ABSTRACT
The purpose of this paper is to investigate students’ perception of concept maps as a learning tool where knowledge transfer is the goal. This article includes an evaluation of the learning performance of 42 undergraduate students enrolled in a nanotech course at a university in Taiwan. Canonical correlation and MANOVA analyses were employed to examine if students’ perceptions toward concept mapping have a positive relationship with knowledge transfer; that is, students who perceive concept mapping more positively tend to perform knowledge transfer better than those who perceive concept mapping less positively. The results revealed that positive concept-mapping perception is helpful for knowledge transfer in five learning stages: acquisition, communication, application, acceptance, and assimilation.

Keywords
Concept mapping, Knowledge transfer, Knowledge management, Nanotech

Introduction
In recent years, the development of information technology has led to rapid knowledge flow. People gain knowledge through a variety of ways. Consequently, knowledge management (KM) becomes increasingly more important for individuals to understand what information is essential, how to administer this essential information, and how to transform essential information into permanent knowledge.

Knowledge transfer (KT) is an important aspect derived from KM. KT takes place to the extent that an organization benefits from knowledge acquired at other organizations or in other parts of the same organization, and can improve the performance level of the organization (You, Li, & Yu, 2006). In practice, KT has been applied in different fields such as business (Darr & Kurtzberg, 2000) and biology (Schönborn & Bögeholz, 2009). KT, in general, is when experts in a field of study transmit their knowledge to younger generations. In a like manner, the transfer would also occur among people of the same generation. Our study focuses on KT in an educational context; in particular, we examine the impact of concept mapping (CM) on KT in a science lecture.

It is widely acknowledged that concept maps (CMs) have been used in many facets of education and training. CM has many advantages, including playing a multi-level tool role, scaffolding for cognitive processing, summarizing and organizing what has been learned, supporting collaboration, consolidating educational experiences, teaching critical thinking, improving achievements and interests of learning, etcetera (Adamczyk, Willison, & Williams, 1994; Chiou, 2008; O’Donnell, Dansereau, & Hall, 2002). Additionally, numerous studies indicate that CM is an effective learning strategy that precipitates meaningful learning for different learners in a variety of fields, such as science (Kinchin, 2001).

While much research has explored the relationship between CM and learning achievements, little research has focused on KT. Therefore, we investigated how students use CMs to achieve KT in an effort to provide valuable reference work for science education.

Literature review

The role of advanced organizers (AO) and graphic organizers (GO) in CM learning

Assimilation theory addresses the issue of using CMs to promote meaningful learning. The theory also explains how concepts might be accurately acquired and organized within a cognitive structure in learners through the use of a
variety of teaching/learning strategies (Novak, 2003). Ausubel (2002) advocates the use of advanced organizers (AO) to foster meaningful learning, and he describes the role of AO in the progressive differentiation of learned concepts. Ausubel further states that the major goal of schooling is to foster development of schemas that learners can use to acquire other relative information and to stimulate integrative reconciliation in the process of acquiring knowledge. Through AO, integrative reconciliation occurs in the consciousness of learners who perceive that learned concepts are related or not related.

In order to improve meaningful learning, the content to follow should be well organized. The schema production should be under guided advice of teachers. It requires teachers and students to monitor their thinking and learning in traditional classroom settings. However, the advent of various multimedia in which a broad range of possible elements can be used has given rise to modern AO in computer-based or web-based learning contexts (Brabec, Fisher, & Pitler, 2004; Langan-Fox, Platania-Phung, & Waycott, 2006; Mayer, 2003; Vekiri, 2002). Graphic organizers (GO) form a powerful visual picture of information and allows the mind to “see” patterns and relationships. GO can help motivate, increase recall, assist understanding, create interest, combat boredom, and organize thoughts (Robinson & Kiewra, 1995). AO, along with GO, appear to be constructed in the form of text passages, graphical representations, and maps, which are commonly used in some commercial computer applications, such as FreeMind. AO and GO have been used successfully in a wide range of courses and knowledge domains.

**Relationship between CM perception and KT performance**

Pinto (1997) explains that CM perceptual strategy or pedagogy improves the KT performance because students facilitate the application of knowledge. They use CM perceptual strategy to gain insight into new and existing knowledge. CM can help students develop good learning habits, which may contribute to future KT.

Some studies found that CM generally has positive effects on both students’ achievements and attitudes and promotes meaningful learning by helping them see the links between scientific concepts (Adamczyk, Willison, & Williams, 1994; Chiou, 2008). The benefits of CM reported in the literature include organizing information, assisting learning, communicating particularly complex CMs, understanding literature, improving clarity, testing students’ learning progresses, and more (Novak & Gowin, 1984; Novak, Gowin, & Johansen, 1983; Ruddell & Boyle, 1984). For these reasons, it is argued that CMs stimulates KT.

CM is also useful for knowledge retention and transfer on learning nuclear technology (Mann & LeClair, 2009). González, Palencia, Umaña, Galindo, and Villafrade’s (2008) study in medical physiology students showed that CM strategy promoted meaningful learning that allowed the students to transfer this knowledge to solve problems. In addition, CM strategy had a greater impact on the students who came into the study with the lowest cognitive competence. So, educators have recognized that the process of creating CMs is important for meaningful learning. It is proposed, based on the above literature, that perceived CM also promotes the conversion of the stages of KT performance.

**The process of KT**

Gilbert and Cordey-Hayes (1996) identified five stages in the process of KT, including acquisition, communication, application, acceptance, and assimilation. At the organizational level, KT has to go through these five active learning stages to achieve an organizational goal, as shown in Figure 1. In this study, we define KT as the interactive process between individual learning and organizational level learning to continually develop, change and react to internal and external effects to achieve competitive success.

The process of KT is dynamic and continuous. Individuals complete this process by going through the five stages. KT is both the movement of knowledge from one place to another and the altering of that knowledge into an understandable form (Major & Cordey-Hayes, 2000). For this reason, we use Gilbert’s model to illustrate how CM affects KT through the five stages.
Figure 1. The five stages of KT (Gilbert & Cordey-Hayes, 1996)

Acquisition. Knowledge acquisition is the first step of KT. Before the knowledge is able to be transferred, it has to be acquired. A student might learn from various sources: direct experience, mass media, schools, parents, and so on. Sources of knowledge influence the type of knowledge acquired.

Novak and Gowin (1984) claimed that CMs can be viewed as a schematic device for representing a set of concepts and meanings embedded in a framework of propositions, as a tool for students to examine their prior knowledge. Therefore, CM is a particularly good way of organizing information related to a problem or subject. The construction of CMs help us pull together information already known about a subject while integrating new information as we learn and expand our understanding (Akinsanya & Williams, 2004). Some studies also propose that CM provide learners with a key scaffold to help them relate concrete examples to the conceptual structures and help retain the information to be learned through graphic formats (Reader & Hammond, 1994; Adamczyk, Willison, & Williams, 1994).

Accordingly, we considered that CMs help students understand new knowledge. Thus, the stage of acquisition in KT occurs. Students’ acquisition of new knowledge is often affected by their past knowledge and sources of new knowledge.

Communication. Once the knowledge is acquired, communication follows. Communication increases knowledge and understanding, which enriches prior knowledge and stimulates new thoughts. Individuals use this process to enhance the effectiveness of KT. Thus, fluent communication ought to be established in advance in order to lead the whole model to be efficient. In particular, communication mechanisms and barriers need to be identified to encourage KT. KT is a process through which the individuals are affected by another experience produced by knowledge. And knowledge can be transferred by moving tools and technologies, routines, and networks. Any transfer does not exist in one party. The movement should occur between a source, where the knowledge is acquired from and a recipient, to whom the knowledge is transmitted. Learners often share and transmit the acquired knowledge to others who do not possess this knowledge. This kind of learning approach is similar to a collaboration style. Many studies present collaboration as a result of successful interaction between parties. The students were able to engage in a discussion to consider the knowledge context (Kao, Lin, & Sun, 2008; Kwon & Cifuentes, 2007). Studies argue that CM can be used to display individual knowledge structures for comparison at different stages of the learning process, and to distinguish between expert and novice knowledge structures (Kinchin, 2001). Furthermore, Cicognani (2000) claimed that CM is viewed as a collaborative strategy, is applied to learning communication, and is described as a process through which one or more participants use brainstorming techniques. Consequently, CM is a reflective process in which students engaged in a rich discussion about how and why the concepts are related.

CM helps students not only understand the relationships among concepts, but also communicate this understanding to their classmates. Through discussion, individuals could understand better what they had learned and modify it to be more clear and comprehensive. That procedure benefits all participants. Previous studies emphasize the relationships
among important concepts and help students generate creative thoughts to make conceptual connections while doing team tasks. At the communication stage, students share knowledge and clarify misconception when they collaboratively plan and discuss the construction of CMs.

**Application.** No matter what knowledge is acquired, if the learner fails to apply it, it has little value to KT. The application of knowledge could promote familiarity of the knowledge, increase the benefits of learning and even stimulate better performance. Application can motivate students to continue the learning activity, thus improving learning quality.

Learning within practice is a matter of building up skills for students to become fully functional members of the practice community (Wenger, 1998). CM facilitates application because learners get familiar with the knowledge through practising tangible reference materials. According to Akinsanya and Williams (2004), visual learning is essential for students’ success in prioritising new information, organizing and clarifying their thinking and thus stimulating creative thinking and achieving deep learning. CMs drawn by the students show that CM provides them an organized approach for learning concepts, from the known to the unknown, from the core to the subordinate. This is an analytical approach in which knowledge is organized for cognitive retention. Kinchin, De-Leij, and Hay (2005) presented how CMs were used to integrate disparate topics and were developed into personalized mapping structures. CM has also been reported to improve students’ problem-solving ability (Okebukola, 1992).

The above characteristics of CM facilitate students’ drawing of their final CMs, which is a kind of immediate application of their knowledge. Therefore, we argue that CM could inspire learners’ application of knowledge. This knowledge can be applied in both the final presentation and future learning.

**Acceptance.** Acceptance is an intermediary process. Complete KT must go through mental acceptance. People absorb knowledge after they accept it. Thus, acceptance must occur before assimilation. Unless they are accepting the knowledge voluntarily, learners would not be satisfied with the importance of the knowledge. Acceptance is indispensable because, without acceptance, assimilation will not happen.

From the perspective of constructivist learning theory, CM is not only a self-driven learning style, but a self-directed learning experience (Teo & Gay, 2006). In other words, it makes room for learners to figure out what is suitable for them. Self-directed learning helps individuals progress in learning through multiple stages: knowledge, comprehension, application, analysis, synthesis, and evaluation (Cicognani, 2000). Moreover, in learning theory, self-regulation means the degree to which individuals are meta-cognitively, motivationally, and behaviourally active participants in their own learning processes (Zimmerman, 1986). CM fosters a productive psychological climate for learning by aiding the students’ organization of materials and focusing on crucial concepts and their features (Weinstein & Mayer, 1986). We think that CM is a learning strategy that can stimulate learners’ mental achievement. This mental achievement contributes to learning motivation. Therefore, the atmosphere encourages the acceptance of knowledge.

**Assimilation.** Assimilation is a key process in the KT framework. Setting up a formula for learning is very important. When knowledge gained is assimilated, it becomes part of the organizational culture. And then, the culture is developed into the daily routines that are reflected in the behaviour and practices of the student. In other words, the process of assimilation, or learning, occurs while knowledge and ideas are transferred within an organization to lead to the development of a set of day-to-day routines and behaviours. And this process stresses the changes from cognition to behaviour.

**The role of metacognition in KT**

Encoding is more effective when learners are aware that they are linking different items of information, rather than just storing them in isolation. Students who adopt metacognitive strategies do not only encode information in their memory, but they also may consciously look for relationships in the topics they study, such as CM (Haffker & Calvert, 2003; Scott & Schwartz, 2007). This influences their study strategies and, ultimately, how much they learn. As metacognition is further developed, learners tend to use strategies and plans to accomplish particular goals (August-Brady, 2005). As learners develop, they acquire an increasing number of strategies and they become masters whose adopted strategies can be more selective and efficient (Chularut & DeBacker, 2004).
The use of learning strategies, monitoring and reflecting, improves problem solving and increases KT when metacognition is an emphasis in the learners’ cognitive process (Eckhardt, Probst, & Schnotz, 2003). Metacognition may facilitate the integration and transfer of skills whenever confusing elements have been added to an already difficult learning situation. Metacognition, in this sense, is more likely to be problem solving (Kuhn, 2000). The learners’ involved learning activities are of great meaning when the confusing information has been transferred in an efficient way (Eggen & Kauchak, 2004). Based on the above literature, learners who adopt metacognitive strategies can employ CMs to improve problem solving and increase KT. Therefore, CM may have metacognitive traits and be related to KT.

Methodology

Participants and procedures

The sample included 42 students (33 male and 9 female) taking a nanometer course at a university in Taiwan. No one reported prior experience in CM. They were divided into 11 groups, each about four members. In the first week, each group was assigned a teaching assistant who introduced CM to the class according to the instructions of Novak and Gowin (1984). In the following weeks, the teaching assistants answered questions and provided suggestions regarding the students’ CM assignments. During the class, the instructor presented the students with both traditional lecture notes and CMs. The instructor used CMs to explain the relationship among concepts in the learning materials, as well as how to create CMs. Before the semester ended, students were asked to draw two works of CM. At the end of the semester, they were also required to fill out a questionnaire to indicate their perception of CM and their performance of nanotech KT.

The teaching assistants provided constant assistance during the period of the experiment. Meetings were held every two weeks. It was hoped that students could gain deeper understanding in order to explicitly construct a well-organized CM through the assistance of teaching assistants. In this study, based on the studies of Scheiter and Gerject (2007) and Williams (1996), students were also encouraged to ask any questions related to their task performance during the instructor’s advising hours through one-on-one contact.

Instructional design

This experiment was designed to motivate students to construct their own CMs related to knowledge of nanometer technologies (Chang, Sung, & Chen, 2001; O’Donnell, Dansereau, & Hall, 2002). Because drawing CMs alone is not easy for students who have had no prior computing drawing experience, a step-by-step instruction guide was provided. It was hoped that the learned concepts or knowledge could be illustrated on the maps:

Phase 1. Find meaningful definitions: students define professional terms.
Phase 2. Group similar sub-concepts under main concept.
Phase 3. Find links: explore relationships between two presenting concepts.
Phase 4. Make connections among joint nodes: depict relationships between two presenting concepts.
Phase 5. Illustrate examples related to learned concepts.

Procedure

Figure 2 depicts this experiment’s procedure. Students were expected to acquire the relative knowledge and skills during training.

1. Training in using FreeMind. Because students had no experience using the computer application FreeMind, training was held one week prior to the experiment.
2. Introduction to construction of integrated contents and themes in CMs via AO/GO. Students were introduced to how a well-designed CM can be structured, integrated, and organized via AO/GO. Students were encouraged to ask any questions related to their performance of tasks.
3. Begin instruction of nanometer technology.
4. Draw and submit first CMs. This was the first attempt by students to use FreeMind as a tool to delineate the relative concepts onto maps.
5. Receive comments on submissions. Students received comments and feedback on their first completed tasks.
6. Draw and submit second CMs. This was the second attempt by students in drawing the maps.
7. Receive comments on submissions. Students received comments and feedback on their second completed tasks.
8. Fill out the questionnaires.

![Diagram of the experiment procedure]

**Figure 2. Procedure of the experiment**

**Measurement**

*The perception of CM.* The items on CM perception were adapted from Chou (2008), which was originally designed to investigate students’ attitudes toward using CM to learn advanced accounting. We changed the word from “accounting” to “nanotech” in order to measure students’ perception of using CM to learn nanotech information. This measure has 11 questions to examine two dimensions of the perception. Questions 1 through 5 investigated whether the CM strategy improved the students’ learning performance. For example: “CM learning strategy stimulated me to learn and think independently.” Questions 6 through 10 examined students’ affective acceptance of the CM strategy. For example: “I was satisfied with using CM to learn nanotech.”

In Chou’s study, this scale had high construct validity. Our revision of the scale, just one word, did not influence the high validity. The Cronbach’s $\alpha$ coefficient of the whole scale was 0.92 (see Table 1), and each dimension was 0.89 and 0.90, respectively, as shown in Table 1. Participants’ responses to each item were measured using a Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree). A higher score indicates a more positive perception toward CM.

*The performance of KT.* Based on Gilbert’s definition of the five stages of KT, we constructed 25 questions for the five dimensions. To check their validity, the questions were submitted to one nanometer science expert and four KM experts. The questions were revised in accordance with the experts’ suggestions. The final version of the KT scale is presented in Appendix A.

The reliability verification results for internal consistency indicate that the Cronbach’s $\alpha$ value was higher than 0.90 (see Table 2), revealing sufficient reliability and a high degree of correlation among the questions. All of the items were self-reported from 1 (strongly disagree) to 7 (strongly agree). Higher scores show higher degrees of KT performance.
Additionally, the above two scales of the used questionnaires, KT and CM, were tested in a pilot study of 32 students using item analysis (shown in Tables 1 and 2) before establishing the Cronbach’s α reliability. The student responses to each item in the questionnaires were sorted from a low to a high. The participants were split into two groups based upon the sorted responses to each question item. The difference between both groups for each question was examined using an independent t-test. All the determinant values (t values) were found to be significant (p < 0.001) so that each question could significantly distinguish the high-performing students from the low-performing students. Pearson’s production-movement correlation was then used to examine the extent of correlation between each question and the total score. All the correlation coefficients were found to be significant (p < 0.001) so that there is sufficient consistency between each question and the whole test.

**Table 1. Item analysis and reliability in CM**

<table>
<thead>
<tr>
<th>CM perception</th>
<th>Item analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helpful tool item</td>
<td>Contents</td>
</tr>
<tr>
<td>number</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Help me learn nanotech knowledge</td>
</tr>
<tr>
<td>2</td>
<td>Help me learn the concepts and the relationships of nanotech knowledge</td>
</tr>
<tr>
<td>3</td>
<td>The use of learning strategies motivates my learning Improved learning sub-scale: Cronbach’s α = 0.89</td>
</tr>
<tr>
<td>Affective acceptance</td>
<td>Contents</td>
</tr>
<tr>
<td>number</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Enhance my motivation</td>
</tr>
<tr>
<td>6</td>
<td>Concept mapping is a new learning method</td>
</tr>
<tr>
<td>7</td>
<td>Easy of use of learning strategies to other subject matters</td>
</tr>
<tr>
<td>8</td>
<td>Attempt to use concept mapping to other subject matters</td>
</tr>
<tr>
<td>9</td>
<td>Satisfaction with the use of concept mapping</td>
</tr>
<tr>
<td>10</td>
<td>Enjoy using concept mapping</td>
</tr>
<tr>
<td>11</td>
<td>Adaptation to the use of concept mapping</td>
</tr>
<tr>
<td>Affective sub-scale: Cronbach’s α = 0.90</td>
<td></td>
</tr>
<tr>
<td>The whole scale: Cronbach’s α = 0.92</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Item analysis and reliability in KT**

<table>
<thead>
<tr>
<th>KT perception</th>
<th>Item analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition item</td>
<td>Contents</td>
</tr>
<tr>
<td>number</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Obtaining nanotech knowledge</td>
</tr>
<tr>
<td>2</td>
<td>Participating in extracurricular activities</td>
</tr>
<tr>
<td>3</td>
<td>Use of library resources</td>
</tr>
<tr>
<td>4</td>
<td>Use of media information</td>
</tr>
<tr>
<td>5</td>
<td>Use of network resources</td>
</tr>
<tr>
<td>6</td>
<td>Acquiring the nanotech knowledge Acquisition sub-scale: Cronbach’s α=0.76</td>
</tr>
<tr>
<td>Communication item</td>
<td>Contents</td>
</tr>
<tr>
<td>number</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Discussing with instructors</td>
</tr>
<tr>
<td>2</td>
<td>Listening to others’ opinions</td>
</tr>
<tr>
<td>3</td>
<td>Sharing nanotech knowledge with classmates</td>
</tr>
<tr>
<td>4</td>
<td>Joining online discussions</td>
</tr>
<tr>
<td>Communication sub-scale: Cronbach’s α = 0.60</td>
<td></td>
</tr>
</tbody>
</table>

| Application item    | Contents     | t (sig.) | Correlation (sig.) |
|---------------------|--------------|
| number              |              |          |                    |
| 1                   | Integrating nanotech knowledge | 6.85 (.000) | .627 (.002) |
Data analysis

The data of the relationship between CM and KT were analyzed in two ways: canonical correlation analysis and multivariate analysis of variance (MANOVA).

Canonical correlation analysis

The use of canonical correlation analysis was appropriate for this study since it measures the overall relationship between two sets of variables. The method is mainly descriptive, and the results obtained from the analysis provide answers to the following questions: are the two sets of multiple variables related? And, if so, how strong is the relationship? A canonical redundancy index helps measure the ability of a set of independent variables to account for variation in a set of dependent variables. In this paper, performance of KT, including acquisition, communication, application, acceptance, and assimilation were used as one set, while CM perceptions were used as the other set.

Multivariate analysis of variance

The canonical correlation between CM perception and KT performance was used to examine how different levels of CM perception influence different stages of KT (acquisition, communication, application, acceptance, and assimilation). The data were also analyzed by MANOVA. The MANOVA analysis is appropriate when there are multiple dependent variables as well as independent variables within the model which the researcher wishes to test.

Research results

Canonical correlation analysis was performed to assess the relationship between CM perception (CMP) and KT performance (KTP). The analysis yielded two roots. We report only the results of the first function because the second function is not significant. The first function, $R_c = 0.81$, Wilks’s $\lambda = 0.28$, $F(10, 42) = 46.52$, $p < 0.001$, accounted for 65% of the common variance between CMP and KTP. The structure of the relationships between CMP and KTP, together with their canonical correlations, is shown in Figure 3.
A canonical redundancy index helps measure the ability of a set of left-side variables (e.g., measures of the perception of CM) to account for variation in a set of right-side variables (e.g., measures of KT performance). Table 3 summarizes the structure loading and redundancy index analyses for both the predictor set and the criterion set in the study. The results indicate that the predictor set explained 53.3 percent of the variance in the criterion set. As the canonical loadings reveal, both improved learning (0.93) and affective acceptance (0.88) loaded high on CM perception. They exhibited their strong links to the five stages of KT. Among the five stages, acceptance emerged as the most important stage (0.93), and assimilation is the second most important one (0.84).

The function indicated that improved learning and affective acceptance of CM significantly and positively correlate with the five stages of KT: acquisition, communication, application, acceptance, and assimilation. The practical meaning of the result is that if students have a more positive perception toward CM, they are more likely to perform KT.

Table 3. Canonical correlation between CMP and KTP

<table>
<thead>
<tr>
<th>Predictor set</th>
<th>Canonical loading</th>
<th>Criterion set</th>
<th>Canonical loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM perception</td>
<td>−0.93</td>
<td>KT performance</td>
<td>−0.73</td>
</tr>
<tr>
<td>Improved learning</td>
<td>−0.88</td>
<td>Acquisition</td>
<td>−0.77</td>
</tr>
<tr>
<td>Affective acceptance</td>
<td>−0.88</td>
<td>Communication</td>
<td>−0.72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Application</td>
<td>−0.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acceptance</td>
<td>−0.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assimilation</td>
<td>−0.84</td>
</tr>
</tbody>
</table>

| Redundancy index  | 0.533             | Redundancy index  | 0.419             |
| Proportion of variance | 81.4 %             | Proportion of variance | 64.1 %             |

Wilks’s $\lambda = 0.28^{***}$  Canonical correlation $R_c = 0.81^{***}$

*** $p < 0.001$

To further explore the relationships among the five stages of KT and students’ perception of CM, MANOVA was employed to examine how different levels of CM perception influence different stages of KT (acquisition, communication, application, acceptance, and assimilation). First, CM perception was transformed into a categorical variable with three values: low, medium, and high. The top 26% and bottom 26% were set as thresholds, as described in Table 4. The five stages of KT were used as dependent variables. The result of MANOVA analysis showed whether different levels of CM perceptions produced significantly different performance outcomes of KT in terms of the five stages.

Table 4. Three clusters of students’ perception of CM

<table>
<thead>
<tr>
<th>CM perception label</th>
<th>Range</th>
<th>Mean (SD)</th>
<th>N</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster1—low perception</td>
<td>2.73 – 4.45</td>
<td>3.91 (0.61)</td>
<td>11</td>
<td>Bottom 26%</td>
</tr>
<tr>
<td>Cluster2—medium perception</td>
<td>4.64 – 5.64</td>
<td>5.11 (0.32)</td>
<td>20</td>
<td>48%</td>
</tr>
<tr>
<td>Cluster3—high perception</td>
<td>5.73 – 7</td>
<td>6.26 (0.40)</td>
<td>11</td>
<td>Top 26%</td>
</tr>
<tr>
<td>Total</td>
<td>2.73 – 7</td>
<td>5.10 (0.96)</td>
<td>42</td>
<td></td>
</tr>
</tbody>
</table>

The results of the MANOVA analysis were shown in Table 5. Multivariate tests revealed that the overall model were significant (Wilks’s $\lambda = 0.26$, $p < 0.001$), indicating that CMP has a significant effect on KTP.
Table 5. Test index of MANOVA analysis

<table>
<thead>
<tr>
<th>Effect</th>
<th>Test index</th>
<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Sig.</th>
<th>Partial eta squared</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pillai’s trace</td>
<td>0.86</td>
<td>5.44</td>
<td>10</td>
<td>72</td>
<td>0.000</td>
<td>0.43</td>
</tr>
<tr>
<td>CMP Level</td>
<td>Wilks’s lambda</td>
<td>0.26</td>
<td>6.62</td>
<td>10</td>
<td>70</td>
<td>0.000</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>Hotelling’s trace</td>
<td>2.31</td>
<td>7.86</td>
<td>10</td>
<td>68</td>
<td>0.000</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>Roy’s largest root</td>
<td>2.08</td>
<td>15.00</td>
<td>10</td>
<td>36</td>
<td>0.000</td>
<td>0.68</td>
</tr>
</tbody>
</table>

Furthermore, individual ANOVAs were computed on the scores of the five KT stages. The results in Table 6 show significant differences among the three clusters at each KT stage: acquisition, $F(2, 39) = 8.71, p < 0.001$, communication, $F(2, 39) = 11.59, p < 0.001$, application, $F(2, 39) = 20.71, p < 0.001$, acceptance, $F(2, 39) = 29.03, p < 0.001$, and assimilation, $F(2, 39) = 9.39, p < 0.001$. In summary, different levels of CM perception had significantly different effects on performance outcomes of KT in the five KT stages.

Table 6. Summary of one-way ANOVA and post hoc test

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Dependent variables</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Post hoc tests (Scheffe tests)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM perception</td>
<td>Acquisition</td>
<td>6.22</td>
<td>2</td>
<td>3.11</td>
<td>8.71***</td>
<td>3 &gt; 1, 2 &gt; 1</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>8.47</td>
<td>2</td>
<td>4.24</td>
<td>11.59***</td>
<td>3 &gt; 1, 2 &gt; 1</td>
</tr>
<tr>
<td></td>
<td>Application</td>
<td>20.24</td>
<td>2</td>
<td>10.12</td>
<td>20.71***</td>
<td>3 &gt; 1, 3 &gt; 2</td>
</tr>
<tr>
<td></td>
<td>Acceptance</td>
<td>13.83</td>
<td>2</td>
<td>6.92</td>
<td>29.03***</td>
<td>3 &gt; 2 &gt; 1</td>
</tr>
<tr>
<td></td>
<td>Assimilation</td>
<td>11.01</td>
<td>2</td>
<td>5.50</td>
<td>9.39***</td>
<td>3 &gt; 1, 3 &gt; 2</td>
</tr>
</tbody>
</table>

*** p value < 0.001

As described in Table 7, because all $F$-values were significant, a series of post hoc tests (Scheffe’s tests) were also conducted to further compare the three clusters. The results revealed that the students in cluster three had a significantly higher achievement than those in cluster one. That is to say, students in cluster three performed more “acquisition” (5.86 versus 4.8, $p < 0.001$), and “communication” (5.77 versus 4.57, $p < 0.001$) than those in cluster one. Additionally, their performance in “application” (6.29 versus 4.49, $p < 0.001$), “acceptance” (6.27 versus 4.71, $p < 0.001$) and “assimilation” (5.91 versus 4.56, $p < 0.001$) was better than students in cluster one and cluster two. The detailed information is listed in Table 7. The results of Scheffe’s tests reveal that significant differences were found between cluster one and cluster three across all KT stages. Consequently, we concluded that students with higher CM perception tended to perform better KT than those with lower perception.

Table 7. KT of the three clusters

<table>
<thead>
<tr>
<th></th>
<th>Acquisition mean (SD)</th>
<th>Communication mean (SD)</th>
<th>Application mean (SD)</th>
<th>Acceptance mean (SD)</th>
<th>Assimilation mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster 1</td>
<td>4.80 (0.69)</td>
<td>4.57 (0.50)</td>
<td>4.49 (0.54)</td>
<td>4.71 (0.55)</td>
<td>4.56 (0.99)</td>
</tr>
<tr>
<td>Cluster 2</td>
<td>5.39 (0.55)</td>
<td>5.39 (0.64)</td>
<td>4.91 (0.87)</td>
<td>5.30 (0.51)</td>
<td>4.92 (0.67)</td>
</tr>
<tr>
<td>Cluster 3</td>
<td>5.86 (0.58)</td>
<td>5.77 (0.64)</td>
<td>6.29 (0.63)</td>
<td>6.27 (0.35)</td>
<td>5.91 (0.65)</td>
</tr>
<tr>
<td>Total</td>
<td>5.36 (0.70)</td>
<td>5.27 (0.74)</td>
<td>5.16 (0.98)</td>
<td>5.40 (0.75)</td>
<td>5.09 (0.91)</td>
</tr>
</tbody>
</table>

Discussion and conclusions

The study investigated how students used CM integrated via AO/GO as a learning strategy and the progress of KT. We examined the learners’ attitudes toward CM and investigated whether their perceptions caused differences in their learning outcomes. We also presented the characteristics of each KT stage, illustrating knowledge conversion for operation. The data analysis here also provided empirical evidence for the meaningful study in nanotech of science domain.

The results of canonical correlation showed that students were in favor of using CM and this attitude significantly and positively influences their KT performance. That is, if students express higher perception toward CM, they are more likely to perform KT. The results reveal that significant differences were found between the students who have
highly positive perception of CM and those who have low perception, in every stage of KT: acquisition, communication, application, acceptance, and assimilation. In summary, students with higher perceptions perform more KT than those with lower perceptions.

Previous research mainly investigated the relationship between CM and learning achievement. However, this study broadens the application of CM to individual KM focusing on KT performance. Our findings are similar to those from previous studies in other disciplines, demonstrating that the CM strategy had positive effects on student performance (Chiou, 2008; Kinchin, 2001; Kinchin, De-Leij & Hay, 2005; Lawless, Smee, & O’Shea, 1998). Most of these studies showed that CM brings high and useful effects while learning outcome assessment. For example, Chiou (2008) revealed that CM is useful in fostering students to improve their learning performance in a business and economics statistics course. CM is better than traditional textbook exercises. Most of the students were satisfied with using CM to learn. On the other hand, Lawless, Smee, and O’Shea (1998) mentioned that the use of CMs in business and public administration is concentrated on group decision-making and planning. Through the process of constructing CMs, various viewpoints can be bracketed into categories, which are refined into an index and taken as a guideline for actions. This procedure not only has positive effects on the coordination of different perspectives across institutions and companies but also has benefits for action plans.

In this study, the CM strategy was applied to KM. The results illustrate that there was a strong connection between CM and KT. The findings, consistent with our proposition, indicated that students understand the advantages of the CM and are willing to adopt it because it stimulates the performance of KT. To achieve KT, teachers’ materials should use AO/GO to better organize and integrate knowledge in order to let CM meet the needs of students, considering that it can improve students’ learning perception, accumulation of knowledge, sharing of information, and KT. In addition, previous studies mentioned that students who adopt metacognitive strategies may consciously look for relationships in CM (Haffker & Calvert, 2003; Scott & Schwartz, 2007) and can use these strategies to improve problem solving and increases KT (Eckhardt, Probst, & Schnitz, 2003). Therefore, students may employ CMs when metacognition, the awareness and ability to monitor and reflect upon knowledge, is an emphasis in their cognitive learning process. Metacognition may also facilitate the knowledge integration and transfer. However, individual differences in the level of metacognitive skill, ability, and prior knowledge, etcetera, between students may play a major role if students are low-ability or low prior knowledge learners. Such individual differences may impact the significance of our findings.

Since CM is new to these participants, the students need some effort and time to become accustomed to it. Their perception toward CM influenced learning effects and further affected the consequence of KT. Therefore, it is important to make sure that students possess the capability of using CMs and have positive attitudes toward the measurement before assessment. The results from this study found that there was a significant relationship between CM perception and KT performance outcome. The finding is similar to results of past studies (González et al., 2008; Mann & LeClair, 2009; Pinto, 1997) showing that perceived CM had been associated with KT performance outcome in different disciplines. The researchers conclude that perceived CM promotes the transition among the five stages of KT performance outcome. The limitation of this study was a concern related to the sample selection. Because the experimental class was the only convenient class that could be used at the time the experiment was conducted, bias of sample selection may be a threat to the internal validity in this study.

The result of the study showed that positive perception increases the willingness to use CM. It is argued that through improving the learning attitudes of the students, the instructor can get students to be more satisfied with their learning and thereby make the KT process more effective. That progress encouraged students to produce meaningful learning through CM. It allowed students to organize and share information efficiently through CM. It was beneficial for individual’s curriculum learning and KM.

The core idea of this research was to investigate the use of CMs as a technique that smoothes the transition among the five stages of KT: acquisition, communication, application, acceptance, and assimilation. We conclude that the technique of employing CMs is an appropriate tool to promote students’ positive perception of learning and to facilitate the transitions among these stages of KT. This study confirmed the link between CM perceptions and KT with empirical evidence.
Acknowledgements

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References


Appendix A: Survey of self-evaluation of knowledge transfer

Stage 1: Acquisition
I obtain nanotech knowledge by class learning such as in a school, a cram school, etc.
I participate in extracurricular activities (such as listening to speeches, visiting with friends, participating in competitions) to broaden the horizons of nanotech knowledge.
I utilize library resources (for instance, books, journals, online research resources) to increase my nanotech knowledge.
I use media information (for instance, televisions, broadcasts, newspapers) to enrich my nanotech knowledge.
I use network resources (for example, search engines, blogs, Yahoo! Answers) to expand my nanotech knowledge.
When I meet problems, I know where to acquire the nanotech knowledge.

Stage 2: Communication
Discussing with instructors for the nanotech knowledge clarifies my concepts.
Listening to others’ opinions improves the understanding of nanotech knowledge.
Sharing nanotech knowledge with classmates deepens my knowledge of nanotech.
Joining online discussions (such as bulletin boards, web logs, Yahoo! Answers) reinforces my realization of nanotech knowledge.

Stage 3: Application
I can integrate nanotech knowledge with my original knowledge.
I can draw concept maps with my learned nanotech knowledge.
I can demonstrate the concept mapping with my learned nanotech knowledge.
The accumulation of the experience of nanotech learning improves my appliance of the knowledge.
Knowledge and understanding of nanotech inspires me to learn more in related areas.

Stage 4: Acceptance
Experiencing nanotech knowledge raises the degree of accepting it.
My understanding of nanotech knowledge extends my identification on its value.
My understanding of the nanotech knowledge lifts my acceptance of it.
In-depth exploration of nanotech knowledge motivates me to keep learning.
After gaining the nanotech knowledge, I am satisfied with the whole learning content.

Stage 5: Assimilation
I will actively teach others my learned nanotech knowledge.
I will apply my learned nanotech knowledge on the present subjects.
I will apply my learned nanotech knowledge on the future relevant subjects.
I will apply my learned nanotech knowledge on solving the life problems.
I will expand my learned nanotech knowledge on future projects.