An analysis of logical thinking using mind mapping

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Abstract. Brains can remember information in different forms, i.e images, symbols, sounds, and senses, and the information is connected by logical gate. This information needs imagination and association to construct new meaningful images. The purpose of this research was to describe a method of teaching which is based on Tony Buzan’s mind mapping technique. This research showed how mind mapping could be used to measure students’ logical thinking and how mind mapping could promote students’ understanding in a meaningful way. The test of mind mapping that involved 31 students of XI grade in SMA Batik 2 Surakarta was used as the data collecting method in this research. Then, the Ohasta’s mind mapping rubric was used to analyze the structure and content of mind mapping. The rubric includes four aspects, i.e knowledge, communication, thinking, and application. A qualitative analysis Miles and Hubberman’s was used to assess the obtained data. The result showed that the percentage of knowledge aspect was 53.23 %, communication aspect was 28.33 %, thinking aspect was 28.33 %, and knowledge aspect was 41.53 %. Mind mapping makes logical thinking visible so that the quality of learning that has occurred can be seen and explored. Using mind mapping in the course of teaching means that learning is no longer a complex and intractable process, measurable is not only by proxy but also by an observable phenomenon.

1. Introduction
Education in the 21st century is needed to practice students’ problem-solving skills and thinking skills. A problem must have a solution, but this requires a series of processes. One’s mental operation activities in solving a problem is considered as a logical thinking [1], but it is also said that a logical thinking is one’s ability to solve a problem scientifically [2]. Logical thinking is a rational process of brain by which people find correct conclusions, but it is one of the learning concepts being the most difficult to achieve [3]. It is achieved through the development of the logic capability and a rational relation between the different factors involved in every particular situation. Therefore logic, from this perspective, can be considered like the standardization of human thinking [4]. Logic reasoning, like a cognitive central component, depends on the theories of understanding, memory, learning, visual perception, planning, problem solving and decision-making [5].

Problem solving logically is a search process through known data, information is added to data in order to complement the basic file of this particular subject [6]. For example, to solve a math problem the brain applies logical reasoning: first it searches for the file how to apply mathematics, until it
finds the information related with the problem, but if it does not find the information the requirement itself guides brain to make science in order to find and discovering information, thus it will fill the blanks it has in its files. This process is possible because the person has been educated in logic and he has developed a reasoning that allow him following or constructing a road, through steps carefully structured and taking care that all of these steps is supported firmly on previous knowledge. This problem-solving step requires a logical path of thinking visible from the hierarchy, a system that organizes information in a class, starting from the most general to the specific [7]. The hierarchy is poured in lines, symbols, words and pictures summarized in the mind map [8]. The mind mapping technique developed by Buzan [9] is a technique which presents associations among concepts, thoughts and information through a network or a non-linear diagram, using verbal and symbolic elements [10]. The main principles of making mind maps are as follows: 1) first the central theme (i.e. the main idea) defined and put in the center, 2) key ideas radiate out from the center, like the branches of a tree, 3) the branches contain key drawing or words written in capitals over the line. Each basic idea sprouts a further set of ideas, connected by arrows, like twigs at the end of a branch, 4) the branches for a network of nodes. At this point, words rather than sentences have to be used for an effective mind map and colors can be beneficial for visual impact [11]. In this way you can construct visual and meaningful relationships between ideas, which will assist you in recall, review and understanding [8].

The assumption of mind mapping is based on the associative memory model. The human brain is equipped with structures enabling the storage of some information [12]. Each piece of information reaching the brain is connected to other information by means of associations, forming a network of interconnected elements. This model reflects a system of connections between neurons observed during information processing. It is possible to add words, colors and visual appearances in order to help the conceptualization and contextualization of the brain’s ideas with other ideas for the most effective mind mapping. Therefore, the emerging figure can be said to be like a colorful tree, as it binds all ideas together. These maps with a tree-like or hierarchical appearance are constructed in such a way as to account for a number of issues, such as a story’s flow, the central topic, cause and effect relationships or the relationships of ideas to each other in a clear way [13].

As well as a tool for measuring logical thinking mind map can also be used to improve students' conceptual understanding. Generally, words are used as tool of thinking by human and thus neglect to combine non-verbal pictures, chart, concept map and semantic network. Mind mapping is helpful for problem-solving process and deduction. Under visually and brainstorming provided by pictures and characters, one is able to use both hands and brain. Thoughts are evoked while drawing. Messages obtained from the process can be attached to the concepts and trigger learning motivation [14]. If students are taught to use these non-verbal symbols to think (so-called “Abstract Thinking”) and being equipped with this ability, creativity, comprehension and problem-solving ability will be enhanced [15].

Mind map as an effective note-taking method used to look at the profile of logical thinking ability of students [8]. This paper shows how to know the profile of students' logical thinking ability through mind mapping analysis using rubric of ohassta. Mind map has four aspects: knowledge, communication, thinking, and application [16].

2. Methodology
In this research, a qualitative approach with the type of a descriptive qualitative was employed. The subjects were the 31 second semester students of XI grade in SMA Batik 2 Surakarta, Indonesia. The data were obtained through observations during the test of mind mapping in order to understand the student logical thinking. Then, the structure and the content of the mind mapping are analysed using ohassta’s mind mapping rubric. The rubric includes four aspects, i.e knowledge, communication, thinking, and application. Each aspect has four levels: level 1, level 2, level 3, and level 4. A qualitative analysis Miles and Hubberman’s [17] was used to assess the obtained data, performed in three components include data reduction, data presentation, and conclusion. Data reduction starts from
the collection of students’ mind map results and calculates the percentage of logical thinking from the quality of mind map. The quality of mind map is calculated from the score of each aspect divided by the total score of each aspect of mind map then multiplied by 100%. Presentation of data is described in the form of calculation of students’ mind mapping scores and logical thinking ability diagrams. Verification is taken from the conclusion of logical thinking data viewed from the quality of students mind map. An analysis of the document of the results of the tests was also made to analyse the series of stages in the student logical thinking. The percentage obtained is then interpreted according to criteria according to Arikunto (2009) which is excellent (81% -100%), good (61% -80%), enough (41% -60%), less (21% -40%), and very less (<21%).

| CRITERIA                                      | PERFORMANCE INDICATORS (Observable descriptors indicating extent to which a criterion is met) |
|------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Depth of coverage (Knowledge)                 |                                                                                                 |
| Level 1                                       | • Bare minimum of content covered                                                               |
| Level 2                                       | • Shows a basic level of coverage of key ideas only                                           |
| Level 3                                       | • Shows a solid grasp of most of the content                                                    |
| Level 4                                       | • Shows a solid grasp of all the content covered                                                |
| Central Image (Communication)                 |                                                                                                 |
| Level 1                                       | • Present but difficult to separate from other information                                      |
| Level 2                                       | • Present but not clearly related to key idea                                                  |
| Level 3                                       | • Clear use of picture or image that relates to key idea                                        |
| Level 4                                       | • Stands out meaningfully and grasps the key idea through metaphor or humour                    |
| Ideas have key images (Communication)         |                                                                                                 |
| Level 1                                       | • A little evidence of key images. Has only a few keywords                                      |
| Level 2                                       | • Images and keywords are evident, but either too few or some are imprecise                     |
| Level 3                                       | • Images and key words clearly show an understanding of the content                            |
| Level 4                                       | • Images and key words clearly and dynamically show an understanding of the content. (One or more of use of metaphor, humour, cut-outs from magazines, clipart, illustrations) |
| Colour or codes or links used to illustrate connections between ideas (Thinking) |                                                                                                 |
| Level 1                                       | • A little use of colour, codes, or links to illustrate connections between ideas                |
| Level 2                                       | • Obvious attempt made to use colour, codes, or links to enhance clarity and memory. Still some inconsistency of application |
| Level 3                                       | • Clearly uses colour, codes, or links to clarify connections and to assist with memory for most aspects of Mind Map |
| Level 4                                       | • Effectively uses colour, codes, or links to meaningfully clarify connections for all aspects of Mind Map |
| Ideas radiate out from central image and from most to least complex (Application) |                                                                                                 |
| Level 1                                       | • Some ideas are connected and radiate out from centre                                          |
| Level 2                                       | • All ideas radiate out from centre                                                             |
| Level 3                                       | • Ideas clearly connect to central image and ideas                                              |
| Level 4                                       | • Ideas clearly connect to central image and ideas                                              |
|                                                                                           | • Consistently and accurately shift from most to least complex                                 |

**Figure 1. The Mind-Map Rubric [16]**

3. Result and Discussion
Observation to know the logical thinking of students is done by analysing the mind map on human reproduction system material. The results of the later observations are accumulated into achievements of the students' logical thinking percentage. Figure 2 shows the mind-map results of students with low achievement in thinking and communication but have high achievement in knowledge and application aspect. It seen that the mind map has a little evidence of key images, has only a few keywords, a little use of colour, and codes or links to illustrate connections between ideas. Figure 3 shows the mind-map results of students with high achievement in thinking, communication, knowledge, and application aspect.
Figure 2. The Mind-Map Results of Students With Low Achievement in Thinking And Communication
Figure 3. The Mind-Map Results of Students with High Achievement in Thinking and Communication

Achievement percentage of logical thinking aspect from 31 students can be known from table 1. Based on table 1 can be seen that highest achievement is knowledge aspect that is 55%, second rank is application 42.92%, and at bottom rank is communication and thinking aspect that is 28.33%.

Table 1. The Percentage of Achievement of Each Aspect of Logical Thinking

| No. | Logical Thinking Aspects | Percentage of achievements (%) | Criteria |
|-----|--------------------------|--------------------------------|----------|
| 1.  | Knowledge                | 55%                            | Enough   |
| 2.  | Communication            | 28.33%                         | Less     |
| 3.  | Thinking                 | 28.33%                         | Less     |
| 4.  | Application              | 42.92%                         | Enough   |

The percentage of achievement of each aspect of logical thinking is formed from the achievement of diverse scores of students. The logical thinking score of each student is described in figure 3. The scores on each aspect range from 0-8. Achievement of the highest value of knowledge aspect is 6 and lowest 3. Achievement of highest communication aspect value is 6 and lowest 2. Achievement of highest thinking aspect value is 2 and lowest 1, while achievement of highest application aspect value is 5 and lowest 2.

Figure 4. Logical Thinking Score

The percentage of the number of students by value category of each aspect can be described in Figure 4. Based on Figure 4, percentage of the number of students who categorized less still dominate in aspects of communication, thinking, and application. In the dominant category knowledge aspect is sufficient. The percentage of the number of students who categorized enough on the knowledge aspect
of 48.39%. The percentage of the number of students who categorized less on the communication aspect of 90.23%, the percentage of students who categorized less on the aspect of thinking of 83.87%, and the percentage of the number of students who categorized less on the aspect of the application of 51.61. There are no students who categorized excellent on the aspect of knowledge and there are no students who categorized both on aspects of communication, thinking, and applications. There is a percentage of the number of students categorized very less because there is a student who does not make a mind map.

![Percentage of Students for Each Aspect Category](image)

**Figure 5** Percentage of Students for Each Aspect Category

Mind map is used as a measuring tool to see the profile of logical thinking ability because mind map is a record that contains the demands of thinking and students learn information. The students' learning information includes the depth of the content of the material learned during the learning and translation of the content. Student learns information can be seen from the aspect of knowledge and application. The thinking demands of the students include the demands of thinking from the common to the special and the visualization of the material in the form of symbols and keywords. The thinking demands of students can be seen from the aspects of communication and thinking. The knowledge aspect includes the depth of the content. Achievement of the knowledge aspect affects the performance aspect of the application. This is because both aspects include understanding the concept of students in the form of depth of material content and the elaboration of material concepts. Aspects of communication include visualizing the information that students gain when learning into symbols. The achievement of communication aspect affects the achievement of thinking aspect. This is because the two aspects include the visualization of knowledge into symbols and keywords that represent the components of matter and the relationship between words.

Low achievement of communication and thinking aspect affect to the students understanding of learning concepts. Achieve [3]. It is achieved through the development of the logic capability and a rational relation between the different factors involved in every particular situation. Logical reasoning depends mainly on the skill for structuring and formulating logical procedures and applying inference
processes using a precise language [19]. There is a relation between the concepts of reasoning and logical thinking. He considers the reasoning like a common definition of thinking, which sometimes is used like a synonym in the broad sense of the word thinking [20].

4. Conclusions

This research result shows that students under the low category possesses a low ability in logical reasoning, meaning that they cannot make use of logical thinking stages viewed from the mind mapping result. Those under the medium category may be said that their logical thinking pattern is relatively logic, though some of their thinking is less logic, while those under the high ability category may said to have high logical thinking. Mind mapping is a thinking method which stimulates thinking and helps integrate thoughts and information, and it is also a strategy of thinking visualizing concepts.

Mind mapping is very important to be applied in learning because with mind mapping students will be able of widening the range of things they know and they understand, of promoting the self-knowledge, of understanding problems and presenting efficient and effective to daily problems. Therefore, educational systems must give the required importance to these fields and including them relationally in the course plans.

5. References

[1] Piaget J 1969 The origins of intelligence in children New York: International University Press
[2] Abdulkadir, Cagru A and Lutfi 2013 An analysis of mathematicis teacher candidates logical thinking level: Case of Turkey J. Educ. Instruct. Stud. World. 38
[3] R Haygood and L Bourne 1965 Attribute and rule-learning aspects of conceptual behavior Psychological Review 7(2) 175-95
[4] E Dahlin, L Nyberg, L Bäckman and A Neely 2008 Plasticity of executive functioning in young and older adults: Immediate training gains, transfer, and long-term maintenance Psychology and Aging 23 720-30
[5] A Damasio 2003 Looking for Spinoza: Joy, Sorrow and the Feeling Brain Harcourt Brace & Co
[6] Kıncal R Y and Deniz Yazgan A 2010 Investigating the formal operational thinking skills of 7th and 8th grade primary school students according to some variables Elementary Education Online 9 723-33.
[7] Adodo S O 2013 Effect of mind-mapping as a self-regulated learning strategy on students’ achievement in basic science and technology Mediterr. J. Soc. Sci. 6
[8] Buzan Tony 2007 Buku Pintar Mind Map Jakarta: PT Gramedia Pustakautama
[9] Fah L Y 2009 Logical thinking abilities among form 4 students in the interior division of Sabah, Malaysia J. Sci. Math. Edu. South. Asia 32 161-87
[10] DePorter, Bobbi and Mike Hernacki 2001 Quantum Learning: Membiasakan Belajar Nyaman dan Menyenangkan Bandung: Kaifa
[11] Riswanto and Putra P P 2012 The use of mind mapping strategy in the teaching of writing at SMAN 3 Bengkulu Ina.Int. J. Hum.Soc.Sci. 2(21)
[12] Edward Caroline 2009 Mind Mapping untuk Anak Sehat dan Cerdas Yogyakarta: Sakti.
[13] Evrekli E, İnel D and Balm A G 2011 A research on the effects of using concept cartoons and mind maps in science education Nectatibey. Fac. Edu. Elect. J. Sci. Math. Edu. 5 58-85.
[14] Jones B D, Ruff C, Snyder J D, Petriche B and Koonce C 2012 The effects of mind mapping activities on students’ motivation Int. J. Sch. Teach. Learn. Georgia. Sout. Univ 6(1)
[15] C DeWall, R Baumeister and E Masicampo 2008 Evidence that logical reasoning depends on conscious processing Consciousness and Cognition 17 628-45
[16] Ohassta 2004 Mind Map Rubric Ontario History and Social Sciences Teachers’ Association
[17] Miles, Mattew B and A Michael Huberman 2007 Analisis Data Kualitatif Jakarta: Universitas Indonesia Press
[18] Arikunto Suharsimi 2009 Dasar-dasar Evaluasi Pendidikan Jakarta: Aneka Cipta
[19] Serna M, Edgar and Serna A Alexei 2015 Knowledge in engineering: a view from the logical reasoning *Int. J. Compu. Theo. Eng.* 7(4)

[20] B. Nigel Dovetailing language and context: teaching balanced argument in legal problem answer writing *English for Specific Purposes* 21 321-45

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