



<b>Title</b>	<b>Dual mapping for support of problem solving and knowledge construction</b>
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<b>Citation</b>	<b>The 11th IEEE International Conference on Advanced Learning Technologies (ICALT 2011), Athens, GA., 6-8 July 2011. In Proceedings of 11th IEEE ICALT, 2011, p. 207-209</b>
<b>Issued Date</b>	<b>2011</b>
<b>URL</b>	<b><a href="http://hdl.handle.net/10722/136142">http://hdl.handle.net/10722/136142</a></b>
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# Dual Mapping for Support of Problem Solving and Knowledge Construction

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**Abstract**—Learning through problem solving has received increased attention in constructivist learning, especially in ill-structured domains such as medicine [1]. Previous studies indicate knowledge construction and problem solving can reciprocate each other. However, this is not easily achieved, especially for complex problem solving. Temporal problem solving activities can be easily forgotten, and knowledge situated in problem solving experience may not be possibly retrieved and reused to solve new problems. This paper addresses the problem by proposing a dual mapping visualization approach to support the connection between problem solving and knowledge construction. Diagnostic problem solving in medical education is selected as the application domain, and abdominal pain is used as the case of the study to demonstrate the proposed approach in an online learning environment.

**Keywords**—dual mapping; visualization; problem solving; knowledge construction

## I. INTRODUCTION

The long time belief that it requires years of experience outside school to train a qualified doctor, may cover up two critical issues and their relationship in education, i.e. problem solving and knowledge construction. Medical problem solving is a dynamic, iterative cognitive process combining medical inquiries. Knowledge construction through problem solving involves reconstruction of old memories of knowledge and dynamic construction of new ideas, which precedes the construction of a solution [2]. It is particularly true in medical education, where expertise in medical problem solving requires problem solving experiences and relevant domain knowledge, as well as the transformation between them [3, 4]. Both problem solving and knowledge construction are complex cognitive processes, which cannot be easily captured and mastered. This may cause inefficiency and ineffectiveness in expertise development.

## II. RELATED WORK AND THEORIES

To investigate the above mentioned problem, we refer to the cognitive theories and models of Mayer [5] and Dougherty et al. [6]. Mayer proposed the SOI model describing three sequential cognitive processes, i.e., selecting relevant information; organizing coherent representation in working memory (WM); and integrating incoming information with existing knowledge in long-term memory (LTM). Due to human's limited capacity of information processing, mental models are needed to help learners externalize their mental activities,

and increase cognition and retention of knowledge in LTM. Dougherty et al. proposed a more detailed computational model, outlining the relationship among ecological environment (i.e. perceptual information), memory system (categorized as working memory, exemplar memory, and semantic memory), and problem solving behavior (including hypothesis generation, probability judgment, and hypothesis testing).

## III. DESIGN OF A DUAL MAPPING TOOL AND ITS MECHANISMS

### A. Dual mapping supported problem solving and knowledge construction

The dual mapping approach proposed in this study aims to support problem solving and knowledge construction process based on the models of Mayer and Dougherty et al., with further extension towards visualizing the connection between problem solving and knowledge construction. As shown in Figure 1, during interacting with the learning environment, learners may access or request patient information, select and apply the information to argue for or against generated hypotheses, under the support of retrieved prior knowledge from concept maps or evidence from external references, which can be visualized via argument mapping. Meanwhile, learners may reflect within and after the problem solving process, generalize new or reorganize existing knowledge represented in concept maps. The updated concept maps represent their improved understanding of the domain knowledge, and may support their problem solving and argumentation process when dealing with new cases.

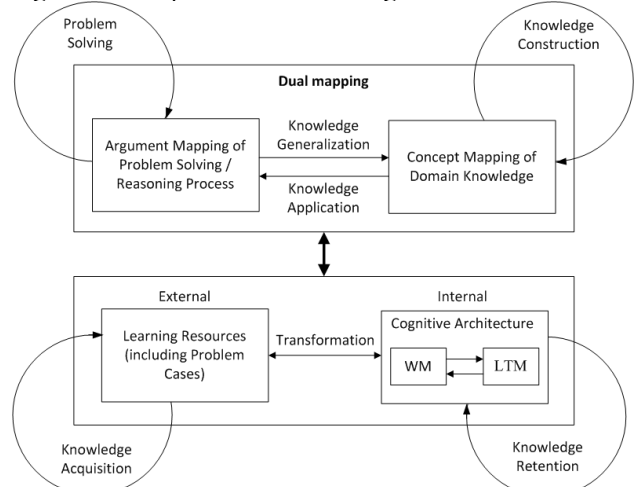


Figure 1. Dual mapping

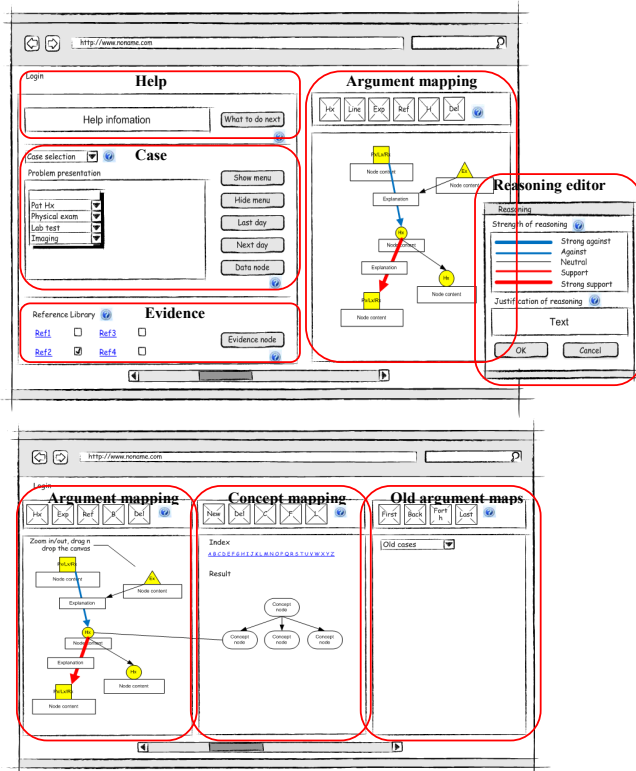


Figure 2. Design of the dual mapping tool

## B. Dual mapping tool design

Figure 2 shows the design of the dual mapping tool to support the above mentioned dual mapping approach. It includes three major parts – learning resource panel, argument mapping panel, and concept mapping panel.

### 1) Learning resource panel

This panel includes three parts, i.e., case, evidence and help. The case sub-panel provides information of patient cases in various forms, such as text, numerical tables, image, etc. After selecting a case, learners can browse and check relevant information of the case. The evidence panel provides journal articles and web-pages related to the disease as evidence in support of reasoning. Learners can choose to download and read the materials. Besides, the help sub-panel provides support to learners in the form of hints or pop up alert to scaffold learners' problem solving and dual mapping process.

### 2) Argument mapping panel

This panel allows users to represent their reasoning and argumentation process for solving the case. A visual map is used for representation by generating *hypothesis nodes*, and linking them with data nodes. These nodes are linked based on three types of *reasoning relationship*, namely “for”, “against”, or “neutral”. The strength of the relationship can be reflected as the width of the line that links the nodes. Besides, each relationship line can be

attached with a piece of *explanation* to justify the reasoning from one node to another. This panel also stores previously constructed argument maps for old cases. The argument mapping process can be played back and forth to see how the reasoning is developed one step after another.

### 3) Concept mapping panel

This panel supports learners to construct domain knowledge in concept maps by creating *concept nodes* and linking them based on their relations in hierarchical or network structures. The panel may contain more than one concept maps to represent different themes of knowledge. Users can retrieve a certain map via keywords. Basic concept maps of domain knowledge are pre-stored in the system; users can update or expand the maps based on their understanding. More importantly, users can build connections between related nodes of a concept map and an argument map.

## C. Underlying mechanisms

The designed approach aims to extend existing concept mapping and argument mapping approaches based on the following pedagogical considerations.

### 1) Construction of problem solving solutions

a) *Hypothetico-deductive reasoning*. The tool helps learners use scientific structures to figure out and generate hypotheses based on intriguing findings. In the meantime, domain knowledge specified in concepts maps can be used to rule in/out specific hypothesis during the problem solving process.

b) *Case-based reasoning*. Learners can evaluate the similarity between the current case and the solved cases accumulated in the system. Solutions to solved cases represented in argument maps may shed light on the problem solving of the current case.

c) *Evidence-based reasoning*. The tool provides journal articles or references to each case for learners to support or argue their reasoning process based on concrete evidence.

### 2) Construction of new knowledge

a) *Anchored points*. The tool offers learners one or more pre-prepared concept maps, which includes basic domain knowledge as the anchored point for solving cases. Based on them, learners can add new or update knowledge through their problem solving experiences, which in turn becomes new anchored points for further knowledge construction.

b) *Self-reflection*. The tool offers opportunities of “reflection-in-action” and “reflection-on-action” by building an explicit connection between problem solving and knowledge construction. Also, the tool allows learners to recall and highlight the critical argument nodes after they complete the problem solving process.

c) *Knowledge generalization*. Similar cases can be figured out by their common domain knowledge reflected in one or more concept maps linked with their argument maps. This may support knowledge generalization for a type of problem.

#### IV. A CASE STUDY

In the pilot case study, an example of abdominal pain case [7] has been selected to demonstrate the use of this tool for training clinical problem solving. The dual mapping process for problem solving and knowledge construction in this case is illustrated as follows.

*First*, a case is selected by the learner from the case list. Then, relevant chief complaint information of the case is shown up in the learning resource panel. The learner may select important information from this text message, such as “29 year old”, “woman”, “left lower quadrant pain”, and generate corresponding data nodes in the argument map.

*Second*, according to the initial information of the case, the learner may refer to the concept library and search for related concept knowledge annotated with the keywords such as “young woman” and “left lower quadrant pain”. The pre-stored concept map of “young woman and left lower quadrant pain” will pop up and show pain location knowledge of several typical diseases in relation with left lower quadrant and young female. The learner can also add additional concept nodes into the concept map based on their understanding, e.g., other possible diseases. Hypothesis nodes can be generated based on these retrieved diseases, and linked with previous data nodes in the argument map.

*Third*, medical history of the patient and related physical exams can be requested such as social history and palpation of abdomen. According to this further information, the learner can continue to generate data nodes such as “not sexually active” and “no bowel or hernia symptom”, which can be used to rule-out generated hypotheses, such as “salpingitis” and “bowel problem”. The learner can also adjust the confidence in hypothesis via setting the width of link between data nodes and hypothesis nodes.

*Fourth*, lab tests and radiology exams, such as CBC and CT-abdomen, can be requested to further investigating the hypotheses. In this case, findings of splenomegaly and lymphadenopathy from CT-abdomen may trigger the learner’s LTM of various causes of this malfunction. Hence, the learner may search again in the concept library for relevant knowledge. Besides, the content and structure of different concept maps may guide the learner to adopt different problem solving strategies.

*Fifth*, evidence from the medical journal report can be referred to in support of diagnostic reasoning. In relation to this case, existing studies have shown that the heterophile-antibody test might be negative in an early stage of infectious mononucleosis, which suggests that the hypothesis of infectious mononucleosis should not be ruled out assertively.

*Sixth*, once the argument mapping of the case is completed, the “reflection-on-action” function of the system may help learners identify the key features of the case, such as splenomegaly, lymphadenopathy, sub-acute

fever, etc. These features can be used to generate an illness script, which can be integrated into the concept map for support of problem solving of similar cases.

#### V. CONCLUSION

This paper has proposed a conceptual framework of a dual mapping visualization approach, within which the dual mapping serves as an affordance for learners to apply existing and construct new knowledge in problem solving process, as well as to externalize knowledge and maintain it in explicit formats for reuse and update in continuous learning and practical experiences.

In future study, the evaluation of the system will be carried out. A survey questionnaire will be delivered to around 30 medical school students participating in this pilot study of using the designed tool for solving abdominal pain problems online. The survey will collect data about usability and effectiveness of the system for further improvement of the system. Learning outcomes and learners’ performance of the learning process will also be collected for investigating the impact of the designed approach on problem solving expertise development. Interviews will also be arranged for in-depth analysis to shed light on how system can better scaffold learners during this dual mapping learning process.

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