Promoting the meta-cognition function using modified concept-mapping in problem-based learning

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In problem-based learning (PBL) with intent to train self-learning, it is important to promote faculty of monitoring own knowledge and cognition, namely meta-cognition. In our previous study, we experimented on conventional concept-mapping by setting learning tasks for promoting students' meta-cognition function, although the effect was seen to be somewhat inadequate. In this study, we used the modified concept-mapping in comparison with the use of conventional concept-mapping in promoting meta-cognition function. Thirty-nine physiotherapy students were randomly divided into a modified concept-mapping group and a conventional concept-mapping group, with four groups in each. After showing a clinical problem to both groups, the modified concept-mapping group started work on a concept-mapping using unknown concepts and propositions with question marks. The conventional concept-mapping group, in contrast, made a map containing only known concepts and propositions. Both groups then presented their learning tasks based on their respective concept-maps, with the level of unknown knowledge quantified by using multiple-choice questions. We finally compared and contrasted the level of correspondence of learning tasks and unknown knowledge between both groups. From these results it was found that the level of correspondence was higher in the modified concept-mapping group than in the conventional concept-mapping group (p<0.01). These results, taken together, suggest that the modified concept-mapping was more effective than the conventional concept-mapping in recognizing unknown concepts and propositions. The modified concept-mapping was effective, therefore, in promoting meta-cognition.

Key words
Problem-based learning,
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Introduction

Throughout the history of change in educational theory, training student intelligence by formal development remains the oldest theory still in use today. Currently, the most widely supported theory in use today is the New Integration Theory, first suggested in the early 1980s[1]. This theory emphasizes that students have the ability to connect the study of subjects in specialized fields to the study of general skills in terms of thinking, and in trying to learn how to monitor and control their own thoughts and studies. This theory, in other

words, centers on the idea of using meta-learning "to learn how to learn," in specialized fields[2].

In the field of medical education, Problem-Based Learning (PBL) has been suggested as a suitable approach for connecting the study of specialized medical related subjects to the study of general skills in thinking. Looking at this idea from the point of view of educational theory, it became possible to equate this model with the similar idea of meta-learning based on the new integration theory. In PBL, students do not receive structured instruction, but are rather required to find what they themselves need to know to be able to handle any problems that may subsequently arise. It is possible, therefore, to say that meta-learning of specialized fields can be achieved through the process of problem solving in a specialized field such as medicine. Up to now, little has been reported about the effects of meta-learning of PBL in medical science, and it has been argued whether or not PBL actually facilitates the ability of independent learning or not. According to a report by Shin[3], doctors educated using a form of PBL (graduates from the University of McMaster), are more likely to have better training in voluntary study, self-evaluation and problem solving ability than doctors from the University of Toronto, who did not receive the same training using this method. The same study also reported that University of McMaster graduates have the capacity to maintain voluntary study in the field of medical science, and that they can absorb knowledge as well as develop an ability to focus their studies on the relevant questions. In contrast to these results, however, is the fact that there were neither differences in studying styles, nor in self-learning styles, among doctors from the University of Ottawa who had received a PBL-based education, and in doctors who did not receive such an education[4]. It is suggested that these contrasting results derived from the inherent differing qualities of

tutors, impractical scenario and burden[5]. The inherent differing qualities of tutors are somber problem specifically[6], meaning it is necessary to analyze the PBL process from the point of view of the new integration theory (meta-learning theory), with no instructor based input.

In an attempt to address this problem, we investigated at what point students were seen to make an error in the PBL process without an instructor or tutor present. The outcome of these results revealed that it was students who find it hard to solve problems within PBL who are also the ones who tend to be held back in the process of setting their own learning tasks[7]. All students involved in PBL require knowledge of how much they actually already know in order to accomplish problem solving tasks, as well as an ability to regulate and plan the process of recognition, to monitor accomplishment, and to modify errors in appropriate cases in learning unknown concepts[8]. In short, these abilities are indispensable in promoting faculty of monitoring own knowledge and cognition, namely meta-cognition during the setting of learning tasks so that PBL can be applied for practical use in meta-learning.

For promoting the function of meta-cognition, our use of concept-mapping[2] in the PBL process is the first attempt of its kind in the world. Concept-mapping is a skillful process that can visibly describe a concept and proposition and is based on Ausubel's meaningful learning theory[9]. As this is a learning strategy for expressing the unique concepts and propositions of each individual, it is possible for students to make it individually evident as to why a certain proposed connection is effective, or to suggest exactly what can be given as examples of the lack of connection from one concept to another and which are therefore necessary for new learning to occur. In short, it can be suggested that concept-mapping is a tool capable of activating the meta-cognition function of individuals' known concepts in ad-

dition to their thinking process.

Our next step involved investigating the effect of promoting meta-cognition function in the use of conventional concept-mapping during the setting of learning tasks. The results of this study indicated that the rate of correspondence between the students' learning tasks and their unknown concepts was higher when this method was used, than when using the conventional PBL process[10]. This could be interpreted as the concept-mapping process having an effect in clarifying students' known concepts, as well as bringing out their meta-cognition of what to study when attempting to solve problems. Concept-mapping, therefore, allowed the affected students to experience the effectiveness of meta-cognitive study on utilizing their ability of "how to study," in order to solve problems correctly. Although the rate of correspondence (the rate of meta-cognition of learning tasks) in this case was comparatively high in relation to that of the conventional method, it was, however, below 50% - a fair indicator of our findings but not high enough to support our research. In particular, areas in which important concepts and propositions were totally ignored were observed in each subject, together with the phenomenon that important learning tasks couldn't be achieved even when using concept-mapping. In order to

improve PBL function during its practical use, these important issues have to be addressed.

In an attempt to solve this problem, we compared a partly modified concept-mapping technique (modified concept-mapping) to a conventional concept-mapping technique to study the differing meta-cognition function in each one.

SUBJECTS AND METHODS

1. Subjects

Subjects were 39 third year students of physiotherapy undertaking a four-year course. Subjects were randomly separated into a modified concept-mapping (MCM) group and a conventional concept-mapping (CCM) group, each containing a further four small groups. The characteristics of the subjects of both groups are shown in Table 1, with all subjects having had considerable previous experience in making concept-maps, although both groups had no difference in this experience. Subjects were informed that they would be the target of research and their consent was given in each case; the purpose of the research, however, was concealed and the examination study of the two groups was performed in two separate rooms.

Table 1. Characteristics of both groups

There were no differences between the modified concept-mapping group (MCM) and the conventional concept-mapping group (CCM) in age, sex, personal history and experience in making concept-maps. CC=concept mapping.

Group	Age	Sex	Personal history before admission	CC experience
MCM	22.19 ± 3.12	10 male, 9 female	High school graduates:15; University graduates:2; Professional background:2	2 years
CCM	22.17 ± 3.40	9 male, 11 female	High school graduates:15; Professional background:5	2 years

Presented with variety of clinical problems

MCM group

CCM group

Understanding of problem

Creating modified concept-map

Creating conventional concept-map

Setting learning tasks

Measuring unknown concepts by MCQs
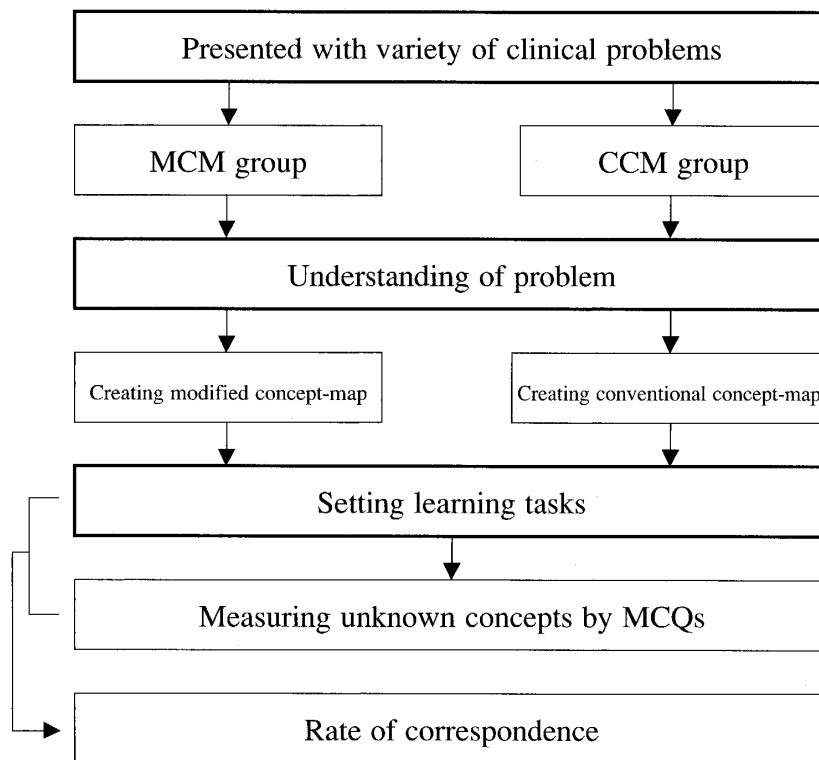
Rate of correspondence

Figure 1. Experimental procedure
Frames with thick lines indicate steps in the PBL process.
MCM= modified concept-mapping; CCM= conventional concept-mapping; MCQs= Multiple Choice Questions.

Table 2. Clinical Problem (Goodman[14], partly modified)

An 18-year-old male, who was injured in a motor vehicle accident has come into the hospital physical therapy department with orders to begin ambulation. He had breast band and bandage on his head and a long leg cast on his left leg and has brought a pair of crutches with him. This is the first time he has been out of bed in the upright position; he has not ambulated in his room yet. Blood pressure measurement taken while the client was sitting in the wheelchair was 110/78 mmHg. Pulse was measured at 72 BPM. The therapist gave the necessary instructions and assisted the client to the standing position in the parallel bars. Immediately on standing, this young man began to experience the onset of sharp mid-thoracic back pain and shortness of breath. He became pale and shaky, breaking out in a cold sweat.

The therapist assisted him to a seated position and asked the client if he was experiencing pain anywhere else while reassessing blood pressure. His blood pressure had fallen to 90/56 mmHg, and he was unable to respond verbally to the questions asked. The therapist noted a weak and rapid pulse, distension of the client's neck veins, and diminished respiratory movements.
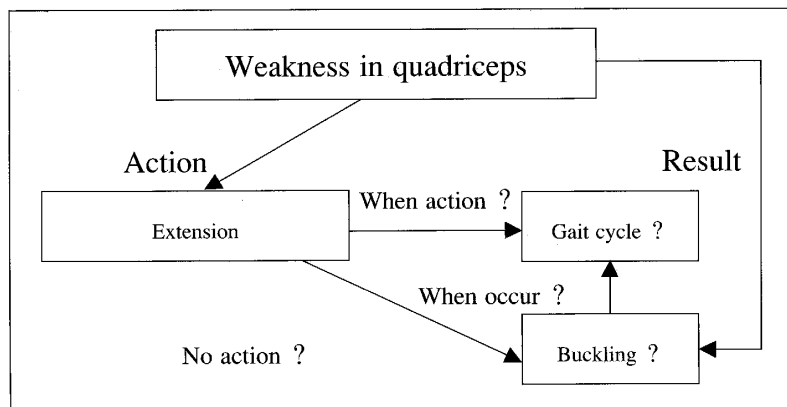
【Tasks】
①What is happening to the patient?
②What should the therapist consider to avoid this occurring?

Task: If M. quadriceps femoris has a weakness, when does buckling occur during gait cycle?
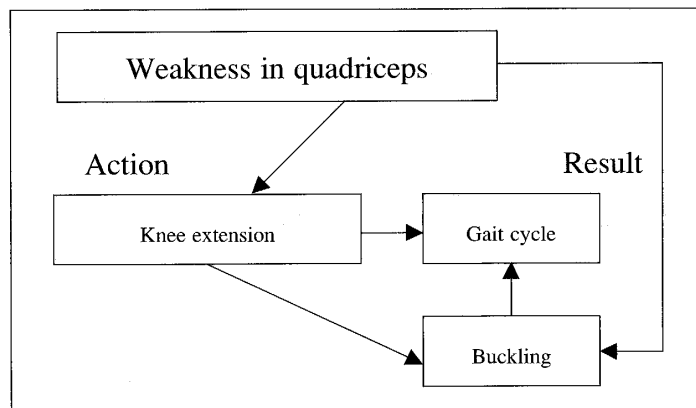
Conventional concept-mapping

Modified concept-mapping

Figure 2. Examples of both concept-maps

2. Procedure (Figure 1.)

In this study, the PBL process was used on problem understanding, creating concept-maps and the setting of learning tasks. The experiment began with an explanation to both groups only on the process of PBL and how to make a concept-map. Groups were later given a number of clinical problems (See Table 2). Subjects were set a specific learning task after they had made a concept-map during the PBL process. The MCM group made a concept-map with unknown concepts and propositions represented by question marks. The CCM group, however, were able to make a map with known concepts and propositions. An ex-

ample of each is shown in Figure 2. Each of the eight smaller sub-groups all made a concept-map. It should also be noted that the instructors gave students no advice during the carrying out of the PBL tasks. Subjects were then measured for unknown concepts by use of Multiple Choice Questions (MCQs), which were given to each student.

3. Criteria of effects

In this study, we regarded the rate of correspondence between unknown concepts and learning tasks as suitable criteria for activation of the meta-cognition function by modified concept-mapping. Meta-cognition is defined

as knowledge or a belief concerning the cognitive process of each one of these tasks, and students are required to recognize unknown concepts as learning tasks in order to solve the problems involved in the self-learning process during PBL. It is possible, therefore, to determine whether meta-cognition function was actually activated or not by the rate of correspondence between unknown concepts and learning tasks. To measure these unknown concepts, we used MCQs (Table 3) in an attempt to examine the knowledge necessary to solve clinical problems. We then compared the rate of correspondence between learning tasks attempted by the subjects, and the unknown concepts measured by MCQs, in both groups. The rate of correspondence was quantified as the rate of the number of problems whose incorrect answers corresponded to defined learning tasks.

In addition to these measurements, the concept-maps were also analyzed thoroughly and the actual process of setting learning tasks was compared between both groups.

4. Blind examination

Subjects were unaware of the intention of the study and the testing was conducted in two separate rooms. Although we did not conceal the purpose of the study from the instructor who performed the explanation regarding concept-mapping and PBL tasks, we did mask the purpose of the study from a third person chosen to mark the MCQs and process data. To ensure we had been successful in our blind examination, we asked the subjects a number of questions after the study about what kind of learning strategy they had received and then compared the two groups.

5. Statistical analyses

Descriptive statistics were used to identify the mean and standard deviation of the rate of correspondence and the MCQs scores. Statistical tests, student's t-test for comparison of the rate of correspondence and χ^2 test for confirmation of no gap in known concepts between the two groups, were used after confirming the normal distribution. The significance level was set at 0.01, and statistical analysis was per-

Table 3. MCQs (Multiple Choice Questions) as criteria of unknown concepts
Unknown concepts were the same for both the modified concept-mapping group (MCM) and the conventional concept-mapping group (CCM).

No.	Questions	Rate of incorrect answers (%)		
		MCM	CCM	Total
1	Diseases or injuries that require breast-band	20.00	26.32	23.16
2	Diseases or injuries requiring a stockinet on one's head	20.00	26.32	23.16
3	Diseases or injuries that require long casts on lower limbs	35.00	26.32	30.66
4	Diseases or injuries that can be caused by traffic accidents	35.00	41..32	38.16
5	Muscles involved during standing between parallel bars	10.00	10.39	10.39
6	Diseases or injuries that cause mid-thoracic back pain	25.00	31.85	28.29
7	Diseases or injuries that cause difficulty in breathin	95.00	100.00	97.50
8	Diseases or injuries in which blood pressure declines	85.00	84.21	84.61
9	Diseases or injuries that cause communication disorder	75.00	78.95	76.97
10	Diseases or injuries that cause tachycardia	100.00	94.74	97.37
11	Diseases or injuries that cause dilation of jugular veins	100.00	100.00	100.00
12	Diseases or injuries that cause decline of respiratory movement	85.00	94.74	89.87

＊Alternatives are omitted; only questions are shown in expression of results of MCQs

Table 4. Results of rate of correspondence and quantity of knowledge

No significant difference was observed between the modified concept-mapping group (MCM) and the conventional concept-mapping group (CCM) in terms of quantity of knowledge, although the modified concept-mapping group was significantly higher than the conventional concept- mapping group in the rate of correspondence.

Group	Rate of correspondence and rate of correct answers in MCQ	p value
1. Rate of correspondence between unknown concepts and learning tasks (%)		0.006
MCM	59.15 ± 21.28	
CCM	27.84 ± 7.50	
2. Known knowledge measured by MCQ (%)		0.754
MCM	54.58 ± 12.53	
CCM	56.58 ± 11.65	

Traffic accident

Medical treatment

*Stockinet on head
*Breast band
*A long cast on his leg

Possible hypotheses
*Where was he injured and to what extent?
* What is his current condition?

||

What kind of risks could be involved?

② Risk management

?

First
Physio dept
Sitting in wheelchair

Standing

① What actually occurred?
Changes inside and outside the body

Orthostatic hypotension?
?_____
?_____

Occurrence

Subjective symptoms
Sharp mid-thoracic back pain?
Difficulty in breathing?
Paleness, cold sweat, tremble

Objective symptoms
Blood pressure   90/56 (110/78)
Pulse diminution and tachycardia (72bpm)
Dilation of jugular veins?
Decline of respiratory movement?

Learning tasks

· Possible diseases involved with each medical treatment
Investigate each treatment
· Possible diseases that can be diagnosed from the symptoms
(Orthostatic hypotension, other probabilities)
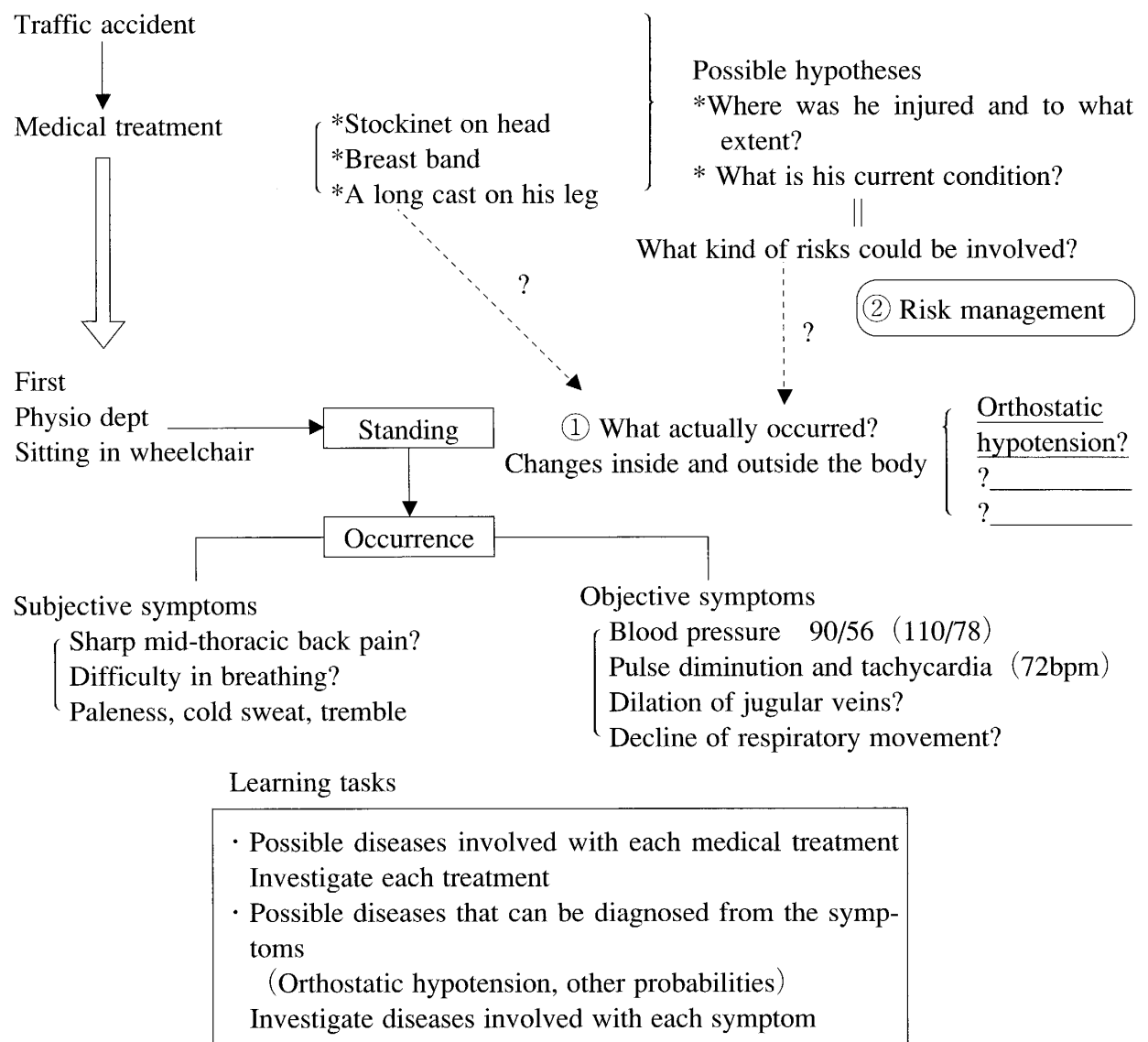Investigate diseases involved with each symptom

Figure 3. An example of concept-map and learning tasks created by modified concept-mapping group

formed using the SPSS+, version 10.1 software package.

RESULTS

1. Rate of correspondence between the learning tasks and unknown concepts (See Table

4)

In the MCM group, the correspondence number of learning tasks in incorrect answers was 4.10 ± 1.71 out of 12, and the rate of correspondence was $59.15 \pm 21.28\%$. In the CCM group, the correspondence number of learning tasks in incorrect answers was 1.95 ± 0.52 out
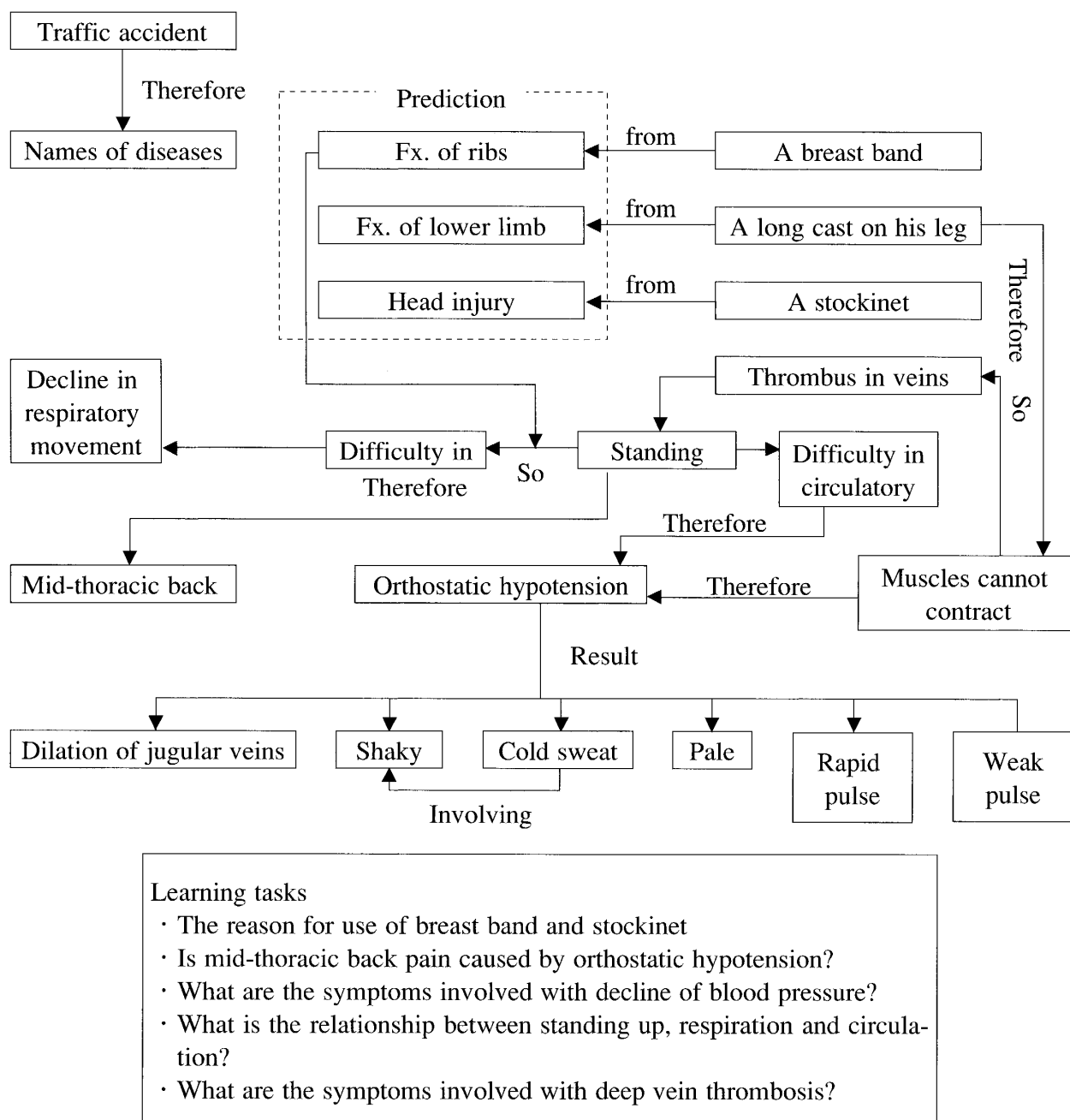
Figure 4. An example of concept-map and learning tasks created by conventional concept-mapping group

of 12, and the rate of correspondence was 27.84±7.50%. There was a significant difference in the rate of correspondence between the two groups (p<0.01, 95%CI: 20.82~41.80).

2. Known concepts of the two groups and difference between them (See table 4)

The rate of known concepts measured by the MCQs was 54.58±12.53% in the MCM group, and 56.58±11.65% in the CCM group, with no significant difference (p=0.75, 95%CI: −0.62~0.82). The correction rate of each question is given in Table 3.

3. Analysis of process from the making of concept-maps to the setting of learning tasks

Figure 3 is an example of the concept-maps and learning tasks that the MCM group drew up. The characteristics found in this concept-map suggest that the students attempted to link medical treatment (breast band, for example) to patient mobility and the onset of actual symptoms, before attempting to actually answer the question, "what happened?" by additionally taking into account any of their unknown concepts. Using this form of concept-mapping the subjects could therefore reach the conclusion that statements such as, "illnesses that can been identified from medical treatments," and, "illnesses that can be identified from each symptom," are learning tasks. These learning tasks were still unclear, and it can be seen that the subjects were trying to make up for the presence of unknown concepts by learning and attempting to fully understand what had actually occurred in the relevant scenario.

Figure 4, in contrast, is an example of the concept-mapping that the CCM group drew up. The characteristics of this map suggest that the students attempted to understand the problems in an organized and confident manner. As it was ambiguous whether the expressed concepts and propositions actually originated from unknown concepts or from

known concepts, and as the core of the learning tasks was dependant on this factor, there was therefore an accumulation of information to prove orthostatic hypotension. The MCM group, in contrast, could draw up a concept-map, which also included unknown concepts and could take into account learning tasks with any probability and therefore show a route for solving the relevant problems. The CCM group, however, had to demonstrate learning tasks based solely on hypothesis as a result of their unknown concepts and known concepts not being clearly defined.

Both groups, however, did share some common characteristics regarding concept-mapping and learning tasks, such as that the key concepts and propositions in the clinical tasks of this study were not expressed in every sub-group. More specifically, the key concepts and propositions of this clinical case, namely that the contraction of muscles responsible for the movement of ribs such as the pectoralis major during the process of moving from a sitting to standing position made the ribs spread, subsequently causing tension pneumothorax, were not expressed in either Figure 2 or 3.

DISCUSSION

In a previous study[10], we investigated the effect of promoting of the meta-cognition function in the use of conventional concept-mapping during the process of setting learning tasks. Although the rate of correspondence was comparatively high compared to that of conventional PBL, it was not sufficiently high as to ensure complete certainty in these results. In this study, the rate of correspondence proved that modified concept-mapping in which the concept-map was made containing unknown concepts, was more effective than conventional concept-mapping in making the subjects recognize their unknown concepts and propositions as learning tasks. In judging the effect of promoting meta-cognition by

concept-mapping in PBL synthetically, the conventional process of PBL in addition to "drawing up the concept-map" is more effective than the conventional PBL alone for students to recognize unknown concepts as the learning tasks in "setting learning tasks" in the process of PBL.

We have attempted to view and examine this effect from a cognitive psychology point of view. When encountering a learning based situation, a student's cognitive or knowledge structure is not entirely empty as the student brings his or her intellectual background, and relevant experience, to learning activities[11]. The process of problem solving begins with the student observing any information related to the problem that is available to them, or that can be remembered from previous experience. The student will then attempt to make clear what information is lacking in order to solve the problem, and what he or she has to learn to try and comprehend this missing information. Using learning to acquire this information gives rise to a more complex knowledge structure, meaning that problem solving becomes easier. As mentioned previously, concept-mapping consists of clearly expressed concepts or ideas that each person has had previously. In this way, concept-mapping enables students to recognize how they have approached the PBL tasks (clinical problems in this case), and allows them to recognize exactly what areas they have insufficient knowledge of, as well as enabling them to recognize the links between concepts that are hard to understand[12]. In short, concept-mapping facilitates meta-cognition function in learning activities[13]. The maps created by the subjects using only the conventional concept-mapping method, however, consist of only known concepts or ideas, with no unknown concepts or ideas being expressed in them. In the modified concept-mapping used in this study, in contrast, the subjects had to express the structure of the proposed clinical problems using both known concepts and ideas in combination with unknown concepts and ideas. Compared with the conventional method, therefore, unknown concepts and ideas can be incorporated into the map and these can have an effect on, "the learning tasks". Students can learn, therefore, concepts in the medical field and how to learn by themselves (meta-learning) by using the concept mapping in the process of PBL, consisting with the New Integration Theory.

The rate of correspondence of the modified concept-mapping to the learning tasks was relatively high, however dispersion was relatively large. We guess that the results originated from ignore, similarly to the previous study[10]. In the conventional concept- mapping, this way can use only known concepts and propositions. Because unknown knowledge was not used in making the map, students were hard to notice their unknown knowledge. And there would be no differences between the two groups in their knowledge, because they studied in the same class. Therefore, probability of ignore will be high and dispersion is relatively small. In contrast, students were easy to notice their unknown knowledge, because they must use unknown knowledge itself in the modified concept-mapping. However, there are several contexts in process of problem solving, and accordingly a level of consciousness of unknown knowledge depends on the depth and width of inquiry of each student. Therefore, probability of ignore will be low and dispersion is relatively large in the modified concept-mapping. "Ignore," as used here, means that the concepts and ideas vital to solving the relevant problems are expressed on the concept map neither as known concepts or ideas, nor as unknown concepts and ideas. In the previous study, concerning clinical problems inherent in improving obesity, the physiological field of energy metabolism was the area that was commonly ignored (subjects were 1st year students). In this study regarding the clinical

problems involved in tension pneumothorax during physiotherapy treatment, the relationship between the motion involved when moving from a sitting to standing position and the contraction of the muscles of the upper limbs and displacement of the ribs, was ignored. All students could not notice possibility of this mechanism, and they seemed to adhere to their hypothesis. This ignoring seems to derive from simplistic interpretation of context in the process of problem solving. In other words, the modified concept-mapping was possible to make students recognize unknown concepts and propositions which they can notice, but it was not possible to recognize possible concepts besides students' hypothesis necessary to solve the problems. Thereupon, it is necessary to improve further the concept-mapping for solving the problem of "ignore" as the meta-learning tool.

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