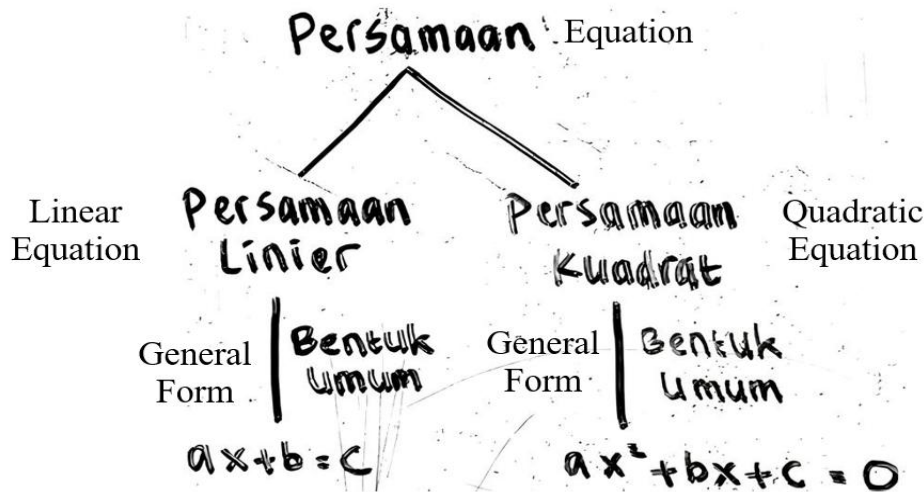


Figure 6. Concept maps developed by students

The dialogue illustration above was conveyed during the interview to exemplify teachers’ instructional strategies and to clarify how questioning was used to scaffold students’ conceptual understanding. The teacher’s strategy of asking about the types and general forms of equations aimed to activate students’ prior knowledge. This approach was intended to connect new knowledge with existing understanding. Based on this strategy, the teacher acted not only as a provider of information but also as a facilitator of meaningful learning, helping students construct an interconnected knowledge structure. At the end of the fourth session, the teacher asked students to summarize the quadratic function material in the form of a complete concept map. One example of a student’s completed concept map is presented in Figure 7.

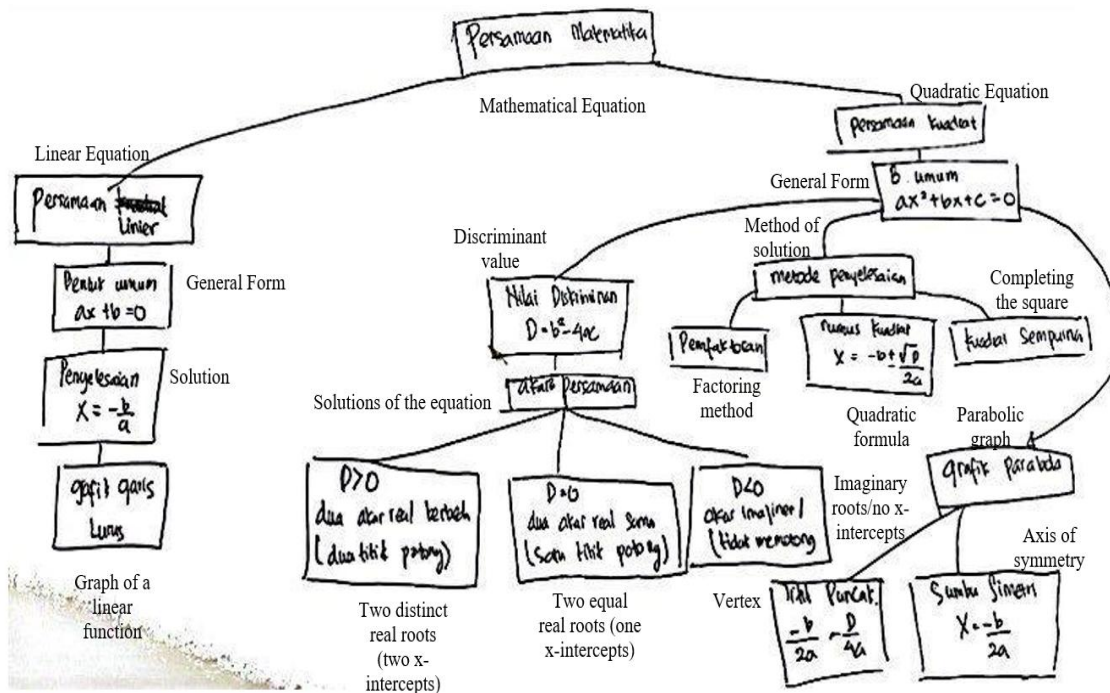


Figure 7. Completed student concept maps

3.2. Discussion

Based on the research findings, there are three main results that can be discussed in accordance with the research questions. First, the results of the study reveal discrepancies between the concept map scores assigned by the researcher and those given by the teachers themselves, especially regarding cross links and examples. This indicates that most teachers did not fully comprehend the evaluation criteria in the concept map rubric. Watson et al. (2016) observed that rubrics can be employed to assess the knowledge structure within concept maps, emphasising the importance of clear assessment criteria. In accordance with this, Krebs et al. (2022) found that using rubrics can improve the accuracy of self-assessment. Therefore, it is crucial for teachers to understand the rubric to evaluate concept maps accurately. The concept map rubric used in this study assessed four main aspects: propositions, hierarchical organization, cross links, and examples (Novak & Gowin, 1984). The rubric aims to measure how well a concept map represents a comprehensive conceptual knowledge structure. Besterfield-Sacre et al. (2004) developed rubrics to assess concept maps as tools for evaluating conceptual understanding. The utilisation of such rubrics has been shown to enhance consistency and objectivity in assessing the quality of relationships among concepts in concept maps. Concept map assessment aids teachers in gaining insights into students' understanding of mathematical concepts, identifying misconceptions, and evaluating the structural complexity of connections among concepts (Nesbit & Adesope, 2006). However, most teachers demonstrated limited understanding of the meaning of cross-links. Of 16 teachers, only two could accurately identify cross-links, while the rest misinterpreted the connections across different concept branches. This mistake suggests that teachers tended to view cross-links as hierarchical relationships rather than as links between concepts. Tseng (2017) pointed out that difficulties in recognising cross-links reflect limitations in fully understanding the interrelationships among concepts.

Based on the interview data, teachers began to demonstrate improved understanding of the cross-link aspect after being provided with examples and additional explanations by the researchers. Teachers who had previously interpreted cross-links as subheadings began to correctly identify meaningful cross-branch relationships after receiving this guidance. This change highlights the importance of guidance and examples in helping teachers understand how to apply rubrics. Other errors were also observed in the aspect of propositions. One teacher assigned a score of zero, whereas the researcher assessed the propositions in the concept map as quite complete. This occurred because the teacher did not understand that propositions in a concept map represent relationships between two concepts connected by linking words, forming meaningful statements, rather than merely representing the main topics in the concept map. Novak and Gowin (1984) explain that propositions are the basis of meaning in concept maps, and the quality of the propositions created reflects the conceptual knowledge structure of the map creator.

Second, the research findings indicate that teachers held positive perceptions toward the use of concept maps in instruction. Teachers viewed concept maps as tools that help them design more structured instruction and support students' conceptual understanding. This finding is consistent with Alenezi (2023), who stated that teachers' positive perceptions of

concept maps can enhance their motivation to integrate them into instruction in order to support deeper conceptual understanding.

Third, teachers demonstrated the ability to implement pedagogical strategies to assist students in constructing concept maps. They guided students through systematic learning steps, starting with eliciting prior knowledge about linear and quadratic equations, helping students identify the general forms of these equations, and ultimately assisting them in creating concept maps based on their understanding. Prior knowledge is an essential component of the meaningful learning process, as it enables the integration of new concepts with students' existing cognitive structures (Ausubel, 1968). Therefore, teachers not only assess but also act as facilitators of meaningful learning by helping students represent relationships between concept.

Most teachers in this study stated that they tended to use concept maps at the beginning of the lesson to evaluate students' understanding of quadratic function concepts. Meanwhile, only a small number of teachers considered its use at the end or in the middle of instruction. This pattern indicates that teachers still view concept maps primarily as a formative learning tool. This aligns with Mutodi and Chigonga (2016), who stated that concept maps can be used to support teaching and learning processes, monitor the development of conceptual understanding, and serve as a formative assessment tool. The use of self-assessment for formative purposes is more likely to enhance learning effectiveness than using it for summative purposes (Andrade, 2019; León et al., 2023; Panadero et al., 2019; Pinedo et al., 2023; Yan & Brown, 2017; Yan et al., 2023). Beyond formative assessment, concept maps also play a critical role in providing information for diagnostic assessment before instruction begins (Llewellyn, 2014). Therefore, concept maps should be regarded as tools for conceptual thinking and reflection, not merely as assessment instruments. Mintzes et al. (2005) emphasized that evaluating concept maps requires experience and training because assessors must understand conceptual structures and the hierarchical relationships between concepts to assign scores consistently and accurately. Without proper training, teachers may interpret the criteria based on intuition rather than valid theoretical understanding. Hence, professional development programmes for teachers should include training on using concept map rubrics so that they can assess objectively and reflectively.

Overall, the findings of this study indicate that teachers' understanding of the concept map assessment rubric remains limited, particularly regarding the cross-link aspect. However, teachers' comprehension improved after being provided with examples and direct feedback. This indicates that the concept map assessment rubric functions not only as an evaluation tool but also as a professional learning resource that can strengthen teachers' understanding of their conceptual knowledge structures. Therefore, teacher professional development programs should incorporate training on the use of concept map assessment rubrics to enable teachers to conduct assessments objectively, reflectively, and based on a strong theoretical understanding.

4. CONCLUSION

This study reveals that teachers' self-assessment of their own concept maps remains inaccurate, especially concerning the cross-link aspect. Most teachers struggle to interpret the assessment criteria correctly, leading to discrepancies between their self-assessment scores

and those of the researcher. Nevertheless, teachers' understanding improved after they were shown examples and received feedback, highlighting the significance of guidance and training in using concept map assessment rubrics. Teachers have positive perceptions and attitudes towards concept maps, as they help students connect new knowledge with prior understanding. Additionally, teachers tend to utilise concept maps as a summative evaluation tool rather than as a formative learning instrument, indicating that concept map-based learning strategies have yet to be fully exploited.

This study significantly contributes to teacher professional development in implementing meaningful learning. The findings highlight the need for professional training that stresses the consistent use of concept map rubrics to improve teachers' ability to assess, reflect on, and deepen their understanding of concepts. Through such training, teachers are expected not only to perform objective assessments but also to utilise concept maps as tools for reflection and as learning strategies that promote students' deep conceptual understanding.

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Declarations

- Author Contribution : RJ: Conceptualization, Data curation, and Supervision; CK: Resources, Software, and Writing - original draft; CMZ: Data curation, Formal analysis, and Methodology; AHA: Validation, Supervision, and Writing - review & editing; LI: Investigation, Project administration, and Software.
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