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Development of an Intelligent Practice Supporting System for High School Chemistry

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Abstract. In this paper, we discuss on development of an Intelligent Practice Support System (IPSS) for high school chemistry. IPSS can solve problems and evaluate learner's problem solving process using the result. IPSS has several functions for supporting learner's problem solving and reflection: Helping function, Interruption function, History function and Searching function. We also report on experimental evaluation of IPSS.

Keywords: Intelligent Educational System, Practice supporting, High school chemistry

Introduction

In this paper, we construct a learning environment for high school chemistry that supports learners' problem solving and reflection process. We call it IPSS (Intelligent Practice Supporting System). IPSS has the following features:

I. IPSS can evaluate answers and descriptions of problem solving process input by learners. Learners describe problem solving process by using templates which are prepared for typical steps of solving process of problems that our system can handle.
II. IPSS has several functions for supporting learners reaching in impasse.
III. IPSS has functions for supporting some types of reflections: Reflection on process of problem solving, on themes of an exercise and on expression style for answers.

We have already constructed Exercise Solver capable of solving problems using chemical knowledge [1] [2], and Explanation Generator capable of generating adaptive explanations of the problem solving processes output from Exercise Solver [3].

As an existing educational system supporting practice, Andes [4] is well-known. It also has functions to accept description of problem solving process, to evaluate it, and to help learners reaching in impasse. However, it is designed for physics and few systems having such functions are known for high school chemistry.

We also report on an experiment to evaluate effectiveness and usability of IPSS.

1. Outline of IPSS

We consider that conventional methods of exercise which use paper media (workbooks and notebooks) have several issues. Firstly, learners who reach in impasse tend to easily give up thinking, and then they finish exercise by only reading the explanation of solution in workbooks. Secondly, even if learners cannot understand some knowledge in problem solving process clearly, most of such learners don't consult chemical knowledge in order to understand it more clearly, because it needs much effort to consult it by textbook or other materials. Thirdly, learners tend to concentrate only on finding the answer, so they may miss the important parts that are themes of the exercise. Finally, when a leaner retries solving problems which he failed to solve formerly, it is not so easy to remember mistakes that he/she made. We designed IPSS to solve these issues (mentioned in chapter 2).

IPSS covers the domain of inorganic chemistry for high school in Japan. We adopt a

standard textbook [5] as a resource of our chemical knowledge base and a problem collection [6] as a resource of problem database. We classify the problems into the following four types [1] [2]. Currently, IPSS supports the types (1)-(3) of problems.
(1) Simulate a chemical phenomenon; a part of result on simulation is the answer.
(2) Find a material attribute value using numerical relation knowledge.
(3) Problems composed of (1) and (2).
(4) The answer is written in domain knowledge base directly.

2. Functions for supporting learners in IPSS

Supports for learner's reflection by IPSS: Lin et al. [7] classify methods to support reflection technologically. Based on the paper and the issues mentioned in chapter1, we design the features for supporting reflections as follows.

[For reflection on problem solving]

A) Listing up learner's mistakes: IPSS shows a learner lists of his/her mistakes in the current problem solving to let him/her overview their weak points.
B) Retrying an exercise from any steps: When learners retry a problem that they failed, they don't have to solve from the beginning but can restart any step of problem solving. The feature helps learners concentrate on what he/she really want to learn.
C) Pointing out the past mistakes: Helping learners to remember their mistakes, IPSS call learners' attention when learners try the same problem which they tried before.

[For meta-level reflection on themes of an exercise and expression style for answers]

D) Calling learner's attention the themes of exercise after a leaner finishes answering.
E) Advising on methods to describe problem solving process: IPSS shows learners both exemplary description of answer generated by itself and learner's answer. It helps learners find the deference in order to learn good style to express the answer.

Function evaluating learners' problem solving process: Exercise solver solves problems and generates two types of representation of problem solving process: CWM (Chemical World Model) and PSPM (Problem Solving Process Model). CWM represents chemical phenomenon in the problem. PSPM represents calculation process (Figure 1). IPSS can evaluate learner's input by comparing them with CWM and PSPM.

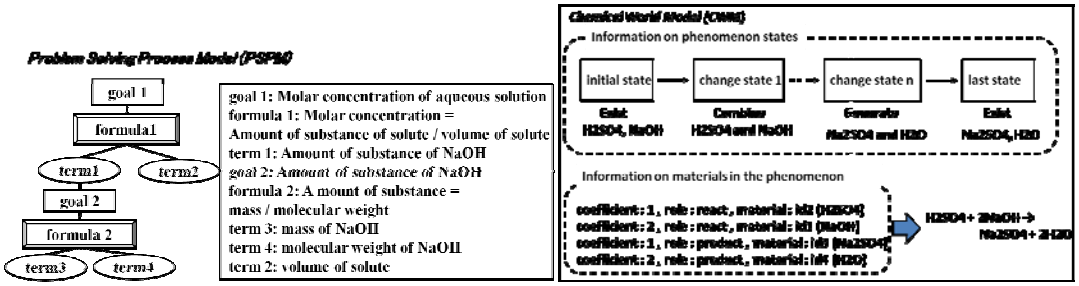

Figure 1: Problem solving process model (PSPM) and Chemical World model (CWM)

Helping Functions for learners reaching in impasse: IPSS supports learners when they reach in impasse. We classify the impasse into 4 levels and provide 3 types of helping functions for each impasse. Learners can choose any types of supports that they needs.

(i) A Learner cannot make a plan for problem solving: IPSS gives the learner hints that show what the learner should do next (Hint function).
(ii) A Learner can make a plan, but the learner is short of chemical knowledge that is necessary to execute the next step of the plan: IPSS provides Search function that helps the learner search chemical knowledge easily.

(iii) A Learner cannot proceed with solving process even if the learner has used Hint function and Search function: IPSS provides Skip function that proceeds with one step of problem solving process instead of the learner.

(iv) A Learner cannot see what to do even if the learner has used Helping functions of (i)~(iii): After the learner gives up problem solving, IPSS shows him/her explanation of exemplary description generated by Explanation generator.

Interruption functions during problem solving: IPSS has 3 interruption strategies for specific conditions on exercise. Firstly, when a learner input problem solving process using a template, IPSS judges whether the type of the template is acceptable to the current context of the solving process. If it is unsuitable, IPSS suggests his/her mistake. Secondly, when a learner fills a blank in a template with mistaken or useless description, IPSS points out that it is invalid and then requests input again. Finally, when a learner retries a problem and the learner reaches the part that mistook in the past, IPSS warns on the mistake.

History functions: History function records learner's history on operations and mistakes and shows the leaner his/her history when he/she wishes. IPSS provides three types of history functions. First, history of mistakes: IPSS records the location of mistakes in the solving process, mistakes of choosing template, and mistakes of filling blanks in templates. Secondly, IPSS records the parts of the problem solving process where each learner is helped. In addition, hints given by IPSS, and searched knowledge by Searching function are also recorded. Finally, learner's input and correct answers are also recorded.

Searching function for chemical knowledge: Learners can consult chemical knowledge appeared in the current exercise relatively easily by Searching functions. For searching, IPSS accepts the following keys: By name of a concept (material, phenomenon, unit, etc), and by (a part of) formula. Combination of the keys is also acceptable.

3. Implementation of IPSS

At first, the learner inputs a problem number. Exercise solver solves the problem and generates CWM and PSPM. Explanation Generator generates explanation by referring CWM and PSP. The learner inputs the problem solving process with templates. IPSS evaluate the input and gives him/her the result. IPSS helps the learner by Helping function, Interruption function, History function, and Searching function.

Figure 2 shows interface of IPSS. (A) is the main frame. (A)-(i) is frame for displaying learner's answer. Characters in this window are displayed in three kinds of colors: black is correct part, red is wrong part, and blue is skipped part (inserted by IPSS). (A)-(ii) shows history of wrong inputs, used Helping function and messages from IPSS such as explanation of themes of the exercise. (A)-(iii) are buttons for selecting templates. When learners push a button, a template window appears. An example of template windows is (D). In IPSS, learners use templates to describe problem solving processes. We design 12 kinds of templates by case study on representation of problem solving processes in the textbook [6], and interview with teachers of high-school chemistry. IPSS has two types of simple templates: on phenomenon and on calculation. We also prepare compound templates which are composed of simple templates. They work as scaffolds for learners to pay attention to good style of describing problem solving process. For example, template window (D) means "Variable x means [Mass], x=[1.0 / 2]=[0.5]" ([__] are blanks in the template). (A)-(iv) are buttons for Helping functions. (A)-(v)shows the current problem. Learner can select a problem from problem collection by (A)-(vi). Learners can retry from any step of the problem by (A)-(vii). (B) is the window for Searching function. Learners can input keywords to (B)-(ii), then the results are displayed in (B)-(i). When learners

finish answering, the answer and adaptive explanation generated by IPSS appear in (C). Learners can compare them and do reflection on styles of describing answers.

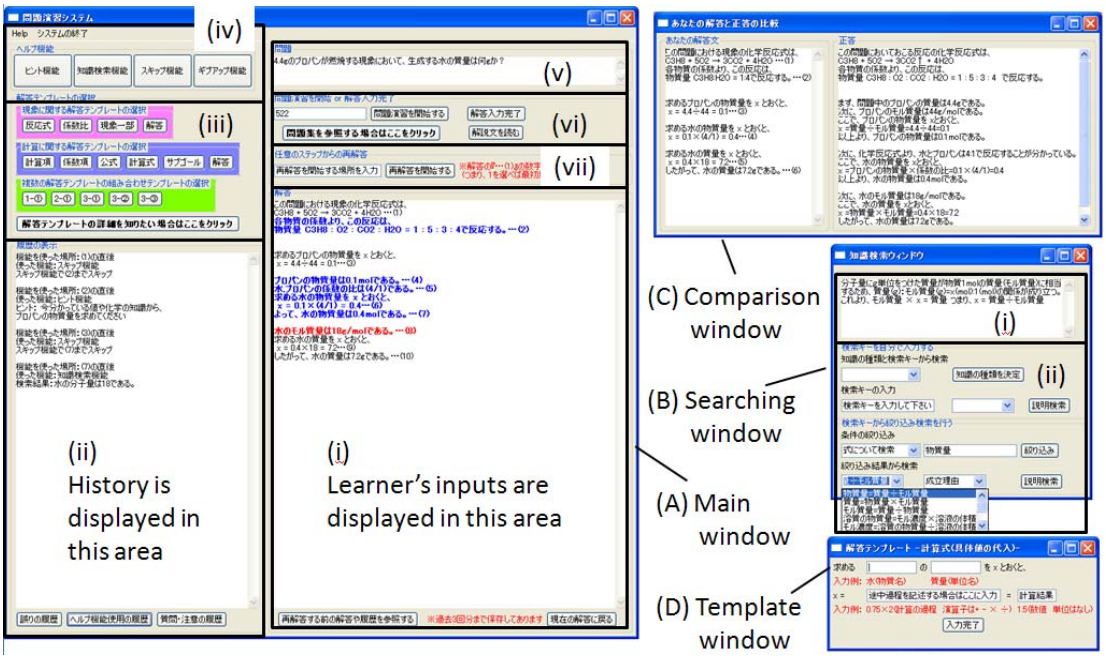

Figure 2: Interface of IPSS

4. Experimental Evaluation

We perform an experiment to evaluate effectiveness and usability of IPSS. We measure the effectiveness by comparing learners using IPSS with ones using paper media. Moreover, we ask learners using IPSS the usability by questionnaire. A purpose of the experiment is to measure how much sense of resistance they feel. There are 10 subjects of this experiment who are undergraduate students or graduate students. They major in computer sciences and have learned chemistry in their high school days.

(1) At First we performed pre-test that consists of 50 basic problems in order to measure each subject's understanding level on chemistry. Then the subjects are separated into two groups (group A, B) of which average scores are nearly the same level. The result of the pre-test is also used for making each subject's learner model. Explanation Generator can generate adaptive explanation by referring the learner model [3].

(2) We lecture in 10 minutes to remind the subjects of chemical knowledge that is themes of problems used in the following experiment.

(3) We give the subjects 25 minutes to solve 4 problems and to do reflection on them. In this phase, learners in the group A exercises on IPSS and ones in the group B exercises on papers (Group A is lectured on methods to operate IPSS before solving the problems).

(4) We performed post-test to measure effectiveness of each exercise. The post-test includes 10 questions; 8 are basic questions which are also used in the pre-test, and 2 are advanced questions. We can see the effectiveness of the exercises in increase of the basic question's scores from the pre-test to the post-test.

(5) We measure usability of IPSS by questionnaire. We let the group B use IPSS in 10 minutes in order to they also have experience using IPSS.

Table 1 shows scores of each group. Comparing the group A with B, group A's average scores of both the basic questions and advanced ones are better than B. Moreover, The group A's average of score increase on basic questions is also better than B. The results suggest exercises using IPSS is more effective than using paper media.

Table 2 shows the result of questionnaire on usability and the sense of resistance. At question1 (How about usability?: bad (=1) to good (=5)). On question2 (What do feel if you have to do problem exercise on IPSS: feel the sense of resistance (=1) to feel comfort (=5)). By the result on question1, we find IPSS has both good and bad factors on usability. The opinions of subjects are as follows: As a positive comment, all subjects wrote that Helping functions and History functions are useful. But some subjects wrote "choosing correct template takes costs", and "learners have to describe answers along with discipline made by IPSS developers". These opinions suggest we will have to improve usability in order to apply IPSS to actual educational field. In particular, input method using templates is important. On the other hand, result on question2 shows that learners don't feel so critical sense of a resistance on IPSS (even if they don't feel so better than paper media). However, we have to point out that all subjects are familiar with operation on PC, so the score might be lower if the subjects are usual high school students.

These results suggest that supports of IPSS will be accepted by learners. On the other hand, we find only weak evidence on effectiveness on learning using IPSS. We have to develop more effective pedagogical strategy.

Table 1: Scores of the pre test and post test

	Common 8 problems			All (10)
	pre test	post test	increase	problems
Group A	3.4	5.6	2.2	7.0
Group B	3.0	4.6	1.6	5.4

Table 2: Result of questionnaire

	Group A	Group B	Total Average
Q1	3.6	3.4	3.1
Q2	3.4	2.8	3.1

5. Conclusion

We constructed IPSS and performed a simple experimental evaluation. The result of this experiment shows we have to improve usability of IPSS. Although IPSS isn't evaluated in actual schools, we are planning to test IPSS in a high school. We are also planning to apply IPSS on a network based homework system.

References

[1] Ishima, N., Ueda, T., Konishi, T., Itoh , Y(2006). Developing a Practical Domain Knowledge Base and Problem Solving System for Intelligent Educational System of High School Chemistry. *Proc. of ICCE2006*. pp.115-118,

[2] Ueda,T., Nanko, R., Konishi, T., Itoh,T (2007). Extension of Problem Solving System for Intelligent Educational System of High School Chemistry. I*CCE2007, Supplementary Proc.:Poster*, pp. 49-50.

[3] Okada, Y., Konishi, T., Itoh, Y (2009). Explanation Generator based on Themes of Exercises and Learnder Moderl in TIS for High School Chemistry. *Proc. of ICCE2009*. pp. 137-141.

[4] VanLehn, K. , Lynch, C. , Schulze, K. , Shapiro, J. A. , Shelby, R. , Taylor, L. , Treacy, D. , Weinstein, A. , Wintersgill . M. (2005). The AndesPhysics Tutoring System: Lessons Learned. *International Journal of Artificial Intelligence and Education , Volume 15*(3) , pp. 147-207.

[5] Suuken Syuppan (2002) Koutou gakkou Kagaku I, Suuken Syuppan (in Japanese).

[6] Kihon mondaisyu Kagaku IB (2003), Shinkou syuppansya Keirinkan (in Japanese)

[7] Lin, X. , Hmelo, C. , Kinzer, C. K. , Secules, T. J. (1999). Designing Technology to Support Reflection. *Educational Technology Research and Development, 47*(3), pp. 43-62.