Development and Practical Use of Microcomputer Software in Chemistry Curriculum

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This paper describes a review of microcomputer-aided instruction in chemistry curriculum through the author's overseas research work, and a policy of preparation and practical use of chemical education software. Microcomputer software is needed for the chemical education, but it seems that there are not so many kinds of software in Japan. The author has studied on chemical education software and published some attractive results. Microcomputer software of chemical education may cover the chemistry curriculum.

Key Words: Microcomputer Software, CAI, Chemistry Curriculum, Chemical Dry Lab, Software Communication.

The computer age would require the use of microcomputers in chemical education in Japan. A new approach to teaching chemistry has been developed complementary to the traditional education methods of textbook and blackboard. Computers can be of great help in overcoming chemical complexities that often arise in chemistry teaching. The visual techniques available when using a microcomputer offer many advantages: colorful graphic display, flexible tool, and so on, as teaching materials. A new approach to teaching chemistry is the use of computer-aided instruction(CAI), and new media, such as CD-ROM, sounds and voice-speaking. They are very good tools. Besides chemistry, CAI is very useful for several subjects and educational fields.

1) Situation of CAI in Chemistry Curriculum

It is already ten years, since Prof. Shimozawa had organized the chemical education division of the Chemical Society of Japan, and started to develop the software for chemical education in 1981[1]. However, the application of CAI to chemistry is still in the research level, and is rarely used practically for schooling.

CAI software is needed for the teaching of chemistry. However, there are not so many kinds of CAI software in Japan, because the research of CAI of chemistry has only begun recently at a researcher's level. Development of CAI software as a text is in an individual level, now also without Japanese Government support. In Japan, developing groups for chemical education are in the follows;

Prof. Shimozawa's Group, and

Japanese Association of Personal Computer for Chemists.

These activities are microcomputer software communications in chemistry and chemical education[2]. The number of members is about seven hundred. Prof. Shimozawa is the president, and the author is a representative. An official bulletin of our Association, which is published four times per year, has English abstracts academically for an English reading person. It is available to you if you are a member. A topic of this journal is a paper with the full list of a program, which is very useful for users. We began operation in 1982 as a clearinghouse for instructional microcomputer information in chemistry. We have been collecting and distributing a lot of chemical softwares free to our members. Our plan of founding an academic society was authorized in 1992 by the Ministry of Education of Japan. We would reorganize it to the Chemical Software Society of Japan.

In the world, there are several similar groups including the following;

Project SERAPHIM (Prof. Moore organizes in USA), and

CTI Centre for Chemistry (Dr. Walker organizes in UK),

where CTI means Computers in Teaching Initiative. These groups are supported by big funds, and are therefore very active in the field of chemical education. The author has visited to investigate the activities of Project SERAPHIM at University of Wisconsin - Madison in USA, and CTI Centre for Chemistry at Liverpool University in UK. Project SERAPHIM began operation in 1982 as a clearinghouse for instructional microcomputer information in chemistry. It has rapidly grown into a unique organization that: carries out research; develops new materials; collects and distributes materials; trains teachers; and maintains large databases of available software, computer users, and software reviewers. It has about 650 different microcomputer programs on about 225 different disks. We would wish to exchange the CAI software, and then became a distribution center of Project SERAPHIM in Japan. We hope to establish a permanent fund in Japan in order to continue the activity of development and distribution of chemical CAI software.

Anyway, we are thinking about a policy of practical use in chemistry curriculum. The microcomputer demonstrations of chemical CAI are very useful and practical in the following five cases;

- (1) teaching before and after an experimental lesson
- (2) covering a failed student
- (3) covering a chemistry curriculum
- (4) teaching of a non-visible experimental lesson
- (5) teaching of a high-cost instrumental lesson or a dangerous

experimental lesson.

The first case is very suitable for chemical CAI, which we call chemical dry lab[3]. Figure 1 shows the scheme of practical lessons with or without a pre-teaching of CAI. For example, there are two students, A and B. If student A has undergone vaguely the practical experimental lessons without the pre-teaching of CAI, his experimental results would be full of mistakes and then he must undergo reteaching of the same subject.

Figure 1 Scheme of practical lessons with/without a pre-teaching of Chemical Dry Lab lessons.

On the other hand, as the intention of the experiment would be pre-taught before the experimental lessons, student B, who has learned given chemical experiments on chemical dry lab lesson, could run the experimental lessons more exactly and more actively than student A. With the CAI pre-teaching before the practical lessons, we would consequently minimize lesson time for the reteaching of a repeater. Furthermore, after students have undergone the experimental lessons, they would take the CAI learning in order to report the experimental results.

Next, the student, who could not take part in the practical lesson time of the chemistry curriculum, would take the chemical dry lab learning instead of the practical lessons. With regard to a failed student or a learner of unattended lessons, it is very useful to learn individually.

Thirdly, as covering a chemistry curriculum, it is suitable for learning the chemical experiments as an extracurriculum. If an interesting subject is unfortunately omitted, a student can always take the chemical dry lab lesson of the subject at his own convenience.

Fourthly, teaching of a non-visible experimental lesson is very suitable for chemical dry lab education. There are very important chemical experimental

lessons which are non-visible. For example, there are Rutherford's dispersion experiment and Millikan's oil drop experiment.

Finally, CAI can play an important part in the teaching of dangerous or high-cost experiments. There is a tendency to omit teaching dangerous experiments (where explosions may occur, for example) or high-cost lessons (an instrumental analysis, for example). CAI can be used to simulate the experiment in a dry lab or, alternatively, it can be used as an introduction to the students to prepare them for the real theory.

The importance to the chemistry student of participating in actual experiments, however, cannot be stressed enough. In fact, the more extensive the experiments are, the more effective they are. Since chemistry is an experimental science, it is also essential that students have experience of dealing with chemical substances.

2) Preparation of CAI Systems

At first we should explain preparation of CAI system is very important. How do we develop CAI system? Handmade software by a chemistry teacher is the most ideal, but a chemistry teacher is hardly the most talented person for programming. He must be responsible for the educational courseware, and construct CAI software with the help for softwaremaker and programmer. The teacher must be in a good association with a designer and programmer.

There are a lot of good textbooks in chemistry and chemical education. For the most part, real teachers always use a textbook in their lectures, because Japanese teaching style is generally by the use of a textbook and a blackboard in schooling. Recently this style is still continued. If we have a good teaching tool, we do not readily accept a new teaching style. We propose that CAI software be modelled on a textbook. We think it is a very good idea. For example, in UK Atkins' Physical Chemistry has been transferred to CAI library of physical chemistry software[4], which offers students a dynamic new way of understanding concepts of physical chemistry. It has been very effective. In Japan also Prof. Shimozawa's Group has made the teaching package of a general chemistry[5], whose idea is from the chemistry monograph. We should develop many CAI softwares from a textbook and then always use CAI text in our schooling with a help of microcomputer. This would be of great help to the spread of chemical CAI in Japan.

We would wish to make up a CAI software easily. How can we develop CAI software? As we write chemistry knowledge on a blackboard, we want to put it in a computer. In order to make up software easily, we have developed CAI building shell, such as Chemical Dry Lab shell. The technical term for this type of software is 'chemical dry lab'[2,3]. We should prepare three softwares for building a chemical dry lab system, as three followings;

- (1) Word processor
- (2) Graphic processor

(3) Building shell system

Word processor and graphic processor are available on the market. This building shell system is handmade and written in BASIC language for NEC, PC-9801 series microcomputer, and consists of many subroutine programs. Chemistry teacher has a courseware of chemistry teaching that he teaches his students on chemistry. The materials of chemistry teaching are divided into two types of information;

(1) **Letter information** (cf. sentences and chemical keywords),

(2) **Graphic information** (cf. figures, tables and modelling).

We would put letters into the building shell system by a word processor, and draw figures into the shell system by a graphic processor. The result would be a chemical dry lab system made up perfectly in regard to the desired chemical courseware.

On the other hand, software on the market is also very good. We have, for example, HyperTalk, HyperCard in Macintosh, and utilities of MS-Windows. These softwares would give us a good computational condition in order to make up CAI software easily. For an example of good use of MS-Windows, we have a Model Builder. This system was developed by Dr. Cox's project Modus in the UK. When the author stayed in London University, he made up several chemical models in the Model Builder. This is a very good tool for building CAI model. It is available.

In order to use MS-Windows 3 in a CAI system, a Visual Basic is the most suitable programming language for our BASIC users. Visual Basic is modified from Quick BASIC for Windows 3, and very useful and understandable for us. Windows 3 has Write as a word processor, and Paintbrush as a graphic processor. We can easily add the graphic information by Paintbrush.

3) Chemical Dry Lab System

In a limited curriculum, the subject of increasing educational effect on an experience learning has been dealt with by means of education technology. CAI can offer a solution to this problem, and encourage chemistry teaching. Microcomputer software of chemical dry lab education might cover a chemistry curriculum.

How about the system constitution of chemical dry lab? This system consists of two frames: explanation frame and examination frame, as shown in Figure 2. In the explanation frame, we would teach a chemistry knowledge, for example, demonstration of chemical experiments, modelling of chemical phenomena, visual instrument, and so on. In the examination frame, we would examine a student's level. There are three patterns of questioning;

(1) **choice among the five terms,**

(2) **selective keywords, and**

(3) **calculation.**

In order to test flexibly, this system has a random presentation of questioning, and a presentation of hits and answer. This system is designed so as to enable

Explanation frame	Examination frame
<ul style="list-style-type: none"> ○ Presentation of letter-to-beep ○ Stepwise study by fuction-key ○ Retaining by fuction-key ○ Simulation of chemical experiments ○ Modelling of chemical phenomena ○ Visual instruction ○ Simple operation of fuction-key 	<ul style="list-style-type: none"> ○ Choice among the five terms ○ Selective keywords ○ Calculation ○ Random presentation of questioning ○ Presentation of hint and answer

Figure 2 System frame constitution of Chemical Dry Lab.

a student to make the learning in stepwise order of functions; repeating, skipping, backing, interrupting. We have set a function-key operation of keyboard. The used function-keys are eight keys: f.1, f.2, f.3, f.5, f.6, f.7, f.9, and f.10. In order to answer by a number, we may use ten-key. The other keys aren't used, because of the simple key-operation of microcomputer keyboard. Function-key operations of a microcomputer are simple and very easy, and everyone can operate and practice this system, and causes no interference, no problem. A student, who wants to learn chemistry study, may select the desired subject or chapter, and start at the system. He may select the desired section from the menu display, and begin to study.

The system is designed so as to enable him to practice in stepwise order. Well, by student's practice, this system may make an automatic comparison of the studying records with tutorial results. When a student has been putting our system to tutorial use, the floppy disk of the system will have been recording his learning record and tutorial results. It is very useful in chemistry teacher that our system has the functions of managing and counting the learning records of the unit class.

Anyway, on a practical use, how to use practically? We think that there are two style of CAI practice, as follows;

(1) individual learning

(2) class demonstration lecture.

Individual learning means that we would supply the floppy disks of this system to the students, and then let them study in their individual time. It includes home work also. As a class demonstration, we would have a video projector connected with a microcomputer, as shown in Figure 3. This method is very useful in a class size. A visual picture of graphic display is projected on a big screen through a video projector. During the class demonstration, teacher would explain the subjects on a screen by using of an indicator, and practice in response to students.

When we would use CAI software, we should have to feed back educationally. CAI can't take place of the human teacher's role in teaching.

Microcomputer Video projector

Big screen

Figure 3 Layout of a video projector connected with microcomputer.

CAI needs teacher's follow-up. Real teacher must be covering during CAI teaching. Tutorial results are recorded during CAI learning. It is also very important point. For example, in a personal report card, when a student has been putting our system to tutorial use, the floppy disk of the system has had his learning records as a personal record automatically. An example of S-P chart[3] is shown in Figure 4. S means a student curve, and P means a problem curve. In Japan, S-P chart is very popular in schooling. If a score is more than sixty, a marking is one, and if less than sixty, it is zero. Line of the chart is ranking of students, and the row is ranking of problem. S-P chart is very useful on learning and/or teaching process.

4) Available Chemical CAI Softwares

We have been developing chemical dry lab systems all this while. In this paper, we will describe only four chemical CAI softwares.

4.1) Chemical Dry Lab

This system has eight chapters in a general chemistry, the titles of which are materials, aqueous solutions, chemical bonding, gaseous states, liquids, chemical kinetics, electrolytic reactions, and organic compounds. Figure 5 shows a sample of the display. For example, this display hardcopy is section 2 in chapter 7, which illustrates the diagrammatic representation of the electrolytic reaction on a Daniell cell. Figure 6 shows an example of examination frames. Examination 3.3 is for packing in metal crystals. These colorful circles represent sizes of particles. This hardcopy is made by photocopy, so it shows black and white. Really, this display is in beautiful color. There is a question of a choice among the five terms. In order to test flexibly, this system has a random presentation of questioning, and a presentation of hits and answer.

4.2) Seminar of Instrumental Analysis software

S - P 表										
コード	氏名	7章	5章	4章	2章	6章	3章	1章	8章	合計
002	池田	1	1	1	0	1	1 S	1	0 P	6
009	杉浦	1	1	1	1	0	0 S	1	1	6
019	吉見	1	1	1	0	1 S	0	1	0	5
003	江崎	1	1	1	0	1 S	1	0	0	5
005	影山	1	1	1	1	1 S	0	0	0	5
010	鈴木	1	1	1	1	0 S	1	P	P	5
011	高柳	1	1	1	1 S	0	0	0	0	4
007	清水	1	1	1	1 S	0	P	0	0	4
006	倉内	1	1	1	0 S	P	0	1	0	4
001	有田	1	1	1	0 S	0	1	0	0	4
020	若林	1	1	1	0 S	1	0	0	0	4
004	大内	1	1	1	0 S	1	0	0	0	4
012	福本	1	1	1	0 S	1	0	0	0	4
016	神藤	1	1	1	0 S	0	1	0	0	4
008	神藤	1	0	1	P	1 S	0	1	0	4
018	矢野	1	1	P	0 S	1	0	0	0	3
015	平松	1	0	0	S	1	0	0	1	3
013	中野	1	1	0	S	1	0	0	0	3
017	宮城	1	0	S	0	0	1	0	0	2
014	平野	1	P	0 S	0	0	0	1	0	2
	正答数	20	16	15	9	8	6	6	1	

【注：60点未満は0，以上は1で表示】

Figure 4 Example of S-P chart of Chemical Dry Lab.

Figure 5 Example of the explanation frame display of Chemical Dry Lab.

This system has a textbook which is written in Japanese[6]. In this book, there are several colorful samples of computer display. The purpose of this software development is to acquire a knowledge which would be studied at

Figure 6 Example of the examination frame display of Chemical Dry Lab.

first time for learners. Recently an electronics technology has achieved a remarkable development, and a chemical analysis method using many instruments has been developed on making remarkable progress in the precision and sensitivity of a chemical analysis. It is very important for student of a chemistry course to study an Instrumental Analysis.

As to the important kinds of main instrumental analysis methods, absorption spectrometry, atomic absorption spectrometry, infrared spectral analysis, nuclear magnetic resonance spectroscopy, gas chromatography, voltammetric analysis, X-ray spectroscopy, mass spectroscopy, thermal analysis, emission spectroscopy, and high performance liquid chromatography would be developed, and contribute to an instrumental analysis of great practical value, respectively. We would choose the former six methods as a basic one of the above methods, and then develop Chemical Dry Lab System of Instrumental Analysis in Japanese. This system consists of the above six chapters.

It is of interest to hear about such an extensive use of simulation software in an introductory analytical chemistry course. With the current high cost of modern instrumentation, instrumental methods can be taught by the use of a computer simulation.

4.3) Chemical Experimental

We have developed chemical dry lab system of a general chemistry, and physical chemistry. In general chemistry, the author wrote a monograph[7] which is entitled "Simulation of Chemical Experiments by a Personal Computer" in Japanese with CAI softwares. A topic of the monograph is textbook with a software whose program list open for users who wish to modify the program.

4.4) Chemical Calculations

The author wrote a monograph[8] which is entitled "Chemical Calculations by a Personal Computer" in Japanese with CAI software. When the author did the overseas research in 1991, it was translated from Japanese to English.

The contents are the following eight chapters; chemical units of mass, physical behavior of gases, water solution, chemical kinetics and reaction, balance of mass and energy, exploratory data analysis, least squares method, and simultaneous equations.

During oversea travel, the author had brought an English version, and showed it as a demonstration by use of portable computer Toshiba DynaBook. When the author was staying at University of Wisconsin - Madison, he had converted it from Japanese BASIC98 NEC version to Quick BASIC US IBM version, and submitted to Project SERAPHIM. We hope it would be required for chemistry users in the world. We would revise it to a new version with voice-speaking function in order to cover reading of the sentences in a display.

5) Tutorial Results and Effect

Tutorial results and educational effect are very important points, when we have applied chemical CAI to students in schooling. As to learning records, it is very important to record for a tutorial. When a student has been putting CAI system to tutorial use, the learning records are very important. Chemical dry lab system has three spreadsheet patterns; personal report card, record list of chapter part, and S-P chart. For example, S-P chart describes relationship between a student curve and a problem curve, as shown in Figure 4. It is very useful on learning and/or teaching process.

For example, in the case of an instrumental analysis software[9], as the target of this system is to acquire a knowledge of instrumental analysis, we would survey the well-known knowledge of the inexperienced students on this lecture by a pre-test. A subject of pre-test consists of basic terms and questions for six methods of an instrumental analysis as the above. The number of the lectured students was 44 persons. Students were divided into two groups from the scores of the pre-test. The results of this test is shown in Figure 7. One group A consists of students who got better marks than 30 points per 100 full marks, and the number of the students was 16 persons. The other group B consists of students who got less marks than the group A, and the number of the students was 28 persons.

In order to investigate the rate of acquiring a knowledge of an instrumental analysis, after the lecture which is assisted by microcomputer, we would give the students a test, the subjects of which are all explained at the lecture. A vertical line of the histogram in Figure 7 is a % improvement of acquiring the knowledge, which is defined as the value that the score after the lecture is divided by that before the lecture. That is, if a student gets 30 points of pre-test and then gets 90 points of final test, the % improvement of acquiring the knowledge is a value of 3. The value of the histogram means the number of persons. Left side of histogram describes the score % improvement of students who got lower marks on the pre-test, and right side those of students who got better marks. In the final test, the left side group A got 83.6 points

Figure 7 Histogram of the results of score % improvement of acquiring the knowledge.

A: students got bad marks in the pre-test;

B: students got good marks in the pre-test.

of average mark, and the other group B got 86.9 points. Each mark is a good score and achieves the pass mark sufficiently.

At the class demonstration, this system could not be evaluated by the students because the tutor would operate it and teach subjects of instrumental analysis. On the other hand, we would supply the floppy disks of this system to the students, and then cause them to evaluate this system in the individual learnings. With regard to the questionnaire, we could discuss eight points on an individual use : object of computer-aided instruction (CAI), operating interface, non-trouble operation, suitable visualization, comparison with a textbook, suitable introduction system, individual learning, and acquisition of knowledge.

These eight points of the questionnaire are classified into two groups: learning suitability of CAI system and chemistry teaching material. The first four points may belong to the former group, and the last four points to the latter.

Firstly, as to learning suitability of CAI, it is very well evaluated on man-machine interface operating, non-trouble operation, and visual representation for tutorial of Chemical Dry Lab system. However, a main target of this system would be a learning of an instrumental analysis only by using microcomputer-aided software. In particular, tutor would not support a textbook, such as the monograph[6].

Secondly, when students would want to learn an instrumental analysis for the first time, we would ask them how they would want to study it by microcomputer-aided learning or by textbook. The answer of questionnaire might show few points of comparison with a textbook and suitable introduction system. Students would wish to use both microcomputer-aided

software and textbook. The evaluation should suggest the use of microcomputer-aided instruction with a textbook.

As to learning suitability of chemistry teaching material, in particular, this system would be very well evaluated on the material of an individual studying and acquiring unknown knowledge. Both these points were quite effective as we had expected.

Next, on development of chemical CAI software, an evaluation and a feedback of the software are very important points. CAI software must always be improved with an evaluation and feed back. Handmade software by a chemistry teacher is the most ideal, but a chemistry teacher is scarcely the most talented person for programming. For this purpose, we should look at the relationship of student, teacher, and programmer to decide how to most effectively develop CAI software.

In the case of textbook, we always have a revised edition. CAI software also needs a follow-up system. An improvement and bugging of CAI software must always be continued. Unfortunately sometimes developing project has finished and closed after the development of software. This is not so good. We think an improvement and bugging of CAI software must be always continued by the developing group.

Conclusion

In a wide view of Japanese education, microcomputers are used in the following ways[10];

- (1) **in teaching computer literacy,**
- (2) **as instructional tools,**
- (3) **as tools for self-expression** (cf. word processing, drawing, composing, experimentation, and information retrieval),
- (4) **as tools for school administration and management** (cf. scheduling sociometry, preparing test items), and
- (5) **for educational research.**

The development time of microcomputer software for chemistry teaching and/or learning has been past about ten years, since the address and proposal of Prof. Shimozawa in Japan[1]. However, the recent topics of chemical education software would be still in the field of educational research, and not on impact from a practical point of chemical education view. It is very important that software is in agreement with hardware. Development and spread of chemical CAI would depend on the chemistry teacher's intention. Obviously, we have an insufficiency of microcomputer softwares for chemistry teaching and/or learning in contrast to chemistry books and texts. We hope CAI will be coming into wide use in all curricula for schooling.

Teaching computer literacy for teacher is continuing yet in Japan. However, even if the real teacher can't have a programming technique or skill to modify a microcomputer software, he can / he should introduce it to his lecture and experimental lessons. We believe that a chemistry teaching and/or learning

should be innovated by the advantage of microcomputers, since we are living in the computer age.

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化学教育におけるパソコンソフトウェア の開発と活用

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この論文は著者が在外研究を通して、化学教育におけるパソコン支援教育について研究し総説したものであり、さらに、化学教育ソフトウェアの開発と活用における方策を論じている。化学教育には、パソコンソフトウェアが必要であるが、日本にはそんなに多くの種類のソフトウェアがあるわけではないと思われる。著者は化学教育のソフトウェアについて研究していく中で、何種類かのソフトウェアを開発・出版した。化学教育におけるパソコンソフトウェアは化学の授業を補助する上で重要である。