AR-based Learning Support System for Inorganic Chemistry

Masaru OKAMOTO[a*], Ryoya SUMIDA[a] & Yukihiro MATSUBARA[a]
[a]*Graduate School of Information Sciences, Hiroshima City University, Japan*
*okamoto@hiroshima-cu.ac.jp

Abstract: In this paper, we proposed AR-based learning support system for inorganic chemistry. In order to perform experiments in virtual environment, markers are utilized as control interface and arranged markers are recorded by USB camera. Virtual environment is created from recorded image and various CGs (such as beaker, flame and so on) corresponding to markers. By operating markers, user can perform various experiments (such as flame test). Additionally, so the system can give questions and hints, user acquires knowledge of chemical reaction by solving questions in virtual environment. The verification of the proposed system was conducted by analysis of 12 subjects' learning results.

Keywords: Augmented Reality, Experience-based Learning, Inorganic Chemistry

Introduction

The importance of learning from experiences is strongly described by many teachers and researchers [1]. In order to understand the physical phenomena, our group proposed VR-based learning support system. Virtual environment can show simulation of dynamics experiments for learner. This simulation helps learner to understand the physical phenomena intuitively. In the fields of chemistry learning, experience-based learning support systems were also proposed [2], [3]. Konishi developed of an Intelligent Practice Support System (IPSS) for high school chemistry [2]. IPSS can solve problems and evaluate learner's problem solving process using the result. However, as for field of inorganic chemistry, IPSS is not taken into consideration in study. In the field of inorganic chemistry, it is important for learners to observe an experimental result and process of experiments in Japanese High School education.

In this paper, we proposed AR-based learning support system for inorganic chemistry. Although the experience-based learning support systems using AR technology were developed [4], [5], most of all systems need actual instruments. By this limitation, there is difficulty of preparation and risk. So, in the proposed system, a virtual experiment environment is constructed without the actual instruments. In order to perform experiments in virtual environment, markers are utilized as control interface. Virtual environment is created from recorded real image and various CGs corresponding to markers. By operating markers, user can perform various experiments (such as flame test). Additionally, so the system can give questions and hints, user acquires knowledge of chemical reaction by solving questions in virtual environment. Therefore, there is possibility that learner can find his/her mistake through experiments corresponding to given question. Thus, by using proposed system, leaner can learn about chemical reaction in inorganic chemistry through trial and error.

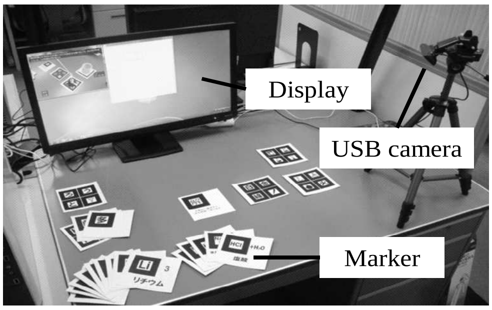


Figure 1: The structure of the proposed system

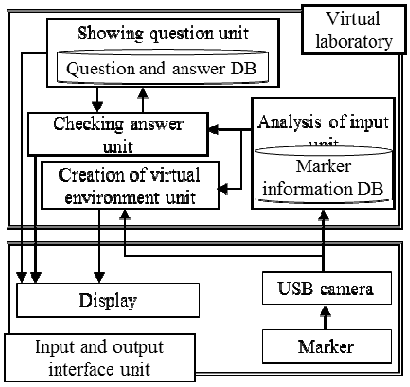


Figure 2: The system structure of the proposed system

Table 1: Examples of Markers corresponding to instruments and item for experiment

	Instruments	Solutes	Water solutions
An Example Image of Markers			

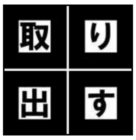
1. AR-based learning support system with questions for inorganic chemistry

1.1 System structure

Figure 1 and 2 show the overview and structure of proposed learning support system respectively. As shown in Figure 1, USB camera records image of user's operation in order to create the virtual environment for experiments based on real image and CGs. Simulation of experiments and creation of virtual environment are carried out by computer, and in display virtual environment (processes and results of experiments) is displayed. In order to construct the virtual environment from real image recorded by USB camera, user's operation must be recognized from real image. Then various markers are utilized for recognition of user's operation. By putting and moving marker in recorded area, user's operation of items, used for performing experiments, are easily recognized. Table 1 shows examples of markers used in proposed system. Used markers are classed into 6 groups. The set of multiple markers is used as marker corresponding to instruments (such as burner and beaker). By putting these marker in recorded area, this system understand that user utilize the corresponding instruments. Additionally corresponding CGs are displayed near the marker in virtual environment. Then, using solutes and water solutions have to be selected for performing experiments which user wants to conduct. In order to indicate the using solutes and water solutions, markers shown in Table 1 are used. In the proposed system, 17 solute markers and 6 water solution markers are prepared.

However, in order to perform experiments in virtual environment, not only the markers as instrument and so on, but also markers corresponding to operation are required. So operation markers shown in Table 2 are used for showing user's intention of operation. Moreover, in the proposed system, practice questions of inorganic chemistry are used in order helps user's learning. For answering a question, user can put marker corresponding answer command in recorded area. By using these markers, user can operate various items in virtual environment learn the chemical reaction about inorganic chemistry.

Table 2: Examples of Markers corresponding to operation by learner

	Operation for water solutions	Adjustment of Solutes' parameters	Checking leaner's result of experiment as answer
An Example Image of Markers			

(a) Creation of copper ion solution (b) Dipping a platinum wire into solution (c) Putting a wire into the flame

Figure 3: Example of experimental process flame color test.

Next subsection shows the chemical experiments which can be carried out in virtual environment of proposed system.

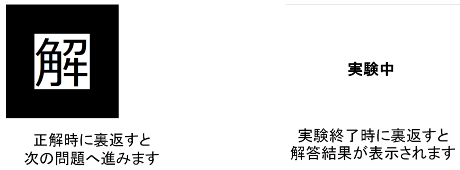
1.2 Chemical experiments in virtual environment

In this system, user can perform the three chemical experiments (1: flame color test, 2: precipitation of ion, 3: positive ion analysis). These experiments can be selected by putting instrument markers (shown in Table 1) which are used in experiments.

For example, a virtual environment of flame reaction experiment is shown in Figure 3. In Figure 3(a), four markers corresponding to instruments and a solute marker are put in recorded area. By putting or moving solute marker as copper ion near the beaker marker, user can create water solution containing copper ion (shown in Figure 3(a)). In Figure 3(b), by moving a platinum wire marker near a beaker marker, a virtual platinum wire is dipped into beaker and a wire have gotten copper ion. In next process, so user should put a wire into the frame in virtual environment for checking change the frame color, platinum wire marker is moved near the burner marker (Figure 3(c)). Then, user can observe the characteristic color of the flame (green) when the wire is in the edge of the flame. As described above, user can conduct the frame reaction experiment by using only the proposed system. Additionally, in virtual experiment, there is no risk by using flame (burner) and no necessity to wash the instruments under the experiment.

By performing these experiments, user can see and know the chemical reactions which are given by textbook and reference book used in Japanese high school. However, it may be difficult for learner to learn chemical knowledge from only these experiments. Additionally, in order to perform experiments effectively, various operations in virtual environment including some operations which cannot be performed in real experiments should be designed.

Next subsection describes about the questions-based learning process and designed operation method for proposed system.



(checking the result of experiment) (during experiment)

(a) An example of presentation of a question in virtual environment

(b) Checking marker

Figure 4: Question and marker for checking answer.

1.3 Question for learning about inorganic chemistry and operations in virtual environment

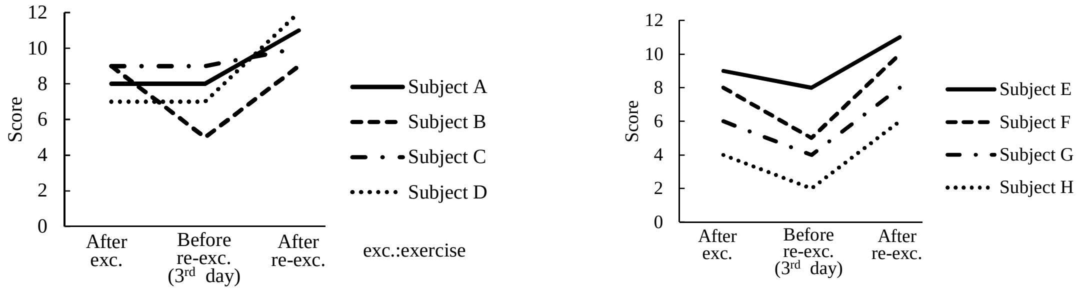
In this subsection, at first, question-based learning approach is described. The question is displayed on the upper part of virtual environment. Figure 4(a) shows an example of presentation of question in virtual environment. In this question, “What is ion which can change the color of flame into blue-green?” is written in Japanese. By presenting a question, user perform experiment in order to find answer about presented question. In proposed system, user’s answer corresponds to results of experiment. User can show his/her situation (experiment is finished or not) by checking marker (Figure 4(b)). This marker is printed at both sides. When this marker is turned, system evaluates the answer (result of experiment). If user makes mistake, hint is displayed on the underside of virtual environment and user perform experiment again based on given hint. After having a correct answer, by turning this marker again, next question is given for user.

Thus mentioned above, by answering to the given question through the experiment in virtual environment, the user can learn about inorganic chemistry. Additionally, markers, corresponding to some functions, help user to perform learning and experiment efficiently.

2. Evaluation experiments

In this section, in order to evaluate the learning effectiveness of proposed system, learning experiments about chemical reaction were conducted. Six subjects (A, B, C, D, E, F, G and H: graduate students and college students) participated in the experiments. Each subject took tests three times. The first test was conducted after the subjects learned about the chemical reaction using the proposed system. The second test was conducted three days after the first test. After the second test, all subjects learn the chemical reaction of inorganic chemistry again using the proposed system. The subjects, that reviewed chemical reaction with the proposed system, were confirmed his/her score by the third test. The number of questions, given by the proposed system, is 12. Similarly, the number of questions written in test is also 12. In the experiments, the subjects were divided into two groups (Group 1 and 2). In order to avoid the influence of given questions, the used questions and test for Group 1 were different from Group 2’s that. The number of questions of each experiment (flame test, precipitation of ion, analysis of positive ion) is 4 respectively.

The results of test are shown in Figure 5. At the first test, most of subjects belonging to Group 1 could get the high score (60% or more). Although the scores of Group 2 are totally smaller than the scores of Group1, it is confirmed that subjects can learn about chemical reaction of inorganic chemistry by using the proposed system. Next, the results of second test show that most of subjects’ score is smaller than the scores of first test. However, the scores of the third test increased from the scores of the first test by relearning using the proposed system. (see results of the third test in Figure 5). From these results, it is confirmed that the proposed system can help learner to learn the chemical reaction of inorganic chemistry. Additionally, it is expected that subjects' learning results improve by learning repeatedly using this system.



(a) Scores of Subject A-D (b) Scores of Subject E-H

Figure 5: The results of scores of all subjects.

3. Conclusions

This paper proposes an AR-based learning support system for inorganic chemistry. The system utilizes markers as control interface in order to perform experiments in virtual environment. Based on positions of arranged markers, virtual environment is constructed from recorded image by USB camera and CGs (such as beaker, flame and so on). By operating markers, user can perform various experiments (such as flame test). Additionally, so the system can give questions and hints, user acquires knowledge of chemical reaction by solving questions in virtual environment.

In future works, we plan to increase the number of subjects and test times for detailed verification. And, we would like to improve the proposed system by adding the effective feedback information for user in learning process. Furthermore, questions and suitable hints given by this system should be investigated.

Acknowledgements

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