University Students Perspective in Nanotechnology Learning: Assessing the Relationship Between Concept Mapping and Metacognition

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Abstract: Nanotechnology, novel and multidisciplinary knowledge, has emerged in the engineering education of universities, and increased students' difficulties in understanding and learning it. Concept mapping as a metacognitive tool may be appropriate for students to learn nanotechnology because previous research has confirmed that this tool helps students learn disciplines like chemistry, physics, biology and materials science. The current study used both quantitative and qualitative survey data to examine whether concept mapping as a metacognitive tool helps students learn nanotechnology, and to investigate the correlation between the students' perceptions of concept mapping and their metacognition ability. The quantitative data consisted of 42 five-point Likert scale questions measuring students' perceptions of concept mapping and metacognition abilities with high reliability of the measurement. The qualitative data involved in-depth and semi-structured interviews to explore more detailed students' experience and perceptions in terms of how and why. The findings show that there is a significant positive relationship between students' positive evaluation of concept mapping and their metacognition. Students agreed that concept mapping was helpful in generating and clarifying the key concepts of nanotechnology, beneficial to guide the topic concept, and forming a more systematic knowledge structure through integrating prior knowledge and new knowledge. During the learning process of concept mapping, learners adopted a great quantity of metacognition behavior to examine and reflect the self-developed knowledge structure. The study concluded that concept mapping as a metacognitive tool was able to facilitate students to achieve high-level performance in the learning of nanometer knowledge. Future studies should further explore the interrelationships among concept mapping, metacognitive and knowledge transfer.

Keywords: nanotechnology, engineering education, concept mapping, metacognition

1. Introduction

Nanotechnology, as a new frontier of engineering education, contains a wide range of disciplines like chemistry, physics, biology and materials science. To trigger the exploitation of nanotechnology, those disciplines have to be converged from theory into application. However, this convergence to a certain extent brings challenges to

the existing educational system that it increases students' difficulties in understanding the relevance and utility of nanotechnology [7]. To equip students with the ability to exploit materials involving different domains, learning through cognitive ways may help assess the use of "stimulation and meaningful experience" [1, p. 1277].

Concept mapping has long been considered a visual facilitator for constructivist learning in the educational context, and in a concept map, nodes represent concepts and links represent relationships between the concepts [2, 9]. It can be claimed that concept mapping is appropriate as a learning tool because it allows learning performance to be easily measured. Novak [5] argues that concept mapping plays the role of a metacognitive tool in the fields of science and mathematics education. Introduced by Flavell in 1976, the notion of metacognition refers to using the ability, including knowledge and awareness, to plan, monitor and evaluate one's own cognitive activities in order to enhance his/her thinking processes [4]. According to Rye and Rubba [8], concept maps serve as effective graphic metacognitive tools. Some researchers posit that knowledge acquisition is a result of concept mapping [9] and metacognitive activities [3].

The multidisciplinary nature of nanotechnology implies that concept mapping may be an appropriate tool for students to learn nanotechnology because it has been confirmed that this tool helps students learn disciplines like chemistry, physics, biology and materials science [8,10]. Thus, this research aims to examine whether concept mapping as a metacognitive tool helps students learn nanotechnology. In other words, with the help of metacognition, students use conceptual mapping to promote their learning performances in nanotechnology.

The current study investigates the correlation between the students' perceptions of concept mapping and their metacognition ability. The investigation takes university students' experience of learning nanotechnology into consideration. The study mainly adopts both quantitative and qualitative methodologies, and data-collection methods are the questionnaire survey and in-depth interview. The results of this study can provide empirical data and useful suggestions in learning nanotechnology of university students. The hypothesis of this study is that there is a significant positive relationship between students' positive evaluation of concept mapping and their metacognition.

2. Methodology
In total, 32 university students participated in this research. They were enrolled in a course entitled "Introduction to Nanotechnology," and provided a handbook regarding the rules of drawing concept maps with respect to nanotechnology learning.

The perceptions of concept mapping and the metacognition abilities of students are measured with both quantitative and qualitative data. At the last stage of the course, every student filled out a questionnaire, and six of them were interviewed. The questionnaire survey had two sections, measuring students' perceptions of concept mapping and metacognition abilities, respectively. It consisted of 42 five-point Likert scale items. The data present high reliability of the measurement, in which the

Cronbach's alphas of concept mapping and metacognition were 0.845 and 0.880, respectively.

In-depth and semi-structured interviews were carried out to further explore how the students used concept mapping to learn nanotechnology with the help of metacognition. In this part, more detailed experience and perceptions were explored in terms of how and why. The data analysis used grounded theory, and a descriptive analysis was used to evaluate the narrative data. The coding reliability that was built up with a triangulation method was 0.797.

3. Results
The findings of the regression analysis show that the students' positive evaluation of concept mapping had a positive impact on metacognition (Beta=.93, p<.001). Concept mapping explained eighty-six percent of the variance in metacognition (Adjusted R^2=.86). It displays that students' positive evaluation of using concept mapping as a learning tool was positively associated with their metacognition ability, which supports the hypothesis of this study: there is a significant positive relationship between students' positive evaluation of concept mapping and their metacognition.

Results from the regression analysis reveal that metacognition had a positive impact on students' learning effectiveness (Beta=.91, p<.001). Adjust R^2 shows that metacognition explained eighty-three percent of the total variance in learning effectiveness. It indicates that higher learning achievement of nanometer knowledge occurred when students were more engaged in metacognitive behavior. Thus, there is a significant positive relationship between students' metacognition and learning effectiveness.

The qualitative data indicate that students generally "*agreed that concept mapping is an effective learning tool (B092, D044, H024, I035, J154)*", and mentioned that "*concept mapping was helpful in generating and clarifying the key concepts of Nanometer Technology (B042, G064)*", "*beneficial to guide the topic concept (B200, J102)*", and "*forming a more systematic knowledge structure (G090) through integrating prior knowledge and new knowledge (B056)*".

During the concept mapping learning process, learners adopted a great quantity of metacognition behavior to examine and reflect the self-developed knowledge structure. They explained that in order to improve the organization of a concept map, "*continuous evaluation and reflection on the quality of the concept map (B241, G344, H006, I077) and an active search of new knowledge (B137, G210, H089) are required*". Students also perceived "*after acquiring the new knowledge, I needed to re-read and reconstruct the focal concepts (B157, H024, I088, J415)*". Through "*continuous examination and modification of the concept map, the acquired knowledge was able to be integrated into my own knowledge structure (H006, I083-I088)*". Besides, students further indicated "*concept mapping learning strategy stimulated my learning interest and helped me obtain better learning performance (H131, I039)*".

4. Conclusions and Discussion

The research here examined the students' perceptions of concept mapping as a metacognitive tool in learning performances of nanotechnology with both qualitative and quantitative data. In summary, the coherent results were found from both the regression analysis and the interview analysis. It shows that during the utilization of concept mapping, metacognition assisted students in monitoring and perceiving their thinking process, and examining their own knowledge structure. When students fully understood and deeply analyzed the inner meaning of the constructed concepts, they were able to obtain deeper comprehension, and better performance in learning nanotechnology.

Concept mapping is beneficial to metacognition improvement because it visualized students' abstract thinking process. Students cultivated high-level metacognition skills through the training of concept mapping. During the process of constructing concept maps, students used metacognition to reflect and criticize the quality of concept map structures in order to display their nanometer knowledge structure completely and accurately.

After students utilized a great quantity of metacognitive behavior, the metacognitive experience was accumulated. The metacognitive experience a learner obtained may facilitate his/her knowledge reorganization and thereby promote learning performance. This finding is consistent with Veenman et al.'s [11] argument that metacognition can help to develop adequate learning behavior and result in good learning performance.

This research sheds new light on nanotechnology education as there has been little research on the relevant pedagogical approaches. The most important contribution of this study is that it confirmed the empirical effect of concept mapping as a metacognitive tool to promote students learning performances in nanotechnology. O'Connor and Hayden [6] suggest three new pedagogical approaches: contextualization, visualization and student-centered learning, in which the last one emphasizes "deep learning and understanding" (p. 37). It can be argued that concept mapping is similar because it also encourages deep learning. This association reveals the potential contribution of this research: while the achievement of deep learning requires the assistance of various learning methods, the present study adopted concept mapping and metacognition to attain it. In the future, the researchers should focus on the interrelationships between concept mapping, metacognition and knowledge transfer.

Acknowledgements

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