Process Evaluation for Concept Map Building and Its Experimental Evaluation

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Abstract: Concept map as an assessment tool is widely accepted in the field of education. In this research, assuming the process evaluation of concept map building leads to better evaluation than the product (that is, built concept map) evaluation, we proposed a process evaluation method and conducted an experimental evaluation of the method. The process evaluation method is intended for re-composition type of concept maps, not for general ones. In the re-composition concept map, a learner is provided a set of components of a concept map, that is, links and nodes, and required to recompose a concept map by using the components. The provided components are generated by decomposing the concept map built by an expert as a representation of understanding of the learning target. In this research, we set several submaps with a set of semantics in one expert map and define a good process by recomposing the submap as a series of activities. The process evaluation results were compared with the product evaluation results for the data of a practical use of re-composition of concept map in undergraduate class. As the results of the comparison, we have already confirmed that the result of process evaluation was a better predictor of learner's understanding than the results of the product evaluation. In this paper as an additional analysis, we reported the analysis of relation between process evaluation and product evaluation. The difference between the evaluation methods could result in a case where there is zero score for process evaluation and full score for product evaluation. However, analysis results confirmed that there is a strong correlation between the two evaluation methods with *r* value = 0.8. These results suggest that support for the process of submap re-composition is a promising way for learners to recompose a good concept map. We further explore the usability of the process evaluation to the teachers, and it shows a high rate of agreement of the usefulness and appropriateness of the method. Based on the results, we are developing a formative assessment and support environment for concept map re-composition.

Keywords: Concept map, concept map assessment, process evaluation, Kit-build

1. Introduction

Concept map, developed by Novak in 1972 (Novak & Musonda, 1991) is widely accepted as a promising activity for learning and evaluation of learner's understanding and facilitate independent learning and thinking (Hu & Wu, 2012). Studies of concept map in the assessment across multiple disciplines have conducted (Gregoriades et al., 2009; Kinchin et al., 2000; Yin et al., 2005). Many studies describe the assessment criteria such as structural and relational scoring (McClure & Bell, 1990; Novak & Gowin, 1984). These assessment methods are accepted widely but purposed to assess the product of concept map, not the process of concept map building.

Research in concept map assessment mentioned that to realize sophistication and adaptation of the learning and evaluation, assessment of the process of concept map building is an important issue. A study by Jablokow (2015) suggests the importance of collecting data about learner's actual mapping process that could reveals an insight about cognitive aspect implicit in a concept map building that related to learner's understandings. Concept map building process also shown that produced map quality has a relationship with the order of created propositions (Srivastava et al., 2021) and sequential mapping (Chiu & Lin, 2012). However, to realize the observation of the concept map building process is still a big issue, because most proposed method to evaluate the concept map quality and the process of concept map building relies upon human-dependent, qualitative approaches to conduct the observation (McAleese, 1998; Rautama et al., 1997; Wong & Lian, 1998) which generally lacks consistency and a demanding time and efforts.

In this research, we proposed an automatic process evaluation method and conducted an experimental evaluation of the method to evaluate its relationship with the quality of the produced map. The proposed method is intended for a re-composition type of concept maps, not for a general one where learner builds a concept map from scratch. We applied the proposed method in Kit-Build (KB), a concept mapping re-composition framework that allows knowledge sharing between teacher and learner and allows automatic assessment of learner's concept map (Hirashima et al., 2011, 2015). It is known that KB automatic assessment could be used to assess learner's map quality and the validity has been checked to be similar with other scoring methods (Wunnasri et al., 2018). As an assessment of learner's understanding, KB map score has proven to have a high correlation with learner's actual understanding (Yoshida et al., 2013).

Since the components of building a concept map are provided in the KB, it is possible to record the created propositions that are matched in comparison with the propositions from teacher's build map. To realize the process evaluation, we use the concept of sub-map as a substructure in a concept map. We define several sub-maps with a set of semantics in the teacher's map and define a good process by re-composing the sub-map as a series of activities. Then we analyze the data from learner's KB concept map activity in respective to the defined sub-maps. We already confirmed that the process evaluation has a relation with test scores and therefore related to learner's understanding (Rismanto et al., 2023).

In this paper, we report the results of the analysis of the relation between the process evaluation and learner's map quality, that is, the product evaluation. If there is high correlation, it means that the quality of the map can be improved by supporting the process. To realize the analysis, the process evaluation results were compared with the product evaluation results from the data of a practical use of KB in an undergraduate class. We further explore the usability of the process score to the teacher, in the context of evaluating the process evaluation from the teacher's perspective. To realize it, the process evaluation results were compared with the product evaluation results from the data of a practical use of KB in an undergraduate class. We further explore the usability of the process score to the teacher, in the context of evaluating the process evaluation from teacher's perspective.

Therefore, the research questions for this study are as follows: Does the concept map building process have a relation to the product score (RQ1)? And does the process score is appropriate and useful from the perspective of teachers (RQ2)?

2. Background

2.1 Concept Map Assessment

Concept map is a widely recognized method to visualize knowledge in a graphical format (Novak & Gowin, 1984). It is a simple but powerful representation of knowledge to support the learning activity between teacher and learner. To represent a concept map, a graph is constructed by using only two symbols: Nodes that represent concepts, and links that represents relationship between concepts (Cañas et al., 2016; Dwi Prasetya et al., 2020). In an educational purpose, concept maps have been used such as for sharing meanings between people, planning the problem-solving process, representing, and assessing the learner's knowledge structure.

Many methods and have been studied and proposed in utilizing concept map as an assessment tool (Plotnick, 1997; Yin et al., 2005; Zheng et al., 2019). A person who can well understand the meaning of words in the concept map, called “rater”, manually works to assess the concept map. Novak and Gowin (1984) proposed a structural scoring. This method gives a high score for the correctness of hierarchy level and each valid crosslink. It is because ordering the concepts into hierarchy and connecting the crosslinks can reflect learner’s creative thinking. Hence, this method is called structural scoring.

Other assessment methods that consider the meaning of a proposition instead of the structure have been studied. McClure and Bell (McClure & Bell, 1990) proposed the relational scoring. This method works by checking the relationship possibility between each proposition, concept label appropriateness and compatibility between labels. The reliability and validity of the method has also been studied. McClure et al. (Mcclure et al., 1999) investigated the concept map assessment by requesting students to construct a concept map using provided concepts and creating the link words to connect between concepts. Raters then scored each individual map separately. Result shows that the relational scoring method has a close relation with structural scoring method, using criteria map (teacher-build map).

2.2 Kit-build Framework and Automatic Assessment

Kit-build (KB) is a framework in concept map knowledge sharing and automatic assessment (Hirashima et al., 2011, 2015). In this framework, the learner creates a concept map by recomposing existing components called “kit” which consists of nodes and links. The nodes and links are components that decomposed from an “expert map” (teacher-build map). The teacher constructs the expert map by extracting from the learning material. This method of concept mapping is a re-composition concept map, which means that instead of creating their own concept map from scratch, learners recompose it from the kit. The map constructed by learner (learner map) then superimposed with the expert map to determine the matching propositions.

There are two main tasks in the KB framework (Yamasaki et al., 2010). The first is the segmentation task, in which the teacher is requested to prepare the teacher-build map, called the expert map. The expert map is extracted from the learning material and is the teacher’s expression of a comprehension of the learning topic. The expert map is then submitted to the system and decomposed into “kit” which contains a list of concepts and links from the expert map. The kit then provided to the learners to be recomposed into a learner map. Hence, when utilizing the kit, students are just required to identify the provided components and link them, no component creation is required. Figure 1 (left) shows an example of an expert map and a kit.

The second task is restructuring task. Learners are asked to restructure the concept map from the provided kit, creating the learner-build map, or learner map. Figure 2 (left) shows an example of learner map. After completing the restructuring, the learner map was then uploaded to the system for the analysis. The system then evaluates the learner map by superimposing it with the expert map. The automatic assessment works by matching each learner’s proposition with the expert map propositions.

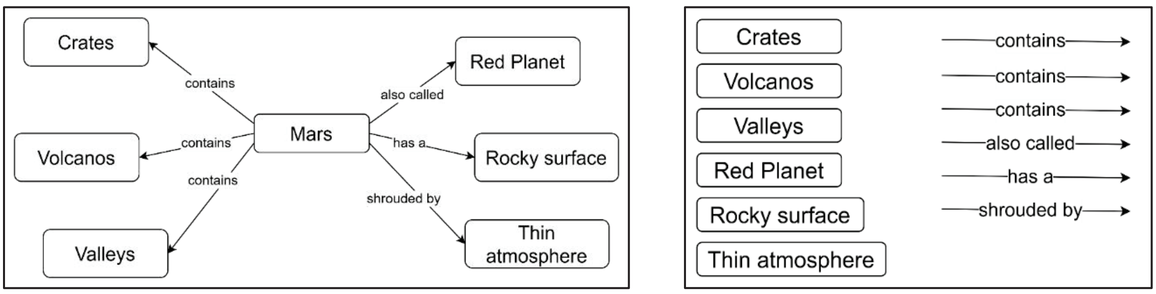

Figure 1. Teacher-build map, or expert map (left) and Kit (right).

Propositions from the learner map that match with propositions from the expert map will be given a score. The total score is the evaluation result of the concept map product, called “map score”. Map score is the percentage of the matching propositions number from the learner map compared with the total amount of propositions from the expert map. Figure 2 (right) shows the learner map superimposed with the expert map. The solid lines are the correct propositions, and the dashed lines are the incorrect and lacked propositions in comparison with the expert map. Map score has been known with a high relationship with the learner’s understanding (Yoshida et al., 2013) which implies that learners with a high map score tend to have better knowledge compared with the ones with low map score. As an assessment of concept map, map score has been validated with other concept map product scoring method and comparable to the manual assessment methods (Wunnasri et al., 2018).

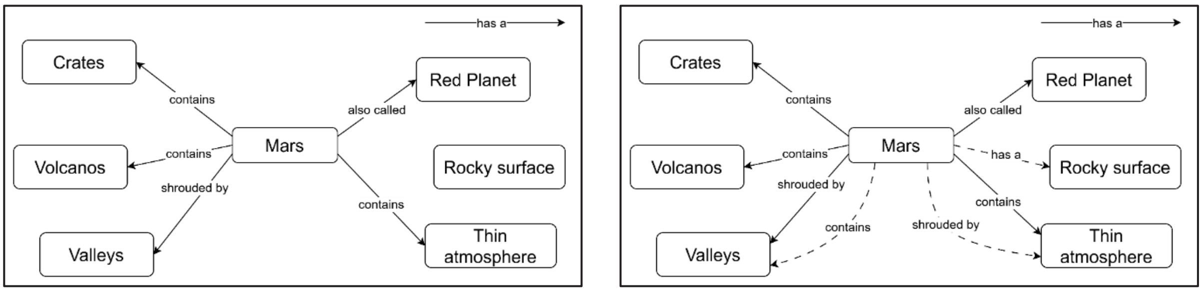

Figure 2. Learner map (left) and learner map superimposed with expert map (right).

2.3 Process Score

The process score proposed in this study aims to assess learner’s process in the KB concept map recomposing activity. The current scoring system of KB, the map score, is based on the produced concept map built by learners using the provided components (Jablokow et al., 2015). Our proposed method purposed to evaluate learner’s actual concept mapping process by analyzing the sequence of connected propositions in KB concept map recomposing activity. As mentioned by Chiu and Lin (2012) and Srivastava (2021), the sequence in concept map building process is related to the map quality built by learner where good process produces a good quality concept map.

In realizing the automatic process evaluation of concept map building, we analyzed it as a set of sequences, grouped by sub-maps. Sub-map is subset composed of closely related propositions in a concept map. Sub-map defined the concept map’s substructure (Gerstner & Bogner, 2009), that demonstrate the teacher’s deep understanding as the subject specialist (Kinchin & Alias, 2005; Roberts, 1999). Therefore, achieving it is an important target for learners. The re-composition process suggests that a learner has a solid comprehension of the substructure indicated by the sub-map when they continually recompose a collection of propositions in a sub-map.

The sub-maps are defined by the teacher after creating the expert map. Generally, a sub-map contains propositions that have a close meaning or extracted from the same subdomain of knowledge. As mentioned by Schneider et al. (2021), segmenting the concept map into a group of sub-map can be based on a particular knowledge domain of the concept map. This is in line with spatial continuity principle stated in Moreno and Mayer (1999) and Schroeder and Cenkci (2018), in which the information in a concept map is spatially ordered nearby within a learning material. Figure 3 (left) shows the example of sub-maps in a concept map.

After the sub-map is defined, learners are then given the task to recompose the kit back into the learner-build map, or learner map. In this stage, learners are not able to see the sub-map. The process scoring is transparent from the learners, as they will be performing the recomposing activity as usual. After completing the activity, learners will submit the map to the system and be given the map score and process score.

To calculate the process score, we analyze the sequence of connected propositions. We scanned the learner's propositions that are sequentially connected as a set and corresponds to the propositions in each sub-map. The percentage of matched propositions sequence set for each sub-map is then calculated, which is, the number of connected propositions as a set divided by the number of propositions in a sub-map. As long as the propositions that are connected sequentially belong in a sub-map, the order of the proposition sequence in that sub-map is not considered.

For example, there are two sub-maps: Sub-map 1 (SM1) contains proposition 1 (P1), P2, P3. And SM2 contains P4, P5, P6. If a learner's connected proposition sequence is P2, P3, P5, P4, P6, P1 then the calculation will be as follows:

P2, P3 connected sequentially as a set and belong to SM1. Therefore, the SM1 score is 2/3 * 100 = 66.67. Moving forward, P5, P4, P6 connected sequentially as a set and belong to SM2. Therefore, the SM2 score is 3/3 * 100 = 100. The process score is the average of the total score of each sub-map (SM). So, this learner will get a process score of (66.67 + 100) / 2 = 83.33. Figure 3 (right) shows the illustration of the process score calculation.

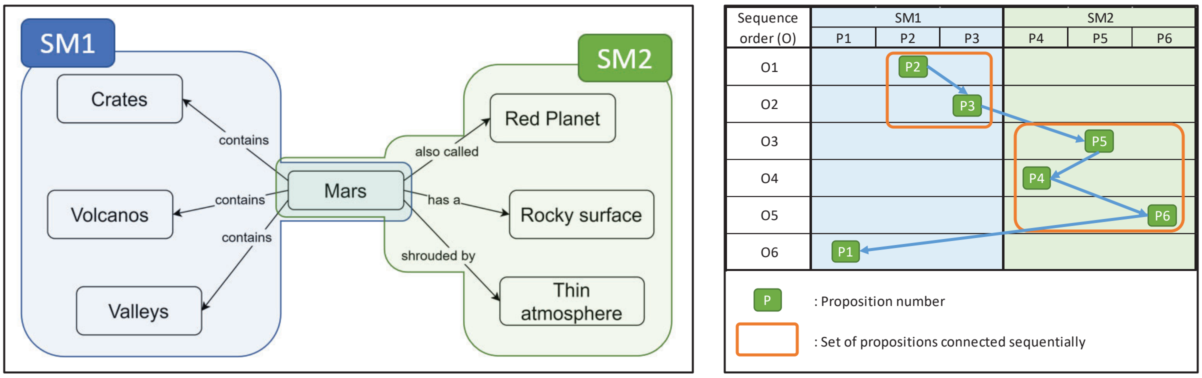

Figure 3. Sub-map in a concept map (left) and example of process score calculation (right).

3. Method

3.1 Experiment details

The study subjects were 28 second year undergraduate students majoring in Information Technology at State Polytechnic of Malang, Indonesia. Subjects have no prior experience or knowledge in building a concept map and in using the KB system. At the first session of the experiment, subjects were given a tutorial about creating a concept map and the usage of KB system. At the next session, the teacher explained about the learning materials in the form of lecture using power point slides. Further, subjects were tasked to perform KB concept map recomposing activity. After completing the recomposing, subjects upload the learner map into the system to be scored for a map score and process score. The total time for the experiment sessions is 60 minutes.

The learning subject is Polymorphism in Object Oriented Programming (OOP). The material was taken from the OOP course module released by the team teaching of the course at the Information Technology department at the State Polytechnic of Malang, Indonesia. The expert map was extracted from the module by the author of this paper and presented to the three teacher that has teaches OOP subjects for undergraduate students. The expert map was then discussed and modified according to the team teaching's input, and the sub-map was also defined. The expert map consists of 10 propositions, 10 links, 11 concepts and five sub-maps.

3.2 Analysis

To assess the relation between KB concept map building process reflected by process score and learner's map quality reflected by map score, a correlation test between process score and map score was performed. This assessment is based on the research by Chiu and Lin (2012) and Srivastava et al. (2021) that mentions the strong relationship between concept map building process and the quality of concept map product. Furthermore, a multiple linear regression analysis between map score and process score was conducted to check whether the process score has a strong influence and can be a predictor to the map score.

Detailed analysis of the sub-maps was carried out to confirm that the process analysis could provide useful information for teachers in recognizing parts of the concept map in relation to learner's map quality. Based on the sub-structure of concept map that is defined by sub-maps (Gerstner & Bogner, 2009; Kinchin & Alias, 2005), we conduct this analysis to evaluate how each sub-map correlates to the quality of concept map product. The information can be used for teachers to provide adequate feedback for learners to improve their quality of produced concept map. To analyze the parts of the concept map that have a strong influence on learner's map quality, correlation test was performed between each sub-map score and map score. Multiple linear regression analysis was performed to confirm that the highest correlated sub-map score with map score, can also be a predictor to the learner's map quality.

To evaluate the teacher's perspective on the reasonability and perspective of the process scoring method, a questionnaire for teachers that have taught OOP subjects for undergraduate students and have familiarities with KB concept mapping has been conducted. The questionnaire was asked after observing the experiment and the method of process scoring and evaluating the results. We explained to the teachers how the process evaluation method works and its result, and the relation between process score and product score. Therefore, the teachers answered the questionnaire based on the relation between process scoring result and product scoring result. The first part of the questionnaire is about the reasonableness of the scoring method (Wunnasri et al., 2018). And the second part is their perspective of usability of the sub-map evaluation.

4. Result and Discussion

To check the relationship between process score and learner's map quality which reflected by the map score, a Pearson correlation test was performed, and the result can be seen in Figure 4. According to the result of the correlation test, the R value of 0.8 means that process score has a high correlation with the map score. With p-value of 3.4e-07 which is less than significance level alpha = 0.05, it is concluded that process score and map score are significantly correlated.

This result means that learners with a high process score tend to have a better map quality compared to the ones that have a low process score. In a cognitive point of view, the process of recomposing the kit into concept map, reflected by the proposition sequence, could be an indication to assess the understanding level of learners, as mentioned by Yoshida et al. (2013) that the map score has a high correlation with learner's understanding.

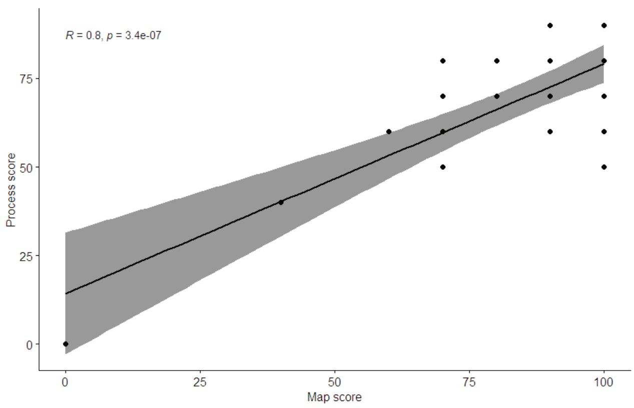

Figure 4. Correlation between map score and process score

Multiple linear regression analysis was carried out between map score and process score, to check that the concept map building activity process can be a predictor of learner's map quality. Result shown in Table 3 concluded that with a p-value of 3.45e-07 which is less than significance level alpha = 0.05, process score has a strong influence on the map score. Therefore, the process score can be used to predict the map score. This result combined with the correlation test result concluded that the process score could represent the learner's map quality reflected by the map score.

Table 2. *Multiple linear regression analysis between map score and process score*

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	16.3931	10.3655	1.582	0.126	
sms	0.985	0.1454	6.774	3.45E-07	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Detailed analysis on the sub-map has been carried out to check the significant sub-map. Pearson correlation was used to check the correlation between map score and sub-map 1 score (SM1), SM2, SM3, SM4 and SM5. The results shown in Figure 5. It is shown that sub-map 2 (SM2) has the highest correlation with map score compared with the other sub-maps with R value = 0.63. Multiple linear regression analysis between map score and each sub-map has been carried out to check the significance of the SM2 on the influence with the map score. Result shown in Table 3 concluded that the SM2 has high influence with the map score compared to the other sub-maps and can be a predictor of the map score.

The correlation analysis result combined with the multiple linear regression analysis result shows that the SM2 is the significant sub-map, that is part of concept map that has a strong influence on learner's map quality. Learners that can connect propositions in the SM2 as a set of sequence tend to have a good map score, therefore, have a good understanding of the learning subjects. In the context of formative assessment, teachers can use this information to provide adequate feedback emphasized on the knowledge domain represented in the SM2 to further improve learner's map quality. Improved map quality leads to a better understanding of the learning subjects, since it represents the learner's knowledge (Novak & Gowin, 1984).

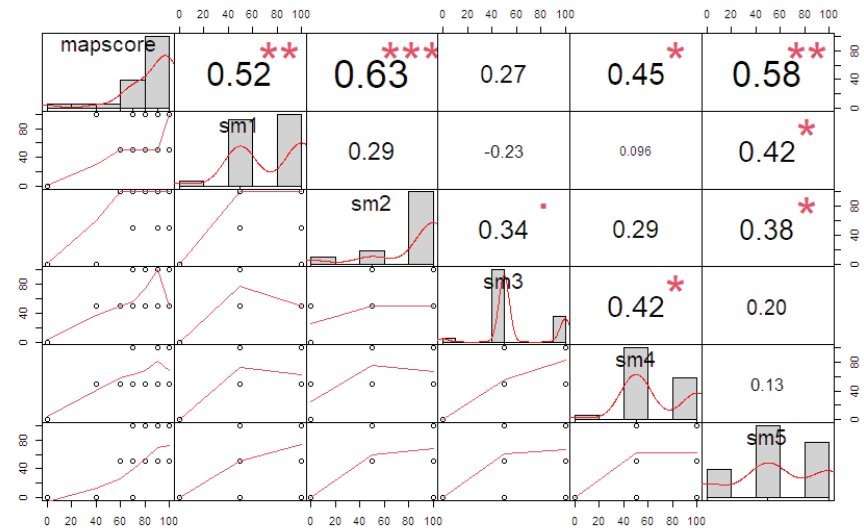

Figure 5. Correlation map between map score and each sub-map (sm).

Table 3. *Multiple linear regression analysis between map score and each sub-map*

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	16.74635	12.23106	1.369	0.1848	
sm1	0.22916	0.12185	1.881	0.0733	.
sm2	0.26448	0.11127	2.377	0.0266	*
sm3	0.05553	0.14394	0.386	0.7034	
sm4	0.21471	0.11667	1.84	0.0793	.
sm5	0.17877	0.09257	1.931	0.0664	.

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Furthermore, a questionnaire to the three teachers that have taught OOP subjects for undergraduate students and have familiarities in KB concept mapping was given to understand their perspectives on the KB process scoring. This questionnaire was asked after observing the experiment, the method and process evaluation result and sub-map analysis result. Thus, the teacher answered the questionnaire based on the relationship between process scoring and product scoring results. The appropriateness of process score evaluation method was asked in the first part, and the usability of sub-maps evaluation was asked in the second part.

The result of the teacher's perspective questionnaire shown in Table 4. In the first question about the appropriateness of the process scoring method, it is noted that the process score is an appropriate method to evaluate learner's process in KB concept map re-composing activity. In the second question, as an alternative to the map score, one teacher disagrees with the process score as an alternative assessment for KB. When asked for the reason, the teacher suggested that the process score is to be used as a complementary score to the map score. This is so that the results of the process score become an additional consideration for a teacher in assessing learner's understanding. In the third question about the detailed analysis of the sub-maps, the teachers noted that the evaluation of the sub-maps in relation to product score is an appropriate method to investigate parts of sub-maps that highly correlated with product score. Finally in the last question, it is noted the provided information can be used for the teacher to provide adequate feedback in emphasizing the important domain knowledge represented by the highest correlated sub-map.

Based on the results of the questionnaire, we concluded that the teachers agreed with the necessity of process evaluation. The teachers agreed that the submap based process evaluation method is a reasonable one. Based on these agreements, they judged the process evaluation scores would be useful for learning support. Therefore, based on these results, we concluded that the process evaluation is a promising method, and it is worth continuous investigation.

Table 4. *Questionnaire on the teacher's perspective*

Questions	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Appropriateness of process score evaluation method					
Process evaluation on kit-build is an appropriate method to evaluate learner's process in kit-build concept mapping re-composing activity.				66.70%	33.30%
Process scores can be used as an alternative assessment for kit-builds other than map scores.		33.30%		66.70%	
Usability of sub-maps evaluation					
Analysis of sub-maps is an appropriate method to find out which parts of a concept map affect the map-score.				66.70%	33.30%
By understanding the important sub-maps and sub-domain of knowledge, teacher can provide appropriate feedback to improve student understanding.				33.30%	66.70%

5. Conclusion

Assessing the learner's process in the KB concept map re-composition activity reveals that process has a relationship with learner's map quality. In this study, we proposed a concrete technique to assess the process of concept map re-composition in KB concept mapping. Based on the KB map score that can represent learner's map quality, correlation analysis between process score and map score shows that process score has a high correlation with map score. Therefore, it answered the first research question (RQ1) that process in KB concept map building activity has a relation with learner's map quality.

Detailed analysis on the sub-map shows that there is a significant sub-map that has a high correlation with the map score. This analysis could provide information for teachers to recognize part of the concept map that represents a knowledge domain that has the importance of the learner's map quality. Teachers can use this information to provide adequate feedback to improve learner's map quality and therefore, improve their understanding. The questionnaire result shows that the process scoring method is adequate and provides useful information in the perspective or teachers. Thus, it answered the second research question (RQ2).

Based on the questionnaire result, we concluded that the process evaluation is a promising method, and it is worth continuous investigation. The limitation of the proposed method is the order of sub-map is not considered. Therefore, further study to conduct more analysis and experiment could expand another aspect of KB concept map re-composing process. As a future works, the bigger size of concept map and number of participants can strongly confirm the conclusion of this study. Furthermore, building an environment to support concept map re-composition based on adequate process is one potential study to improve leaner's map quality.

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