

10_JPCS_997_2018_Suprpto et al

by N Suprpto

Submission date: 04-Aug-2019 07:33PM (UTC+0700)

Submission ID: 1157435631

File name: 10_Suprpto_2018_J._Phys.__Conf._Ser._997_012011.pdf (514.09K)

Word count: 3206

Character count: 16329

PAPER**Exploring physics concepts among novice teachers through CMAP tools**

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To cite this article: N Suprpto *et al* 2018 *J. Phys.: Conf. Ser.* **997** 012011View the [article online](#) for updates and enhancements.

Exploring physics concepts among novice teachers through CMAP tools

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Abstract. Concept maps are graphical tools for organising, elaborating and representing knowledge. Through Cmap tools software, it can be explored the understanding and the hierarchical structuring of physics concepts among novice teachers. The software helps physics teachers indicated a physics context, focus questions, parking lots, cross-links, branching, hierarchy, and propositions. By using an exploratory quantitative study, a total 13-concept maps with different physics topics created by novice physics teachers were analysed. The main differences of scoring between lecturer and peer-teachers' scoring were also illustrated. The study offered some implications, especially for physics educators to determine the hierarchical structure of the physics concepts, to construct a physics focus question, and to see how a concept in one domain of knowledge represented on the map is related to a concept in another domain shown on the map.

1. Introduction

Some previous researchers indicated that students' understanding of physics concepts still low (e.g. Newtonian mechanics [1-4], electric circuit [5], etc.). Indeed, the problem about conceptions in physics happens not only for students, but also it occurs for prospective teachers and inservice teachers. A concept map is one of the solutions for facilitating them to arrange the hierarchical structure of the physics concept [6]. Especially for physics teachers, the use of concept map in practice helps students in understanding physics concepts and improving the quality of the end-products like graphical structures [7]. On the other hand, novice teachers need to learn and to understand the most important part on constructing concept maps since their role as beginner teachers. In other words, they should be given opportunities to reflect on the processes and to examine the qualities of concept maps [6]. Creating a concept map can be facilitated through manually via paper and pencil or utilised a software.

CmapTools software was employed in this study [6]. The software was initiated by "the Institute for Human and Machine Cognition" that proposing the contribution of information and technology in learning by focusing on concept mapping [6][8]. Generally, working with cmap tools deals with some terms: focus question, context, cross-links, parking lots, and propositions. Every concept map is characterised by a focus question that covers the context of map. Context is shorter expression of focus question. It supports lecturer or students to illustrate the hierarchical structure of the map. Meanwhile, cross-link represents the relations among concepts in different aspects [6]. It guides users (lecturer and students) grasp on how a concept in one aspect of knowledge designated to another domain. The list of concepts can be figured out via parking lots. A parking lot contains some concepts due to the users will arrange and fit in these concepts into the concept map target (final concept map).



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If there is not good connection among concepts then these concepts may keep remain on the original parking lots [6]. In other words, a parking lot means the list of concepts before it moves to its position in map.

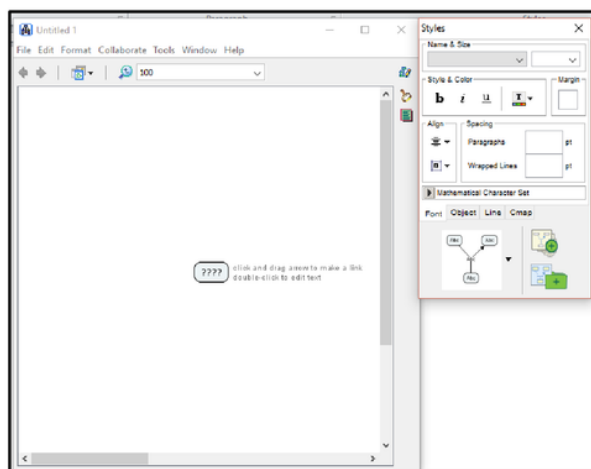


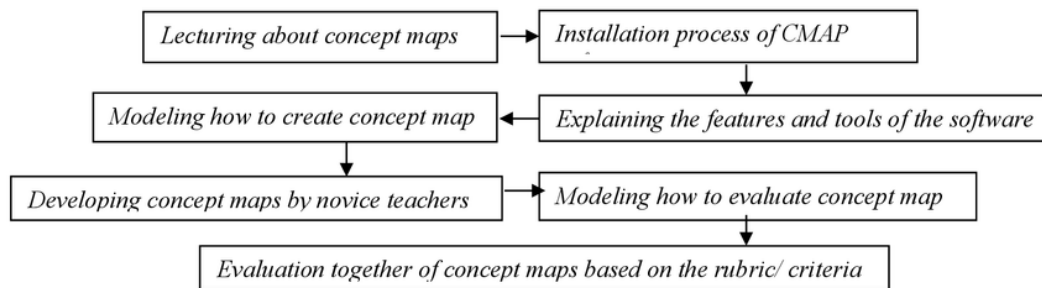
Figure 1. The display of CMAP tools.

The propositions are used to link one concept to another concepts or some different concepts. This feature measures the differentiation level of fundamental concepts. This process has ensued with respect to the levels of the concept meaning quality [9]. Cross-links or grouping of concepts are the ways of concepts can be interconnected together. This feature is “a further way of indicating interrelationships among concepts” [9]. There are three types of cross-links: “(i) point grouping: a number of single concepts emanate from one concept; (ii) open grouping: three or more concepts are linked in a single chain; and (iii) closed grouping: concepts from a closed system” [9]. Indeed, this feature can be seen as a portion of comprehensive understanding of meanings.

This article explores the understanding and the hierarchical structuring about physics concepts among novice teachers. The software helps physics teachers indicated a physics context, focus questions, parking lots, cross-links, and propositions. A total 13-concept maps with different physics topics created by novice physics teachers were analysed. Finally, the main differences of scoring between lecturer and peer-teachers’ scoring were also illustrated according to the rubric which defined previously.

2. Method

The participant of this study was 13-novice teachers who participated in the teacher professional development program through PPG-SM3T, Universitas Negeri Surabaya (State University of Surabaya), Indonesia. The process of collecting data is summarised in Figure 2.

**Figure 2.** The procedure of conducting research.**Table 1.** Evaluation criteria and procedure of scoring of a concept map (modification from [9]).

Criteria of Evaluation	Code	Definition	Procedure of Scoring
Focus question	A	A good focus question is used to overview the whole context for a concept map	Give 5 points for a good focus question, 3 points for focus question in the moderate level, no score for concept map without focus question.
Context	B	A context is aimed to examine the hierarchical structure of the map.	Give 5 points for a good context, 3 points for context in the moderate level, no score for concept map with non appropriate context.
Parking lots or concept recognition	C	Parking lots contain list of concepts, which are objects, events, or situations that are indicated by labels or symbols.	“Give 1 point for each appropriate concept. Count all concepts which are connected to other concepts through propositions” [9].
Cross-links or Grouping	D	Cross-links are the methods on how concepts can be associated together.	Point grouping = 1 point Open grouping = 2 points Closed grouping = 3 points
Hierarchy	E	The hierarchical structure of map indicates “the correction level of concepts, whether the main concepts are at the top position and the specific concepts are at the lower end position” [9].	“Give 4 points for each concept correctly assigned to a level, 2 points for each concept on level removed from an assigned level, and 0 point or no score for concepts that are two levels removed” [9].
Branching	F	Branching denotes “the level differentiation among concepts and the extent the more specific concepts are associated with more general concepts” [9].	“Give 1 point for each branching which has at least two declaration lines” [9].
Proposition	G	Proposition indicates “the association between concepts, which is represented by connecting words or phrases within link-words” [9].	“Give 1 point for each word or phrase as simple propositions, ½ point for repeated use of simple propositions, 2 points for scientific propositions, and 1 point for repeated propositions” [9].

It was noted that there was no an 'ideal' map nor one 'correct' map [9]. Therefore, the evaluation criteria or rubrics for each concept map attempts to overcome the quality and the problem of

idiosyncratic and a large number of concept should be established. The scoring rubric yields data with a interactive structure [11]. Additionally, there are some difficulties in examining concept maps which comprise a huge number of concepts. Therefore, a smoothly criterion and guidance for scoring are needed, as well as the following features [9]: (a) the scoring rubric encompasses criteria that are easier and more quickly to evaluate a concept map and (b) the scoring rubric has a scoring scheme that distinguishes between different stages of concept development. Table 1 depicts the evaluation criteria or rubrics in evaluating concept maps.

3. Result and Discussion

Novice teachers need to resonate the operational definitions and skills associated with concept mapping. Additionally, they also need to integrate the epistemology behind concept mapping into physics courses. The practice of concept mapping which integrated through the design of lesson plans and in microteaching are possible boulevards for reflecting on the task of constructing physics' concept maps [7]. Figure 3 illustrates the concept map created by a group of novice teacher with assisted of Cmap tools with topics of thermodynamic process. Meanwhile, concept maps scores with different physics topics created by novice physics teachers are shown in Table 2.

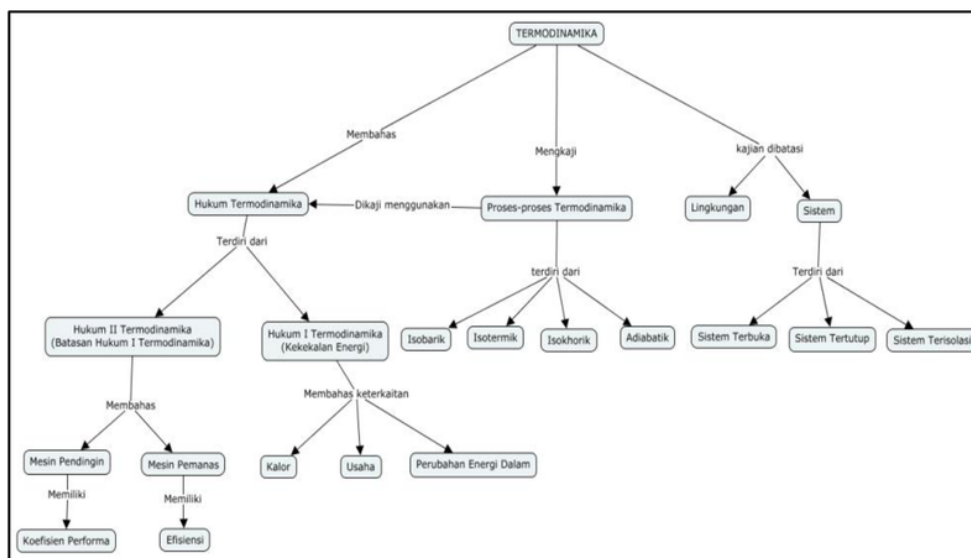


Figure 3. An example of concept map about thermodynamic process.

According to Table 2, the average scores in creating concept maps varied in different topics. The top three among the concepts were heat, thermodynamic process, and vector with average score 87, 83, and 78.5, respectively. Meanwhile, novice teachers performed in a moderate level of these topics, such as rectilinear motion, Newton's law, trajectory, circular motion, dynamical fluid, statical fluid, and measurement. In contrast, they had problems regarding the concepts of the theory of gas kinetic, elasticity, and rigid body with average score 36.5, 41.5, and 50, respectively. Novice teachers have not much idea in developing concept map of these topics. Therefore, instructor or lecturer need more pay attention to these three concepts. However, CMAP tools offer "the use of concept map as an evaluation tool and a learning" [10]. Indeed, its role as learning instruction overlapped with its role as assessment [11-12]. It has great potential as a classroom technique for illuminating the conceptual understanding [12] and identify misunderstanding of students [15]. Thus, a concept map is as reflectors of conceptual understanding. As an implication, a master concept map should be created by

the instructor or lecturer that could be used for tutoring and testing guidance. Then, participants or novice teachers can be encouraged to generate their own maps, and to check their work with the instructor [10].

Table 2. Concept maps scores with different physics topics created by novice physics teachers.

Topics	Sources of scores				Avg
	Peer teacher (1) "A;B;C;D;E;F;G"	Peer teacher (2) "A;B;C;D;E;F;G"	Peer teacher (3) "A;B;C;D;E;F;G"	Lecturer /Instructor "A;B;C;D;E;F;G"	
Measurement	"5; 3; 19; 8; 2; 2; 12"; Total= 51	"5; 5; 19; 12; 2; 2; 12"; Total=57	"5; 3; 19; 10; 2; 3; 11"; Total=53	"5; 3; 18; 8; 2; 3; 10"; Total=49	52.5
Vector	"0; 5; 29; 12; 4; 4; 24"; Total= 78	"0; 5; 30; 15; 2; 5; 25"; Total=82	"0; 5; 31; 10; 4; 5; 23"; Total=78	"0; 5; 31; 12; 2; 4; 22; Total=76	
Rectilinear motion	"0; 5; 25; 14; 4; 6; 24"; Total=78	"0; 5; 25; 15; 4; 5; 20"; Total=74	"0; 5; 25; 18; 4; 6; 26"; Total=84	"0; 5; 25; 15; 4; 5; 20"; Total=74	77.5
Trajectory	"5; 5; 21; 14; 4; 6; 15"; Total=70	"5; 5; 21; 15; 4; 4; 12"; Total=66	"5; 5; 21; 18; 4; 3; 15"; Total=71	"5; 5; 21; 15; 4; 4; 12"; Total=66	
Circular motion	"0; 5; 34; 3; 4; 5; 18"; Total=69	"0; 5; 34; 3; 4; 5; 14"; Total=65	"0; 5; 34; 3; 2; 4; 16"; Total=64	"0; 5; 34; 3; 4; 4; 16"; Total=66	66
Newton laws	"0; 5; 31; 8; 4; 4; 28"; Total=80	"0; 5; 31; 8; 4; 4; 26"; Total=78	"0; 5; 31; 6; 4; 5; 27"; Total=78	"0; 5; 30; 7; 4; 3; 25"; Total=74	
Elasticity	"0; 5; 11; 4; 4; 3; 14"; Total=41	"0; 3; 11; 6; 4; 2; 18"; Total=44	"0; 5; 11; 6; 2; 3; 16"; Total=43	"0; 3; 11; 4; 2; 2; 16"; Total=38	41.5
Rigid body	"0; 5; 12; 6; 2; 3; 20"; Total=48	"0; 5; 12; 9; 4; 3; 20"; Total=53	"0; 3; 12; 9; 4; 3; 22"; Total=53	"0; 3; 12; 6; 2; 3; 20"; Total=46	
Statical fluid	"0; 2; 14; 12; 4; 3; 24"; Total=59	"0; 5; 14; 12; 4; 3; 24"; Total=62	"0; 5; 14; 12; 2; 3; 20"; Total=56	"0; 3; 14; 12; 2; 3; 20"; Total=54	57.75
Dynamical fluid	"0; 3; 21; 10; 2; 3; 22"; Total=61	"0; 5; 20; 10; 4; 3; 20"; Total=62	"0; 5; 20; 10; 4; 3; 22"; Total=64	"0; 5; 20; 10; 2; 3; 20"; Total=60	
Heat	"5; 5; 29; 9; 4; 4; 34"; Total=90	"5; 5; 30; 9; 4; 4; 30"; Total=87	"5; 5; 30; 9; 4; 4; 28"; Total=85	"5; 5; 29; 9; 4; 4; 30"; Total=86	87
Theory of gas kinetic	"0; 3; 15; 4; 2; 2; 10"; Total=36	"0; 3; 15; 4; 2; 2; 12"; Total=38	"0; 3; 15; 6; 2; 2; 10"; Total=38	"0; 3; 15; 4; 2; 2; 8"; Total=34	
Processes of thermodynami c	"0; 5; 21; 15; 4; 5; 34"; Total=84	"0; 5; 21; 15; 4; 5; 34"; Total=84	"0; 5; 21; 15; 4; 5; 32"; Total=82	"0; 5; 21; 15; 4; 5; 32"; Total=82	83

Note: "The codes of (A, B, C, D, E, F, and G)" are based on Table 1.

Some problems regarding the process of developing concept map via Cmap tools included cross-links and propositions [15]. Some novice teachers were unskilled in the ways how concepts can be linked together. They had some problems regarding point grouping, open grouping, and closed grouping. Turning to propositions, the main problem was a level of proposition, either simple or compound. In fact, "the level complexity of the proposition criterion" is distinguished into two levels: (i) simple, and (ii) compound. "A simple proposition is well-defined as a proposition containing only one subject-object clause" [11][15]. Meanwhile, examples of simple propositions are 'isothermic belongs to process of thermodynamic', 'thermodynamic deals with pressure', and 'Carnot machine is part of ideal machine'. Then, "a compound proposition is well-defined as a proposition containing one

or more dependent clauses" [11][15]. The following are some examples of compound propositions: 'thermodynamic explores processes of isobaric, isochoric, isothermic, adiabatic and verifies the law of thermodynamics. Being expert for teachers in emerging their concept maps influence the conception of physics learning [13], self-efficacy for physics learning [13], self-efficacy for physics teaching, and pedagogical content knowledge [14]. Additionally, since concept map is built from focus question in initial stage then it needs to integrate with some innovative models which is questioning as the basic feature, such as socratic model [16] and LBQ model [17]. Finally, the concept mapping exercise itself is something that we would endorse to (novice) teachers.

4. Conclusion

Through Cmap Tools software, it can be explored the understanding and the hierarchical structuring about physics concepts among novice teachers. It appeared to have some essential effects on students learning. The software facilitated physics teachers indicating a physics context, focus questions, parking lots, cross-links, hierarchy, branching, and propositions. Through this research, it can be noted that novice teachers performed at moderate level in creating concept maps, such as heat, thermodynamic process, and vector. In contrast, they have problems regarding the concepts of elasticity, rigid body, and theory of gas kinetic. The study offered some significances, especially for physics educators to determine the hierarchical structure of the physics concepts, to construct a physics focus question, and to comprehend how a concept in one aspect of knowledge signified to another aspect presented on the map. It seems concept mapping has great potential to increase the conceptual change of physics concept. Thus, concept map is as indicators of conceptual understanding on physics.

Acknowledgments

This paper is part of the teacher professional development program through PPG-SM3T, *Universitas Negeri Surabaya* (State University of Surabaya), Indonesia. Therefore, the authors would like to thank all novice teachers who took part in the study.

The image of a concept map shown in Figure 3 was produced using Cmap software, available from <http://cmap.ihmc.us/>.

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