

# AR Chemistry : Building up Augmented Reality for Learning Chemical Experiment

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**Abstract** - Learning is changing behavior and ideas by storing experiences and acquiring knowledge. We focus attention on Chemistry in various learning. This paper describes a learning assist system for chemical experiments "ARChemistry" which is used in augmented reality and tabletop interface for combining physical papers and digital content.

In this system, tabletop interface shows needed related information on tabletop interface. Augmented reality enables us to show chemical reactions by using a virtual model. The user's history is stored for the feedback of the experiment. ARChemistry's feedback function enable us realize mistakes that are made in the "Which procedure", "Who", and "What operation" aspects of the experiment. There are no methods to catch mistakes on traditional experiment.

Through experimental use, the results showed that an augmented reality interface system worked appropriately.

**Keywords:** tabletop, augmented reality, collaborative work, multi user, chemistry

## 1 Introduction

Learning is to change thinking and actions by experience and storing knowledge, for example, remembering how to get to a new office, making a presentation or memorizing new words.

In this research, we focus on academic learning. There are many different types of learning. Collaborative learning is one type, in which, several people work together to achieve a common goal. Collaborative learning often takes place in chemistry courses during group learning experiments. We decided that this is one effective way of learning[1][2].

Many researchers have studied collaborative learning systems that use a tabletop interface or tangible device. Recently systems have been developed with large displays that allow two or more users to intuitively operate the device[3][4][5]. These systems allow users interact with physical objects and retrieve relevant digital information. This paper will propose "ARChemistry" should be used in introductory chemistry courses. The system assists the chemical experiment learning by using augmented reality (AR) and physical objects. The system has an experiment study space with the tabletop interface, and we apply that to chemical experiment. When students use the AR loupe for an experiment they will be able to use physical objects view 3D animations and retrieve any needed information like moving ion, chemical reactions. Augmented Reality offers a way to merge virtual graphics with the real

world in real time[4]. Users will be able to see invisible objects with the system.

By Storing history information the system allows users to search for and find their mistakes in the "Which procedure", "Who", and "What operation" aspects of the experiment. With the conventional experiment it is impossible to refer to history information to find mistakes. It was impossible to refer the history information, but our system enables us to get the feedback. It is important for student to identify and isolate their mistakes. To confirm the utility of this system, an assessment experiment and user discussion were done.

## 2 Related Work

Learning is our ordinaries of life and it influences our operation afterward. Everyone has done it regardless of conscious or unconscious consideration. There are many different types of learning and an Academic learning is a conscious learning.

It falls into two general categories of learning that one is to learn from a textbook and a reference book or that another is to learn from the out-of-door activity and experiment. We focus on the experiment learning of the experience type[5].

### 2.1 Experiment Learning

We view the experiment learning as a collaborative learning that some facing people work jointly at the same time. The second learning style is class room learning that teacher stands in front of students. Learners often achieve high result with the collaborative learning more than with classroom study[1].

In this case, important points are evaluation to group and personal responsibility. Evaluation to group has all learners in group effects in aiming to achieve high level. Working in them responsibility, learners have a great awareness and get a high result. Because two factors are direct motivations for learning. Based on these factors, we focus on the chemical experiment that many students do it at the same time and that chemical reaction is very impressive.

## 2.2 Problem of Experiment Learning

In this research, we make the virtual chemical experiment to assist chemical learning on the tabletop interface. In view of the following factors, we designed the system in order to do such the experiment as actual experiment.

- Cooperation with text study
- Experiment accident
- Experimenter's error in operation
- Experimental environment

First, it is difficult for people to always put all studied information in the head while experiment. But students need many chemical information in experiment to understand invisible reaction. For example, combining ion and electron/other ions, features of cation, how to use instrument and so on. As a result, students often refer to the text or just do without right information.

Second, chemical accident and user's mistake will be caused even if we pay very attention to them.

Third, chemical experiment needs equipment mostly which is not enough at home.

## 3 ARChemistry

ARChemistry is a supporting system for chemical experiment study. The system applies 3DCG to virtual experiment space on tabletop. If the above-mentioned problem is based, it becomes an important point in the following four points.

- Visualization by AR
- Display related information in experiment
- The experimenter's identification
- Record of experiment procedure

At first, movement of ion and electron is ordinarily invisible but it becomes visible by AR. Visualization by AR adds the understanding more than an actual experiment[8][9]. Repeating is important in study. But the repeating in experiment needs many kinds of chemicals and needs experimental instruments which we don't have usually at home. Visualization allows us using chemicals and instruments in a repetitive manner. For example HCl or H<sub>2</sub>S in chemicals and the gas burner etc can be used. These reduce cost and risks. Additionally, this system leverages not only AR but also physical objects. It becomes possible not to lose the experiment feeling by operating physical objects like beakers.

Second, if we access an object, system displays some related information on tabletop. Mainly the information displays ionization tendency or contents of beakers and so on. This operation bridges the gap between text study and experiment study.

Third, identification and record allow users to search for and find mistakes. Correcting work is difficult in an actual experiment though some chance of study are ruined when the

experiment is finished while not correcting a mistake. However, warning and feedback became possible by recording each user's record. Warning is to inform them of the thing that causing to the accident when keeping experimenting or the experiment cannot be correctly ended while working on the tabletop interface. Feedback is to be able to confirm and isolate whether it made a mistake in "Who", "Which procedure", and "What operation" because the procedure and the user's correspondence are made the text sentences after working, it was not possible to do by an actual experiment.

We aspire achievement of construction that virtual experiment system has four necessary elements.

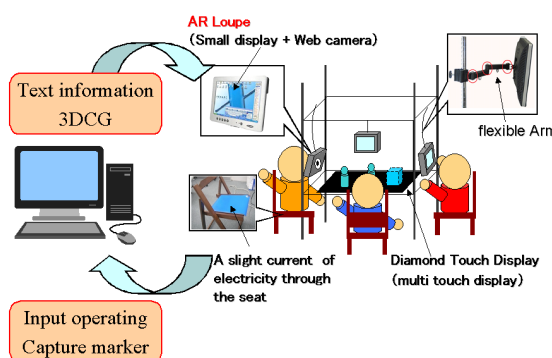


Figure 1: Hardware Construction

## 3.1 Implementation

This system keeps the horizontal and arranges a large-scale touch sensor display (DiamondTouch[6][7]) as shown in Figure 1. The electronic information is projected from the top of the rack, and the physical objects are on the display. We links the information and physical objects with tabletop interface. When user operates a beaker, the system displays beaker's contents information. In addition, we built up the AR loupe which has the Web camera behind a small display. We install the AR loupe by each user's left side. When AR loupe captured an AR markers, AR loupe will display some 3DCG about experiment which are images or some 3D animation. The system progresses order by order in the following three parts.

- operation physical object
- display AR
- operation with tabletop interface

It explains details and the manner of operation of these three parts in order.

### 3.1.1 Operation Physical Object

In this system, user can recognize the beakers as a lab ware. The experiment feeling is not ruined because we move the physical object on the touch sensor display, and the system can recognize it.

To recognize the physical object with the system, the copperplate and the copper wire with high conductance are put as shown in Figure 2.



Figure 2: Overview of Physical Object With Copperplate

A slight current of electricity from DiamondTouch passes the user's body when they operate a physical object, and it is read in the system[6][7]. DiamondTouch is the multi touch sensor display which can recognize the multi point and who use the system. Moreover DiamondTouch can distinguish the physical object according to the size of the sheet copper.

By using this function we can mix contents of the beakers virtually. As Figure 3, user grips the beaker firmly for eliminating a gap between hand and beakers. When we down the beaker on the tabletop, it was recognized. If the operation was correctly, included information would be shown on your space at Figure 4. And user select blending button when last two beakers have been recognized to the system. A marker includes text information and 3D animation, appears with sound effects. User can check the chemical reaction with AR loupe and text about experiment on tabletop.

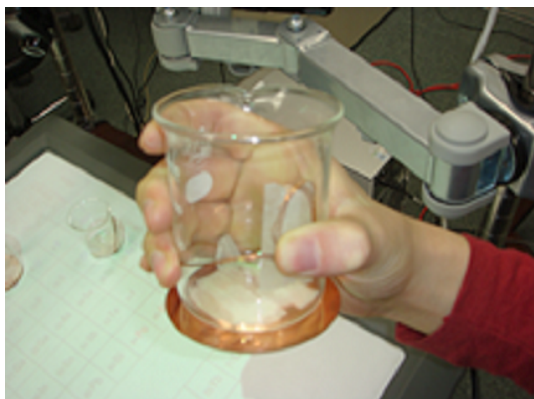


Figure 3: Gripping Physical Object

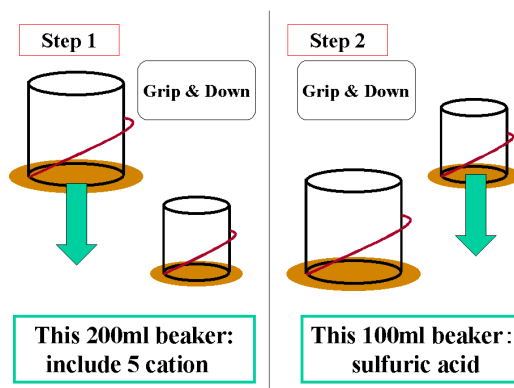


Figure 4: Physical Object Recognition

### 3.1.2 Display AR

We can use AR loupe for viewing virtual objects. As Figure 5, AR loupe is constructed by a 9 inch display and Web camera (Qcam Pro for Notebooks). AR loupes are arranged for all three user's left side. Flexible arm fixes them strongly.

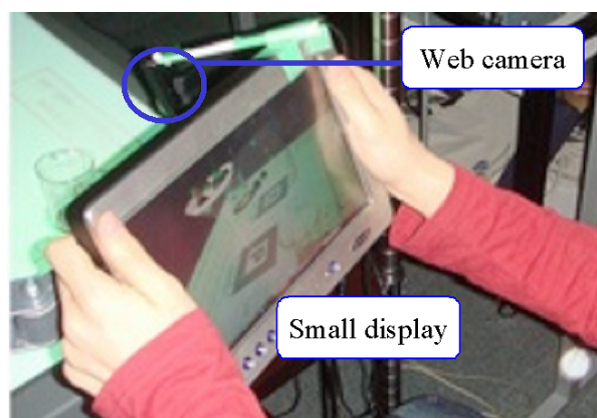


Figure 5: Operating AR Loupe

AR loupe distinguishes the presence of the AR marker through the image which Web camera captured. When the AR marker exists, loupe's display shows 3DCG on the marker after distinguish the shape. Moreover, because the AR marker has been linked not only 3DCG but also chemical information, textual information is shown on the tabletop and 3DCG is possible to display in loupe's display.

Because the AR loupe can be freely moved by using the arm as shown in Figure 5, it is possible to operate the system without closing both hands on the touch sensor display.

When users want to see 3DCG, they can pull AR loupe and peer into the screen of own small display. The display shows some animation. For example flame reaction or a precipitate by uniting ion and so on.

### 3.1.3 Operation with Tabletop Interface

We perform procedure chiefly by using the touch sensor display. Figure 6 shows an actual operation screen.

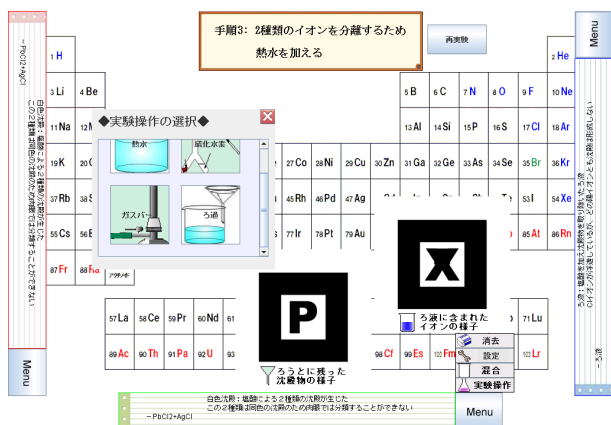


Figure 6: An Operation Screen on Tabletop Interface

It is possible to operate the system intuitively with touch sensor display. Additionally, We innovate a way to use menu list like a usual PC for handling so operating system is more easily. There are some panels to play the system on tabletop display. In figure 6, there are "menu list" at upper blue menu panel and "AR panel" which has an alphabet on black square.

1. an individual note pad panel  
When user operates the system, chemical information of operated object is shown to each user's front panel. The information will be shown in touching AR panel, in gripping a beaker, and after chemical reaction.
2. an indication panel  
This panel shows what you must do next. If you mistake the procedure, the system alerts that you are wrong with warning tone and message.
3. hiding button in menu list  
It hides the marker which user feels obstructive at operating it.
4. log button in menu list  
When this button is pushed, select panel appears. And on that panel, user decides whether they log or not, and what log file name is.
5. blending button in menu list  
As shown in Figure 4, system memorize informations of two beakers. When the indication panel says that you must blend two beakers, this button is possible to use. At blending, AR panel shows 3D animation of chemical reaction process.
6. apparatus button in menu list  
In touching apparatus button, chemical apparatus panel appears as shown Figure 7. When user touches icon in this panel, system shows paired AR marker which corresponds to each operation such as lab wares and a reagent. Figure 8 seemed to select a gas burner icon, and to have looked into the marker with the AR loupe. When user touch again, the gas burner reacts another

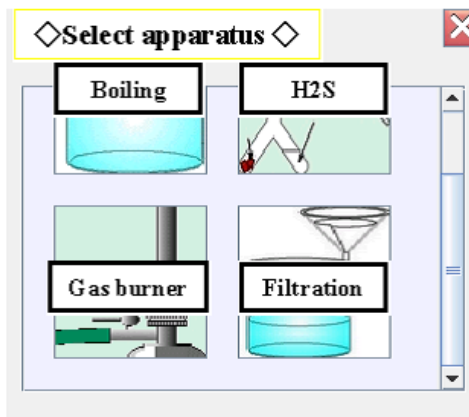


Figure 7: Overview of Apparatus Panel

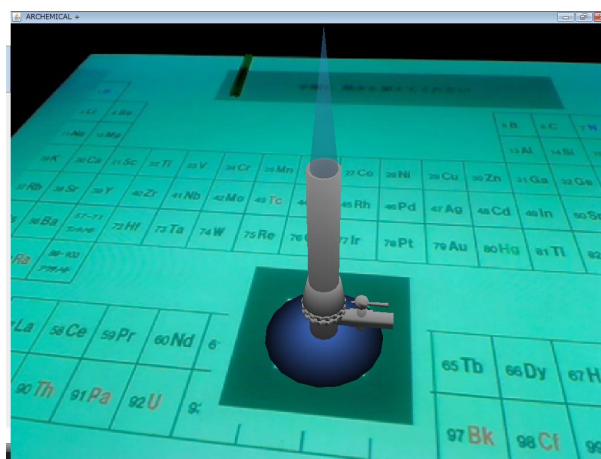


Figure 8: Apparatus : A Gas Burner for Flame Reaction

flame color of the classified ion and user confirms whether it is a specific ion.

There are filtration, to pour heated water, the outbreak of the hydrogen sulfide as well as a gas burner.

### 3.2 Record

When we do the experiment operation, our system records not only the operation but also a physical object and an operator. In a word, Users can confirm "Which procedure", "Who", and "What operation" aspects with the historical information whether they made a mistake. As a result, in actual experiments it was difficult to specify a mistake of procedure but our system allow users to discover a critical point in the experiment. And the system allow users to be able to prevent the accident before happens in real experiment because they are taught by warning message which shows that you must fail if you keep to do your operation.

## 4 User Study

### 4.1 Overview

We conducted a user study to clarify the effects of AR-Chemistry on users. The objective of this study was to observe how the system would affect the users' chemical experiment, and how users would interact with the system. Eighteen university participants aged 21 to 24 years (14 men and 4 females) were asked to participate in this experiment. The participants worked in pairs during the experiment. All of the participants were inexperienced in regards to chemical activity, and were novice users of the interface that we developed.

We used HMD in order to compare ARloupe to a system with HMD. The participants received an explanation of how to use each system before starting the experiment ? cation analysis. The participants were asked to accomplish chemical experiment without a time restriction using each system. The experiment had the following two system setup: Diamond-Touch and ARloupe, and DiamondTouch and HMD.

- ARloupe: Participants had a small display to capture markers and to show 3DCG. They were able to change display's positions freely anytime so they can see both surface of DiamondTouch and ARloupe separately.
- HMD: Similarly participants used a HMD to display 3DCG. HMDs were eMagin Z800 3D Visor and i-visor FX601 - SVGA 800 × 600. We placed a web cam to HMD in order to use it by video see-through type.

We wanted to understand how ARChemistry would allow participants inexperienced in chemical experiment to accomplish cation analysis. We observed the user interaction in each setup, and analyzed whether ARChemistry supported user activities related to chemical experience even if the users had little or no experience in chemical. After accomplishing the cation analysis, we asked participants to fill the questionnaire (ten stage evaluation and free description column).

### 4.2 Result

Through this experiment, we were able to confirm some practical advantages of ARChemistry in the process of accomplishing the cation analysis. The Table 1 shows the average time and standard deviation to finish the experiment. Participants with ARloupe finished more fast than with HMD. The considerable factor of this difference is visibility. User with HMD said that he had been surprised at suddenly user's hand had broken into his sight while he had focused on the task at hand. And another said that it had been difficult for him to read text on surface by image degradation through the HMD. This is why watching at text on surface of Diamond-Touch with HMD is smudgy. Users with ARloupe can watch at the text by naked eyes and check 3DCG in small display so they can have broad eyeshot.

The Table 2 shows the outcome of a questionnaire. When the summary is seen, the high reputation value is obtained for the question No.1, No.5, No.8 that we emphasized these

Table 1: Average Time and Standard Deviation to Accomplish The Experiment

Method	Average Time	Standard Deviation
ARloupe	479.4	102.3
HMD	751.8	155.2

Table 2: Summary of Questionnaire Response.

No.	Question	Average
1.	I found easy to manipulate table top	8.0
2.	I found it intuitive to use beakers	7.2
3.	I performed AR Loupe as intended	7.4
4.	I imagined the actual chemical	7.5
5.	I found it supporting experiment to use 3D or text information	8.1
6.	I feel fun to use this system	8.7
7.	I found Chemistry of interest	6.5
8.	I found easy to understand chemical reaction	8.1
9.	I found the system available for review and preparation	7.7

themes when we made the system. It says that the participants were able to use the system easily by touching the table-top screen or using physical objects (beakers) or ARloupe. Responses say that ARChemistry's operation was easy because it was a very simple operation. About No.5, No.8, they say that 3DCG improves users understanding. In comparison with text learning, virtual chemical reactions are so clear that users see how some ions react.

In addition, the question No.6, No.9 was the high reputation values too. These comments are that this experiment was so fun because we had been speaking each other while operating and that it was possible to operate the system without getting tired. Participants seemed to actively interact with AR-Chemistry while communicating with each other and to provide understanding of chemical experiment. Efficiency goes up to study enjoying it, so this evaluation backs up the utility of this system that these evaluations.

On the other hand, No 7 is lower score than other question. This is why participants who were not interest in chemical from the beginning didn't get their interest from the system a short time later even if that operating is fun and easy to understand.

## 5 Conclusion

There are styles of the learning now for many divergences. Interaction methods with AR and a touch sensor display increased slowly in that. The system "ARChemistry" used AR and tabletop interface and put a focus for the chemical experiment learning. In this system, tabletop interface can show needed related chemical information on tabletop and how you push forward operation. Augmented reality allow us to show chemical reaction by using a virtual model. And the feedback of the experiment is enabled by storing user's history. The

feedback is able to realize us the mistakes made "Which procedure", "Who", and "What operation" aspects. They are new method to combine text study and experiment one in chemical. Through evaluation experiment, the results showed that the system of an augmented reality interface worked appropriately and is interesting in learning and discussion each other.

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