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Context-aware Learning Path Planner

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Abstract: This paper develops a context-awareness learning path planner. The learning path planner constructs suitable learning path for individual student according to his/her misconceptions of the learning objects and the distances in the real world. Beside the remedy learning path, the planner also provides two guidance messages to students, the moving guidance message and the learning guidance messages. The moving guidance messages are used to lead students traveling from one learning spot to another. The learning guidance messages are used to guide students observing the specific part of the learning objects in order to clear their misconceptions. At the end of this paper, an example is showing how the planner works for learning in a museum.

Key-Words: Mobile Learning, Learning Path, Knowledge Structure, Misconception, Situated Learning

1 Introduction

Even the teachers and students are separated in different places, the teaching and learning activities still can be done via web-based teaching materials, e-mails, and video lecturing technologies [13][14]. However, some courses which do need students learning through observations are not very easy to deliver by either traditional classroom teaching nor web-based learning environment, for examples, the butterfly-watching course and plant-learning course in the biology domain [4][5][8][18].

This paper develops a system to offer learners an opportunity to interact with learning objects in the real world. The similarity between the teacher's and the learner's concept maps will be considered for measuring the misconceptions. After the system finds

out the learning objects which the learner needs to study again, the system constructs the best learning path to the learner according the learning gain the learner might receive based on the misconception degrees and travel distances among the learning objects in the real world.

Section 2 describes related research results, including the knowledge structure measurement, situated learning, and mobile learning. The concept maps' similarity evaluation and the learning path's gain are explained in Section 3. Section 4 illustrates the operational flow of the learning path planner and an example of using the planner in the museum. The experiment design plan and system snapshots are described in Section 5 and Section 6. Finally, Section 7 makes conclusions and discusses possible future works at the end of this paper.

2 Learning Strategies, Knowledge Structure & Diagnosis

The students are not just passively receiving the learning materials from teachers as they are doing mobile learning. Students also can learn the concepts, knowledge, skills, and abilities, via interacting with real learning environment [17][20]. Brown coins the situated learning and thinks that the concepts and knowledge are situation-based [3], and the learning effects will be influenced by teaching activities, situations, and interactions.

Moreover, mobile learning can make students get or apply what they have learned in the real environment [9]. Students can get the digital assistance and the experiences when they learn in the real world with mobile devices. And that is also the reason that this research chooses to use the mobile learning strategy.

No mater what kind of learning strategies are taking by the teachers, the most interesting issue to teachers and researchers always is what the students thought and learned [2]. Trying to find out what the lectures students have memorized via testing or exam is very easy. However, the testing scores could not provide enough information of students' learning results to their teachers. Even the concepts and knowledge students read from the same teaching materials, the concept relations stored in students' minds might not exactly the same [6][7].

Therefore, to know what the knowledge structure students have in their minds is much more important than just check what the concepts students have memorized. The concept map was proposed by Novak and Gowin [15], concept map is a graphical tool for organizing and visualizing knowledge in human's mind. Students can concrete the concepts and knowledge they have learned from the course by drawing their concept maps on the papers [16].

Students can keep modifying their own concept maps during the learning process, and the new concepts will be reorganized and added into the concept maps. As a result, teachers could check the students' understandings about the lectures or teaching materials which they provided to students via comparing students' concept maps with themselves [6][7][12][19]. Teachers can discover what students have learned and diagnose students' misconceptions and also adapt their instructions and lectures according to the results of concept mapping.

There is another important issue, which is knowledge structure measurement. Novak proposes Concept Mapping to evaluate the consistence between teacher's and students' concept maps [15]. There are four scoring standards, which are: (1) **Relationships**, which means the relation links between two concepts; (2) **Hierarchy**, the level which presented in concept map; (3) **Cross-links**, the linkages between some concepts which locate at different level; (4) **Examples**, whether a student could give an example about what he/she has learned or not.

Another strategy about concept map measurement is Pathfinder, which is proposed by Goldsmith [1][10][11]. Pathfinder uses the Closeness Index to evaluate the similarity between teacher's and learners' concept map. Closeness is based on set theory, and the value of closeness is between 0 (totally different) to 1 (complete similar).

The closeness will be taken into consideration in measuring the similarity of concept map in this paper. The next section introduces the construction of teacher's and students' concept maps; analyzes and designs the concept map measurement; finds out the improvement; checks the learning gain in the real world according to the travel distances among learning objects; and, generates the learning sequence and context-aware learning path to individual learner.

3 Planning a Context-aware Learning Path

This research wants to give individual student feedback of suitable teaching materials according to students' misconceptions and a context-aware learning path in the real world suchlike school campus. Before providing the feedbacks to learners, there are some questions needed to be solved as Figure 1 shows.

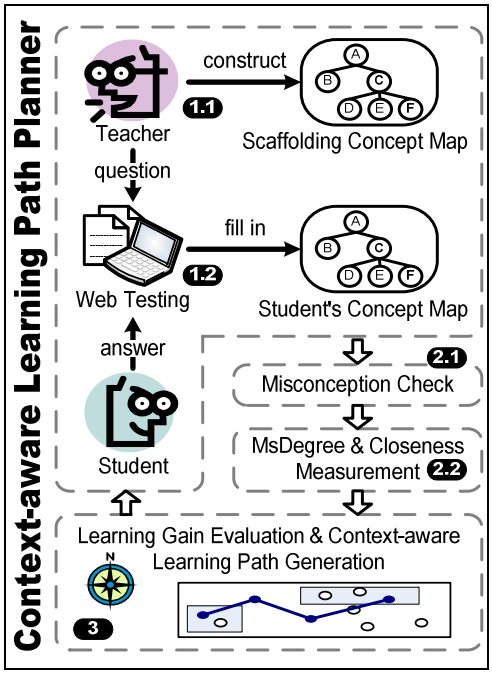


Fig 1. Working flow of context-aware learning path planner

Phase I digs out what the concepts learners have and makes the unconcealed knowledge structures in their minds into concrete and visible concept maps; **Phase II** checks what concepts students might need and measures the similarity between teacher's and learners' concept maps; **Phase III** evaluates the improvements and learning gains that students can get from each learning objects in the real world and generates the context-aware learning path according to their misconceptions.

The concept map can represent the knowledge and concepts stored in the student's mind after learning. The teacher wants to check what the lack concepts the student has and gives remedy teaching materials by comparing the student's concept map with his/her concept map.

The concept map is still too complex to the teacher to make sure what concepts are misunderstanding and lacking by the student, especially if there are many cross-linked relations among concepts. Therefore, the knowledge structure used in this research is the tree-liked form, the **tree-liked concept map** (**concept map** for short in the rest of this paper).

As step 1.2 shows, the system will construct the learner's concept map automatically according to the learner's answers of the questions provided from teacher. After learner returns the answer, the option which he/her chooses will be filled in his/her concept map. What the difference between teacher's and learner's concept map is easy to check and find out the misconceptions the learner has in step 2.1.

Since what the misconceptions learner might have can be found, there are still two important issues which are what the feedback sequence to individual learners (step 2.2 in Figure 1); the second issue is how to generate the learning path based on the learner's misconceptions and learning objects in the real world (step 3 in Figure 1).

This research uses the concept map to record related concepts for each learning object in the real world. Besides, another knowledge structure, the **situated map**, is used to store the related spatial information of the learning objects in the real world, such as the coordinates and the distances. Figure 2 shows the spatial relations among learning objects and the corresponding concept map of a learning object, lo_1. Certainly, there are two identical learning objects located at different places, the learning object lo_2 at the right-top and left-bottom in Figure 2.

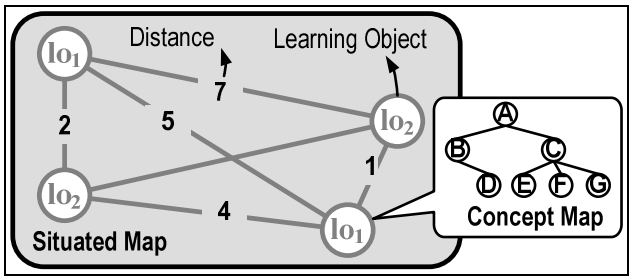


Fig 2. The relationship between the concept map and the situated map

Before digging out what learners have been learned and thoughts in their minds, the teacher must construct his/her own concept map, the scaffolding concept map, for each learning object and construct the related questions (step 1.1 in Figure 1). Figure 3 shows a single-choice question and its options for the concept, *adornment*, in the concept map of the "Ruby-red Kuan-yin Tsun vase". The teacher has to construct observable questions corresponding to the

concepts in the learning object's concept map. The students can answer and learn the related concepts via observation in the real environment then.

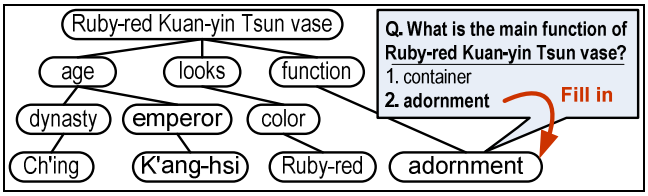


Fig 3. A question corresponding to the 'adornment' concept in the concept map of Ruby-red Kuan-yin Tsun vase

When the students learning in the real environment, they need to spend a lot of time for two things: (1) learning activities, such as observing and understanding what the learning object is; (2) searching and moving, for example, the students will spend a lot of time to travel from one learning spot to another learning spot, and try to find out the learning objects and concepts that they need. The teacher also needs to construct two kinds of guidance messages, learning guidance and moving guidance, for the students learn in the real learning environment.

The learning guidance guides the students to observe the learning objects its concepts with the pre-made guidance messages. For example, a teacher will make a guidance message such like "how does the mark on the vase look like? and why?" for the students who might have misunderstandings about the pattern on a vase.

The moving guidance is to navigate and give students instructions about how to get to the learning spot where learning objects are. The moving guidance messages are also designed by a teacher for each learning objects on the situated map in advance, for example, "please move to the statue at the middle of the exhibition room."

It is not good enough if the learning sequence is generated only based on the misconceptions or without thinking about the concept relations. Therefore, the better strategy of generating learning sequence is taking each concept and its neighbor concepts into account for measuring the feedback sequence. In order to solve the first issue talked above, the similarity of concept maps is used to measure the sequence of learning the misunderstanding concepts.

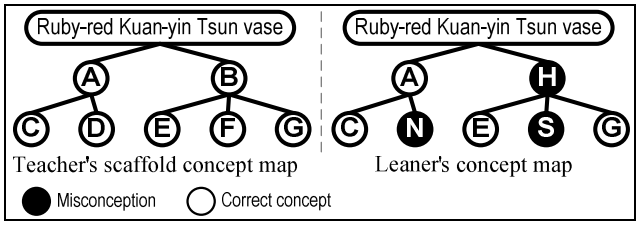


Fig 4. Teacher's and learner's concept maps

Figure 4 shows the teacher's scaffolding concept map and the learner's concept map, the misconceptions are represented by black nodes and the correct concepts are represented by white nodes. As a result, the concept *Accuracy*, which is the similarity of a concept, can be measured easily by comparing the neighbor nodes between the teacher's and the learner's concept maps with the following equation:

$$\frac{|\{\text{Absolutely Correct Neighborhood Concept}\}|}{|\{\text{Neighborhood Concept}\}|}.$$

With the equation, Figure 5 shows an example of how the accuracy can be calculated out for each concept.

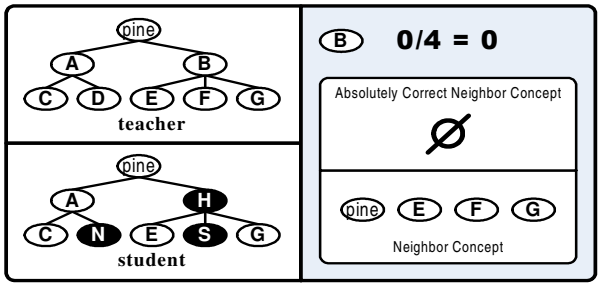


Fig 5. Example of how to calculate the accuracy for each concept

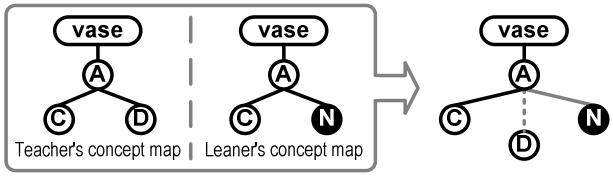


Fig 6. Concept A's accuracy between teacher's and learner's concept maps

Taking the concept *A* in Figure 4 for example, there are totally four neighbor concepts around the concept *A* in teacher's and student's concept maps, the neighbor concepts are {*Ruby-red Kuan-yin Tsun vase*, *C*, *D*, *N*}. There are only two exactly correct concepts which are connected to concept A in the student's concept map, the two concepts are {*Ruby-red Kuan-yin Tsun vase, C*}, as Figure 6 shows. Hence, the concept A's accuracy is 2/4. Figure 7 shows all

concept accuracies in the student's concept map for the learning object, Ruby-red Kuan-yin Tsun vase.

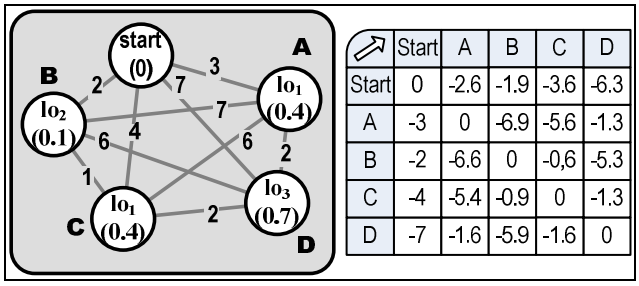
Concept	Misconception	Accuracy	
vase	none	|{A}|/|{A, B, H}|	1/3
A	none	|{vase, C}|/|{vase, C, B, N}|	2/4
B	H	|{none}|/|{vase, E, F, G}|	0/3
C	none	|{A}|/|{A}|	1/1
D	N	|{none}|/|{A}|	0/1
E	none	|{none}|/|{B, H}|	0/2
F	S	|{none}|/|{B}|	0/1
G	none	|{none}|/|{B, H}|	0/2
Closeness = (1/3+2/4+0+1+0+0+0+0)/8 = 0.229166667			

Fig 7. the concept accuracy in the student's concept map for the learning object, Ruby-red Kuan-yin Tsun vase

Furthermore, it is easy to measure the similarity of the learning object, is also called *Closeness*, between teacher's and learner's concept map by summarizing the accuracy of each concepts and then divided the total amount by the concept number. For example, the closeness of the learning object Ruby-red Kuan-yin Tsun vase is (1/3+2/4+0+1+0+0+0+0)/8 = 0.229, as Figure 7 shows.

The system is then able to use the concept map characteristics to get the student's misconceptions, and uses the situated map to plan a context-aware learning path for the student (step 3 in Figure 1). The closeness can be used to indicate how much *Improvement* that the student could be reached if the student re-learns the learning objects. The improvement, has a negative relation with the closeness, take Figure 7 for example, the improvement of learning object Ruby-red Kuan-yin Tsun vase is (1-0.229) = 0.771. The improvement of learning object will also affect the learning path planning.

Beside the improvement, the distance between two learning objects is also need to be taken into consideration when we planning the learning path. Longer distance will waste learners too much time in traveling from one learning spot to another. Hence the possible learning gain from the learning objects is: $LearningGain_{start} = Improvement_{end} - \alpha * Distance_{(start, end)}$. The value of parameter α depends on what kinds of movement strategies that the student uses and/or how important that the distance will be during the student learns in the real world. For example, the value of α will be closed to 1, if the student moves in mobile learning environment by feet, the teacher might think that the distance takes more effects than the improvement.



	Start	A	B	C	D
Start	0	-2.6	-1.9	-3.6	-6.3
A	-3	0	-6.9	-5.6	-1.3
B	-2	-6.6	0	-0,6	-5.3
C	-4	-5.4	-0.9	0	-1.3
D	-7	-1.6	-5.9	-1.6	0

Fig 8. The learning gains in mobile environment

Figure 8 shows the possible learning gain from one point to another, it has two parts. The left part is a situated map, it shows the improvement value that each learning object may have if the learner goes to learn again, for example, the improvement of learning object lo_2 is 0.1, and the distances between two learning objects, for example, the distance from start point to B is 2. Values inside the nodes in the situated map are the improvement of learning objects and values on the edges are the distances between two learning objects.

The right part shows learning gains from the row learning objects to the column learning object that the learner might receive based on the improvements and distances (in this case, α is be set to 1). For example, according to Figure 8, the learning gain form start to learning object *A* will be (0.4-1*3) = -2.6. Therefore, the context-aware learning path will be found with maximum sum of learning gain: (0.1-2)+(0.4-1)+(0.7-2) = -3.8, and the most appropriate learning path will be Start → B → C → D, which has the maximum learning gain.

Besides choosing the best learning path via measuring the learning gains and the distances, what the sequence that the students should learn about the concepts when they reach the learning object is also very important. The value used to evaluate the importance of each concept in the learning object is called *Misconception Degree*. However, the differences between the concepts in the teacher's and the student's concept maps might not be able to represent the importance of each concept without thinking the concept weights.

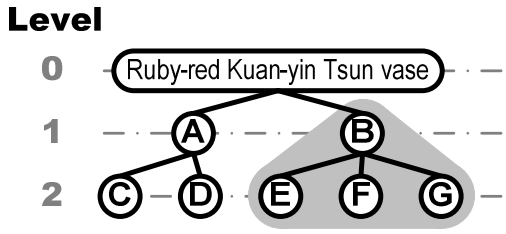


Fig 9. The concepts that might affects the concept B's weight

The concept weights should be known first before calculating the misconception degree. A concept's weight should not only depend on the concept's level in the concept map of the learning object, but the related concepts that might affect students misunderstanding the concept are also important. Take Figure 9 for example, even the concept A and B are at the same level in the concept map of the learning object Ruby-red Kuan-yin Tsun vase, their children concepts and the children concept number are not same.

A concept's weight in this research depends on how many concepts in the whole teacher's concept map are the concept and its children concepts. Take Figure 9 as example, the concept map has eight concepts and the concept B has three children concepts, {*E, F, G*}. There are four concepts will be affect the concept B, hence, the weight of concept B is | {*B, E, F, G* } | / 8 = 4/8. Figure 10 lists the concept weights and the misconception degrees for each concept in Figure 4.

Concept	(1-Accuracy)	*	Concept Weight	=	MsDegree
vase	(1-1/3)		8/8		2/3
A	(1-2/4)		3/8		3/16
B	(1-0)		4/8		1/2
C	(1-1/1)		1/8		0
D	(1-0)		1/8		1/8
E	(1-0)		1/8		1/8
F	(1-0)		1/8		1/8
G	(1-0)		1/8		1/8
Feedback Sequence: B→ A → D→ E→ F→G					

Fig 10. The concept weights and misconception degrees for each concept in the concept map shown by Figure 4

The sequence of concept feedback depends on the misconception degree, which is (1-Accuracy) * Concept Weight. According to the misconception degrees shown in Figure 10, the final feedback sequence is B (1/2) → A (3/16) → D (1/8) → E (1/8) → F (1/8) → G (1/8). Because the concept C is exactly correct, hence, the cocnept C will not be considered in the feedback sequence.

4 Learning Path Planner in Museum

There are two main phases and five steps to learners as they learning with context-aware learning path planner as Figure 11 shows.

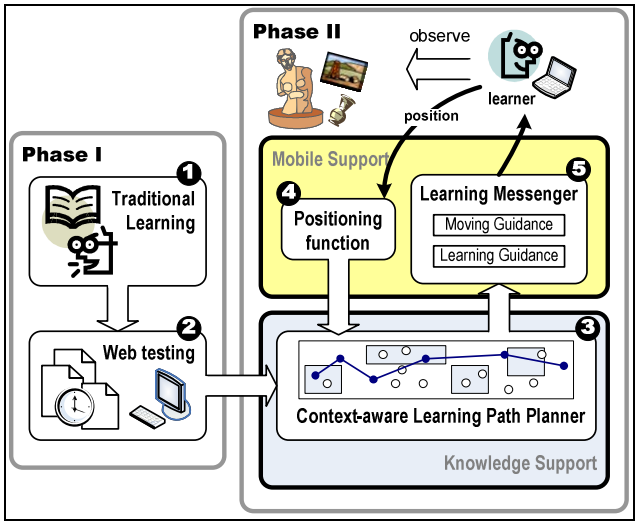


Fig 11. Two main phases of context-aware learning path planner

The two phases are the traditional learning & web-testing phase (phase I) and the remedy mobile learning phase (phase II). Within the two phases, at first, learners recieve the teaching materials (step 1); second, learners participate the web testing (step 2); third, the system checks the concept maps and generates the context-aware learning path with situated map (step 3); fourth, the system asks learner's position (step 4); and finally, the system gives the learner either a moving guidance suchlike "please go to the Area D in the room 203, and find out the artifact No. 23!" or a learning guidance suchlike "please observe what special mark the vase has."

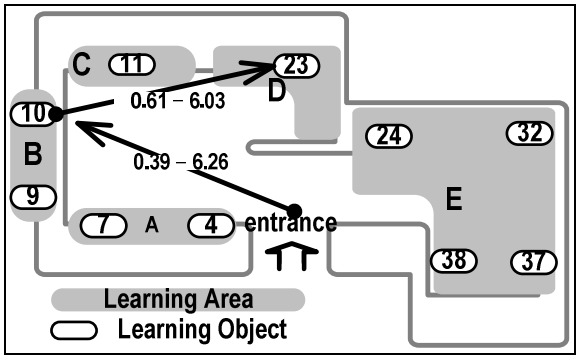


Fig 12. Artifacts at room 203 in the museum

Figure 12 shows Alex's navigation learning path which generated based on the maximum learning gain: (0.61-6.03)+(0.39-6.26) = -11.29. Alex will be guided to the artifact No. 10 at Area B with the moving guidance once he arrive room 203. The system will ask him to observe the artifact No. 10 by the learning guidance, "please take a look at the mark of the bowl." After Alex finished all the remedy learning activities for his misconceptions, the system will use moving guidance message to lead Alex to area D and use learning guidance message again to ask him do remedy learning about the artifact No. 23.

5 Experiment Design

We are now planning to do an experiment in elementary school. The experiment subject is the elementary level biology course unit, The Plant. The students are grade four students, they will use tablet PC to do self-learning in the campus by their own. The elementary school has a hundred and twenty tablet PCs, so each student can have one for his/her remedial learning activity. In order to control the experiment result, there is only one teacher will involve in this experiment, which means, all students in the three classes will be his/her students. All students are divided into three groups according to which class the student belongs to. The three groups are Teacher Guidance group (control group 1), Student Guidance group (control group 2), and Computer Guidance group (experiment group).

		Learning Object	Learning Path
Class A	Teacher Guidance	Chosen by Teacher	Set by teacher
Class B	Student Guidance	Student's Misconception	Particular
Class C	Computer Guidance	Student's Misconception	Set by Computer

Fig 13. Experiment and control groups

The students in the Teacher Guidance group will do the remedial learning activities according to the teacher pre-set learning path, which means, the remedial learning activity is irrelevant to the students' misconceptions. The students in the Student Guidance group will do their remedial learning activities according to their free-wills, which means, the students may not know what are the most of important things for them to take a look first. The students in the computer guidance group will under the guidance of the learning path planner, which means, the learning path planner will focus on the misconceptions that the students may have and guide the students to observe the most of important learning objects as soon as possible.

We assume that the students in the computer guidance group will have significant differences after the remedial learning activities.

The experiment flow like Figure 14 shows. First of all we record students' pre-test scores, semester achievement, and computer altitudes, to for further analysis after they finished the remedial learning activities. Secondly, all of the students are divided into the three groups: two control groups and the experiment group. The learning activities for those students in the elementary level biology course are: (1) the teacher first teaches basic knowledge of the learning unit in the biology course; (2) all students in three groups will be asked to do an online test on the course website; (3) after the online test, the students will be asked to do remedial learning activities with their tablet PCs. At last, the students will be asked to do post-test in order to verify whether they have learned the misconceptions or not. Moreover, interviews will be delivered to both of the teacher and the students for collecting their reflection of the learning path planner.

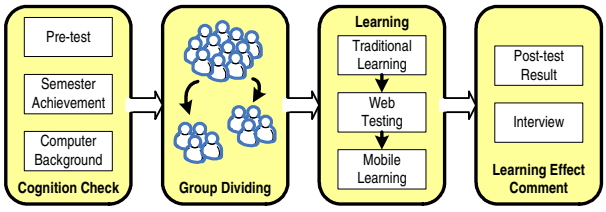


Fig 14. Experiment flow

6 Experiment System

We have implemented related editors for teachers to build the concept maps for their courses and the situated maps for their campus. Also, the experiment system and misconception diagnosis tool which can be used in our planed experiment are also developed.

Figure 15 shows the concept map editor. Usually, teachers make their teaching plans before them giving lectures in the classroom. The teachers can use the concept map editor to build their concept maps (or called scaffolding concept maps).

Because of the learning path planner uses questions to evaluate students' misconceptions, the teachers have to input the related question and options for each concept as the 'question' section on the right-middle area in Figure 15 shows. Furthermore, the learning path planner needs to guide students observing learning objects in the campus, therefore, the teachers also have to input the guidance message for the concept as the 'guidance' section on the right-bottom area in Figure 15 shows.

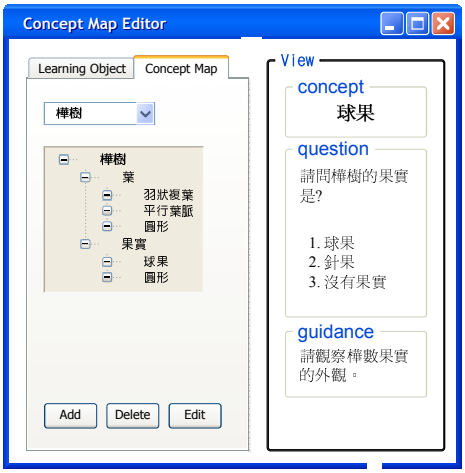


Fig 15. Concept map editor

Beside the concept map editor, Figure 16 shows the situated map editor. The teachers need to build a map and identify all learning objects on the map. For examples, as we can see from Figure 16, number 1 and 4 are identical, the cypress tree; number 2, 5, and 7 are identical learning object, the pine tree; and number 3 and 6 are olive trees.

With the situated map, the learning path planner will be able to plan a learning path for the student according to his/her misconceptions and the distances between learning objects.



Fig 16. Situated map editor

And then, after students finished the online test, Figure 17 shows the student's learning results of each learning objects and concepts. As Figure 17 shows, Alex only familiar with tree peony (the fourth learning object) and fully understand the concept of leaves' edges (the second concept in the misconception degree). The learning path planner then plan a best solution of remedial learning path according to the closeness, misconception degrees, and the distances among learning objects on the situated map. As the suggested learning path listed on the bottom of Figure 15.

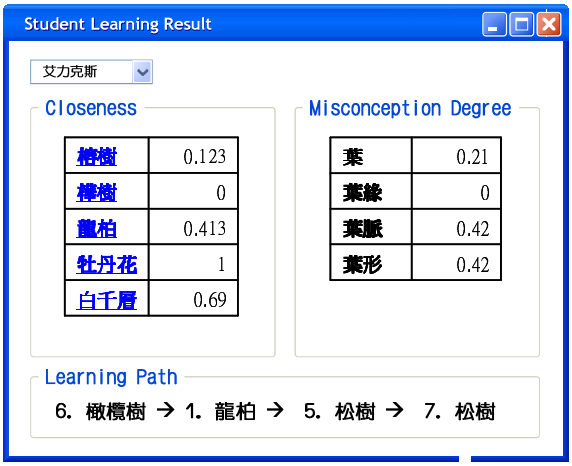


Fig 17. Closeness, misconception degree and learning path

Figure 18 shows a moving guidance demonstration for Alex. At the right panel in Figure 18, the learning path planner will pop-up either moving guidance message or learning guidance message. The moving guidance message is used to lead the student moving from one learning spot to another. The learning guidance message is used to guide the student observing the specific part of the learning object in order to correct his/her misconceptions.



Fig 18. The moving guidance and learning messages

7 Conclusions & Future Works

This paper focuses on developing a personalized context-aware learning path planner to support individual student doing self-learning in the mobile learning environment according to his/her misconceptions and learning gains.

There are still two possible future research issues. First one is strengthening the cognitive level up to understanding such like "which vase shown as following could be used as a sacrificial offering?" Students not only just memorize the features of the vase, but also have to analyze the features which fit the history situations of the vase. The system should give suitable learning guidance based on different cognitive levels in the future.

Second one is generating mobile guidance message automatically instead of teacher pre-made message. The automatic guidance message generation can be used when students don't have idea about the directions in an unfamiliar learning environment. Moreover, students can also do self-learning as they want at anywhere with the automatic guidance message generation function. The system should be able to guide the learners from one learning spot to the next learning spot rather than ask teachers to input the moving guidance in advance.

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