Development of Creative Mind Map Rubric to Assess Creative Thinking Skills in Biology for the Concept of Environmental Change

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Abstract – In Indonesia, creative thinking skills are one of the learning outcomes of 2013 Curriculum. Creative thinking skill has been equated with divergent thinking. Specific aspects of divergent thinking category include fluency, flexibility, originality, and elaboration. One way which can be done for improving students' creative thinking skills is by using the test as evaluation instrument such as mind map because it follows the ways of divergent thinking. However, the studies on mind map rubric assessment which include creative thinking aspect are rare. This study aimed to develop rubric assessment that can assess the creative thinking skills based on the mind map produced by the students. The assessment emphasizes in the fourth of divergent thinking skills, those are fluency, flexibility, originality, and elaboration. In this study, three sets of *Creative Mind Map Test* prepared for 30 students of grade X senior high school. It generates the students to produce several mind maps as the responses. All the mind maps produced by the students were assessed by using Creative Mind Map Rubric that has been developed in this study. Based on the assessment, the results showed that the level of creative thinking skill divided into four level that were not creative, almost not creative, creative and very creative.

Keywords – Developing, Creative Thinking, Mind Map, Rubric, Assessment.

I. INTRODUCTION

Creative thinking skills are currently one of the key focus of education reform around the world. In Indonesia, creative thinking skills are one of the learning outcomes of 2013 Curriculum. This outcome is to prepare the student for the 21st century where full of competition and complex issues are exist. It will necessary to improve students' creative thinking skills as an important educational objective [1]-[2]-[3]-[4]-[5]-[6].

According to Guilford and Torrance, creative thinking skill has been equated with divergent thinking. Because it is regarded as a major aspect of creativity for predicting individual performance [5]. Specific aspects of divergent thinking category include fluency to generate lots of ideas, flexibility is the skill too look at things from multiple perspectives, originality means creating thought different than the others, and elaboration. Is the skill to work something out in greater details [7]-[8]-[9]-[10]-[4]-[2]-[11]-[12].

Several countries are paying more attention to evoke creative thinking skills in different ways [5]. One way could be done to improve students' creative thinking skills is by using the test as an evaluation instrument. The general psychometric measurement of creativity is usually used Guilford's Test, the Torrance Test of Creative Thinking (TTCT), Creative Ability in Mathematical Test (CAMT), and Creative achievement Questionaire (CAQ). In science education, several creative thinking tests have been developed, such as Scientific Structure Creativity Model (SSCM), Scientific Creativity and Scientific Process Skills (SCSPS), and Creative Scientific Ability Test (C-SAT) [13]-[14]-[15]-[11].

The field of Biology has a sufficient range to promote creative thinking skills in its own domain which means it can be brought in the context of Biology Learning. There are several researchers who have done this, such as [16] and [17]. Subali's test only emphasizes the scoring at response quantity, while Purnamaningrum's test assesses the response based on divergent thinking aspects (fluency, flexibility, originality, and elaboration). Both have been developed in open-ended essays. Where the essay tests have several weaknesses that will affect the result and it can decrease the reliability coefficient. Those weaknesses are (1) narration response will make the correcting process harder and longer; (2) narration response will give opportunity to drag the answer; (3) increase the possibility of spelling or writing mistake; and (4) there is subjectivity in assessing or scoring [18]-[19].

Based on the explanation above, it required a solution to overcome the weakness of the essay test that is mind map. In general, there are several functions from mind map such as served as the learning strategy, note taking a technique or learning media. However, a mind map can be used as learning assessment [20]-[21]-[22]. In addition, a mind map is appropriate for assessing creative thinking skills since that it follows the way of divergent thinking. It also an effective brain-based visual technique that helps the students actively use their right brains as well as their left brains by using their association of the concept and ideas [23]-[24]-[25]-[26]. Because of this, Wycoff and Buzan stated that mind map is the most effective technique to improve creative thinking skills. Besides that, the use of mind map will produce the works' results in higher level of creativity and quality [27]-[22]-[28].

It can be concluded that the mind map can be used for assessing creative thinking skills. Therefore, the question that arises is how to evaluate students' mind map to assess their creative thinking skills. The development of mind map rubric has been done, but only in terms of mind mapping rules and component correctness. There are some models that are using assessment scales, for examples 0-3 and other

assessment by using several levels such as great, good, acceptable and unacceptable [29]. All those mind map rubrics doing the assessment by comparing the appropriateness between mind map and the mind map component as the specified criteria. However, the studies on mind map rubric assessment which include creative thinking aspect are rare. This study aimed to develop rubric assessment that can assess creative thinking skills based on the mind map produced by students. That assessment emphasizes in the fourth of divergent thinking skills that are fluency, flexibility, originality, and elaboration.

II. METHOD

Type of this study is development research. Three types of *Creative Mind Map Test* prepared for 30 students of grade X senior high school. It was developed in Biology for the concept of environmental/climate change and waste recycling. The *Creative Mind Map Test* generated the students to produce several mind maps as the responses. All mind map produced by the students were assessed by using Creative Mind Map Rubric that has been developed in this study. The result of mind map assessment was used to determine whether Creative Mind Map Test in assessing creative thinking skills in the fourth aspect of divergent thinking included fluency, flexibility, originality, and elaboration.

III. RESULTS AND DISCUSSION

Results of this studies are Creative Mind Map Rubric that appropriate for assessing creative thinking skills in Biology for the concept of environmental/climate change and waste recycling. Creative mind map rubric which had been developed in this study as follows (Table 1, Table 2, Table 3, Table 4, and Table 5).

Table I. Fluency Scoring Criteria.

No.	Criteria	Score	Point
1.	Central Idea (The answer is true if the central idea appropriate to the topics' concept, which shown in the mind map. Central idea is the same as the name concept; different but have the same meaning; different but related and logic)		
.	Write the main idea	1	1
.	Place the main idea in the centre	1	1
2.	Key words (The answer is true if the key word appropriate to the topics' concept, could be shown in mind map. Key words are the same with the name concept; different but have the same meaning; different but related and logic)		
	a. Give several answers/responses to each question that identified the quantity of key words.		
	X > 15		
	10 < X ≤ 15	4	1
	5< X ≤ 10	3	1
	0 < X ≤ 5	2	1
	b. Legible	1	1
	X>75%		
	X<75%	2	2
		1	1
3.	Use colours throughout the mind map (include mind map centre, branch, relationship link, cross-link, and illustration: picture, image, symbol, code, diagram, graph, etc.)		
	9<X ≤12		
	6<X ≤9	4	1
	3<X ≤ 6	3	1
	0<X ≤ 3	2	1
		1	1
4.	Branching (>75% of branch in the mind map appropriate to the criteria)		
.	Branch is curved or wavy		
.	Radiant branching	1	1
.	Use the same colour in the same hierarchy branching	1	1
.	Use different colour in the different hierarchy branching	1	1
		1	1
	Maximum Total Score		**16**

$$\text{Score Average} = \frac{\text{Total Score in the whole question}}{\text{number of question}}$$

Interpretation of fluency level based on score:
0 – 4   : Not Fluent
5 – 8   : Almost Not Fluent
8 – 12   : Fluent
13 – 16   : Very Fluent

Based on Table 1 it could be showed that scoring of fluency aspect was composed of four criteria, those are central idea, key words, colors, and branching. In this rubric, fluency score was determined based on the quantity. Central idea criteria, the score was given if student writes the mind idea and placed it in the centre of mind map. Key word criteria were determined by the quantity of the answer/response that identified by key word. In these criteria, there was 4 range quantity which had different score. Besides that, it is determined by the legible of key words. In legible criteria, the key word was considered as the true answer if it easy to read and free of spelling errors [29]. Both central idea and key word criteria was calculated if the key word appropriate to the topics' concept, that could be shown in key words table/mind map. Key words are the same with the name concept; different but have the same meaning; different but related and logic. That was indicated that the answer is appropriate for the concept and the student already understood the learning materials [29]-[30]. Color criteria was considered about the quantity of color which had been used whole the mind map include branch, link line, and illustration. The last criteria were branching, the quantity of branching would indicate the quantity of key words and illustrations which is used in whole mind map. That is because the more key words/illustrations/ branches were used, the higher fluency level obtained.

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Table II. Flexibility Scoring Criteria.

No.	Criteria	Score	Point
	Identified by branching (True if the key word appropriate to the topic's concept, could be shown in key words table/ mind map. Key words are the same with the name concept; different but have the same meaning; different but related and logic)		
1.	Basic Ordering Ideas/ BOIs (Level 1) $6 \leq X \leq 7$ $4 \leq X \leq 5$ $2 \leq X \leq 3$	3 2 1	2 2 2
2.	Quantity of branch (include BOIs) $X > 15$ $10 < X \leq 15$ $5 < X \leq 10$ $0 < X \leq 5$	4 3 2 1	2 2 2 2
3.	Quantity of branching branch $X > 12$ $8 < X \leq 12$ $4 < X \leq 8$ $0 < X \leq 4$	4 3 2 1	4 2 2 2
	Maximum Total Score		20

$$\text{Score Average} = \frac{Total\ Score\ in\ the\ whole\ question}{number\ of\ question}$$

Interpretation of flexibility level based on score:
0 – 5 : Not Flexible
6 – 10 : Almost Not Flexible
11 – 15 : Flexible
16 – 20 : Very Flexible

Table 2 was the scoring criteria in Flexibility aspect. In this aspect, scoring was emphasized in the various answer or response. It indicated by the branch that had been used in a whole mind map. The quantity of Basic Ordering Ideas (BOIs) shows that the students able to determine sub-topic that related to the main topic [25]. Branching was showing the student that could generate the answer or response in a different group. In other words, the student able to make segregation to their answer [10]. The quantity of branch and branching showed students' radiant thinking. Branching of concepts refers to the level of differentiation among concepts, to the extent where the more specific concepts are connected to more general concepts [29].

Table III. Originality Scoring Criteria.

No.	Criteria	Score	Point
1.	Words (The answer is true if the key word appropriate to the topic's concept, could be shown in key words table/mind map. Key words are the same with the name concept; different but have the same meaning; different but related and logic) using single key words per branch $X > 15$	3	

No.	Criteria	Score	Point
	$10 < X \leq 15$ $5 < X \leq 10$ $0 < X \leq 5$	4 3 2 1	3 3 3
2.	Illustrations: images, pictures, drawings, symbols, sketches, codes, graphics, etc. (represent key words, relate to key words) Complete the main idea with illustration (*Central Image*) Complete the key word with illustration (in the same branch: above the branch/under the branch/beside the branch; in the new branch) $X > 15$ $10 < X \leq 15$ $5 < X \leq 10$ $0 < X \leq 5$	1 4 3 2 1	3 3 3 3 3
3	Emphasize and 'chunking' (adding Highlight or boundaries) in the group of information, important information. $X \geq 3$ $X = 2$ $X = 1$	3 2 1	3 3 3
	Maximum Total Score		36

$$\text{Score Average} = \frac{Total\ Score\ in\ the\ whole\ question}{number\ of\ question}$$

Interpretation of Originality level based on score:
0 – 9 : Not Original
10 – 18 : Almost Not Original
19 – 27 : Original
18 – 36 : Very Original

Table 3 showed the scoring criteria in originality aspect. It includes three criteria such as words, illustrations, and emphasize or chunking. Key word is essentially a word that will trigger as much relevant meaning as possible. Word notes personally made were far more effective in terms of the understanding, because of that word determined by each student will different to other. It creates the original answer or response. Mind Mapping emphasizes visual imagery, so it was important to add illustrations such as images, pictures, drawings, symbols, sketches, codes, and graphics to represent / indicate/refer to the key word based on their own thinking. Because of that, an illustration which produced by the students would be different from each other. Besides, the illustrations convey more information than any amount of words. In these criteria, the scoring did not judge the aesthetic quality of the illustration because of its subjectivity and indicated the uniqueness [3]. It largely credited to its unique by using the illustration and color that promoted in-depth comprehension of a topic and it could improve the creativity as well [31].

By adding the highlights or boundaries which can make

the specific topics or ideas on the map, it will stand out visually from the rest of its content. There also chunking which gathering and highlighting the key branches within a boundary. Both highlights and chunking were used to give attention to the key parts of a mind map, especially for a larger and more complex mind map with many topics and levels of information. It will differentiate each other because the important levels of information were different.

Table IV. Elaboration Scoring Criteria.

No.	Criteria	Score	Point
1.	Higher level of the hierarchy. The highest branch level or level in the hierarchy/farthest branch from the central mind map 4th Level or more 3th Level 2nd Level 1st Level	4 3 2 1	4 4 4 4
2.	*Cross link* (relation between information in different hierarchies) $X \geq 4$ $X = 3$ $X = 2$ $X = 1$	4 3 2 1	4 4 4 4
3.	*Relationship* (relation between information in same hierarchies) $X > 6$ $4 < X \leq 6$ $2 < X \leq 4$ $0 < X \leq 2$	4 3 2 1	4 4 4 4
	Maximum Score Total		48

$$\text{Score Average} = \frac{Total\ Score\ in\ the\ whole\ question}{number\ of\ question}$$

Interpretation of flexibility level based on score:
0 – 12   : Not Elaborate
13 – 24 : Almost Not Elaborate
25 – 36 : Elaborate
37 – 48 : Very Elaborate

Table 4 showed the scoring criteria in the elaboration aspect. This aspect considered the ability to elaborate or communicate the whole topic or concept in the mind map in detail. In constructing an appropriate and complete concept include examples. Those were indicated by an appropriate hierarchy and linking word on all connections, both relationship and cross-link. The hierarchy could show the linking word which demonstrates the superior conceptual understanding. An appropriate hierarchy indicated through the structure of mind map in which more

general, more inclusive concepts were at the nearest of the central idea; the specific and exclusive concepts were placed on farthest position from the central idea [29].

The linking connection should be labelled precisely. The linking connections, both relationship and cross-link shows the interconnectivity on the mind map, the inks could describe the relations succinctly and accurately. It means that the links would make the mind map more detail.

Table V. Final Judgment of Divergent Thinking.

Aspects of Divergent Thinking	Completeness	Score	Interpretation
Fluency	Complete	13-16	Very Fluent
		9-12	Fluent
	Not Complete	5-8	Almost Not Fluent
		0-4	Not Fluent
Flexibility	Complete	16-20	Very Flexible
		11-15	Flexible
	Not Complete	6-10	Almost Not Flexible
		0-5	Not Flexible
Originality	Complete	28-36	Very Original
		19-27	Original
	Not Complete	10-18	Almost Not Original
		0-9	Not Original
Elaboration	Complete	37-48	Very Elaborate
		25-36	Elaborate
	Not Complete	13-24	Almost Not Elaborate
		0-12	Not Elaborate

Table 5 is used to make a judgment about the level of divergent thinking aspects. Based on the result of scoring in each aspect, it should make the judgment about completeness in each aspect. That result was used for final assessment which determines the level of creative thinking skill in detail described in Table 6.

Table 6 is the rubric for final judgment level of creative thinking skills. Those judgment was considered by the fourth aspects of divergent thinking. The development of those rubric is adapted from [32]. In the Siswono's research, the assessment is used three aspects of divergent thinking, those are fluency, flexibility, and novelty. While in this study the assessment is developed in four aspects which consist of fluency, flexibility, originality, and elaboration. The levels of creative thinking skills that were used in this rubric are has been included in fourth levels, while in the Siswono's argument it includes in five levels. In this Creative Mind Map Rubric, each level of creative mind map test is obtained based on the scoring within the mind map component and the divergent thinking aspect (Table 1, Table 2, Table 3, and Table 4). In each level of creative thinking is different from the completeness of divergent thinking aspects.

Table VI. Final Judgment of Creative Thinking Skills Level.

CTL (Point)	Fluency (1)	Flexibility (2)	Originality (3)	Elaboration (4)	CTL	Interpretation
CTL 0	-	-	-	-	CTL 0	Not Creative
CTL 1	√					
CTL 2		√				
CTL 3	√	√			CTL 1	Almost Not Creative
			√			
CTL4	√		√			
				√		
CTL 5		√	√			
	√			√		
CTL 6	√	√	√			
		√		√		
CTL 7	√	√		√	CTL 2	Creative
			√	√		
CTL 8	√		√	√		
CTL 9		√	√	√		
CTL 10	√	√	√	√	CTL3	Very Creative

Note:

CTL (Point): Creative Thinking Level based on the obtained score in fluency, flexibility, originality, and elaboration
CTL: Creative Thinking Level (Final Judgment)

In this study, the ability of Creative Mind Map Rubric is proven by the assessment result of mind map produced by students. The students have done the creative thinking skills test by using Creative Mind Map Test which has developed in three sets. The question of those test is about environmental/climate change and waste recycle. Each test set covered three indicators, those are 1) analyze environmental change that relates to pollution and environment degradation based on data (media report/environment issues/surrounding environment), 2) clarify data about environmental/climate change and its mitigation, and 3) plan for waste problem solving related to the management and disposal.

Each mind map produced by the students had been assessed by using Creative Mind Map Rubric. The result would be used to identify the creative thinking level (Table 7).

Table VII. The Result of Creative Mind Map Test.

Name	Fluency Score	Fluency Level	Flexibility Score	Flexibility Level	Originality Score	Originality Level	Elaboration Score	Elaboration level	CTL point	CTL	Interpretation
NA	8.7	Flu	12.0	AN.Fle	6.0	N.O	12.0	N.E	1	1	AN.C
MN	6.2	Flu	10.0	AN.Fle	3.0	N.O	8.0	N.E	1	1	AN.C
ADI	6.5	Flu	10.0	AN.Fle	3.0	N.O	12.0	N.E	1	1	AN.C
MKN	10.0	V.Flu	16.0	Fle	6.0	N.O	18.7	AN.E	3	1	AN.C
OMS	10.2	V.Flu	20.0	Fle	6.0	N.O	16.0	AN.E	3	1	AN.C
AM	10.2	V.Flu	16.0	Fle	6.0	N.O	12.0	N.E	3	1	AN.C
MIAK	6.0	AN.Flu	9.3	AN.Fle	25.5	O	22.7	AN.E	3	1	AN.C
AK	11.5	V.Flu	21.0	Fle	12.5	AN.O	20.0	AN.E	3	1	AN.C
TABP	11.3	V.Flu	14.0	AN.Fle	19.0	O	22.0	AN.E	4	1	AN.C
CK	6.0	AN.Flu	14.0	AN.Fle	18.0	AN.O	30.0	E	4	1	AN.C
MSH	11.0	V.Flu	14.0	AN.Fle	17.0	AN.O	30.0	E	5	2	C
LSW	11.5	V.Flu	24.3	V.Fle	25.0	O	26.0	AN.E	6	2	C
MHNF	11.2	V.Flu	23.0	V.Fle	27.5	V.O	28.0	AN.E	6	2	C
AD	11.2	V.Flu	22.3	V.Fle	21.5	O	20.7	AN.E	6	2	C
MFSF	6.0	AN.Flu	21.0	Fle	17.5	AN.O	31.3	E	6	2	C
AA	10.8	V.Flu	22.7	V.Fle	18.0	AN.O	33.3	E	7	2	C
SPA	10.5	V.Flu	22.3	V.Fle	18.0	AN.O	32.0	E	7	2	C
SF	10.5	V.Flu	22.0	V.Fle	16.5	AN.O	28.7	E	7	2	C
WNA	10.7	V.Flu	23.0	V.Fle	18.0	AN.O	32.7	E	7	2	C
SA	6.0	AN.Flu	14.0	AN.Fle	22.0	O	32.7	E	7	2	C
ASU	6.0	AN.Flu	14.0	AN.Fle	22.0	O	30.7	E	7	2	C
EB	11.3	V.Flu	10.0	AN.Fle	27.5	V.O	33.3	E	8	2	C
CF	11.5	V.Flu	14.0	AN.Fle	25.0	O	28.7	E	8	2	C
NKA	8.7	Flu	9.0	AN.Fle	23.0	O	28.7	E	8	2	C

Name	Fluency		Flexibility		Originality		Elaboration		CTL point	CTL	Inter-preta-tion
	Score	Fluency Level	Score	Flexibility Level	Score	Originality Level	Score	Elaboration level			
TCBA	6.0	AN.Flu	22.0	V.Fle	30.0	V.O	42.7	V.E	9	2	C
ARK	11.7	V.Flu	25.7	V.Fle	30.5	V.O	43.3	V.E	10	3	V.C
VNP	10.8	V.Flu	25.0	V.Fle	27.0	O	38.7	E	10	3	V.C
PSI	11.7	V.Flu	24.0	V.Fle	31.5	V.O	38.0	E	10	3	V.C
DQP	11.3	V.Flu	24.7	V.Fle	31.5	V.O	36.7	E	10	3	V.C
LAAR	11.0	V.Flu	21.3	V.Fle	30.5	V.O	42.7	V.E	10	3	VC

Note :

Fluency
N.Flu : Not Fluent
AN.Flu : Almost Not Fluent
Flu : Fluent
V.Flu : Very Fluent

Flexibility
N.Fle : Not Flexible
AN.Fle : Almost Not Flexible
Fle : Flexible
V.Fle : Very Flexible

Originality
N.O : Not Fluent
AN.O : Almost Not Fluent
O : Fluent
V.O : Very Fluent

Elaboration
N.E : Not Flexible
AN.E : Almost Not Flexible
E : Flexible
V.E : Very Flexible

CTL point : Creative Thinking Level based on the obtaining score in fluency, flexibility, originality, and elaboration
CTL : Creative Thinking Level (Final Judgement)

N.C : Not Creative
AN.C : Almost Not Creative

C : Creative
VC : Very Creative

The assessment of creative thinking skills based on the mind map is proved can be done by Creative Mind Map Rubric. The result of assessment showed that the level of creative thinking skills is able to distinguish between one another. Besides that, the students' level in each divergent thinking aspect could be identified.

IV. CONCLUSIONS

Based on the analysis and discussion it can be concluded that the Creative Mind Map Test which developed in this study could be able to assess the creative thinking level based on the completeness within the fourth aspects of the divergent thinking which consists of fluency, flexibility, originality, and elaboration. This rubric is assessing both of mind map component and divergent thinking aspect served as the scoring criteria.

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