2010

Towards the Establishment of a "First-rate" Undergraduate Teaching Programme in Analytical Chemistry: Development of Innovative Multimedium Software Training Package

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Preamble

In our B.Sc. (Hons) degree programme in Applied Chemistry, analytical chemistry is the essential part of the teaching programme. Students enrolled in the programme have to select two core courses (i.e. CHEM 1230 Analytical Chemistry and CHEM 2242 Instrumental Analysis) in this sub-discipline of chemical science. The course design entails the students not only acquiring basic principles in analytical chemistry, but also employing a variety of techniques in tackling real analytical problems. Apparently, problem-based teaching and learning is a viable approach for the course delivery. In that context, four real-life analytical problems pertaining to food, consumer and herbal product were identified. To enrich the learning experience as well as to cater for the self-learning mode of the students, a multimedium software incorporating texts, images and video-clips was designed and constructed. Four modern day instruments including atomic absorption spectrometry, gas chromatography-mass spectrometry, inductively coupled plasma and high-performance liquid chromatography were introduced with both the operation principle and sample measurement method. Detailed sample pretreatment procedures of oyster, cigarette, tea bag and American Ginseng sample were video-taped. The software could provide our undergraduate students with summative knowledge in these two courses.

Abstract

To introduce more fun and incentive for undergraduate students in learning analytical chemistry, the development of innovative multimedium software package that vividly illustrated the relationship between basic scientific principles in analytical chemistry and their applications *in solving real-life analytical problems relevant to Hong Kong was proposed. In this project, unique VCDs containing visual images and interesting stories were developed to allow for step-by step explanation of the analytical procedures involved in the chemical analysis of four cases, viz cadmium in oyster, nicotine in cigarettes, metals in green tea leaves and ginsenosides in American Ginseng. To tackle the analytical problems, unique sample pretreatment techniques were presented in the VCDs. Four modern day instruments including atomic absorption spectroscopy, gas chromatography-mass spectrometry, inductive coupled plasma and high performance liquid chromatography were introduced. By directly connecting teaching materials to real-life problems in Hong Kong, the learning experience and interest of students were enhanced, as students could easily see that what they had learned in class could be immediately applied to solve some important practical problems of local relevance. Their understanding of the principle and practice of these essential pieces of instruments could lead them to better chances of finding rewarding employment after graduation.*

Keywords

Cases studies, multimedium software, analytical chemistry, real-life samples

Introduction

A lack of interest in science among undergraduate students is a problem not just prevalent in Hong Kong universities but appears to be on the rise for many educational institutions worldwide. To solve this significant problem, educators realise that the teaching of science has to be connected to the "fun of learning", especially for freshmen. To most young students, the fun of learning science appears to be closely related to how well the materials being taught can be directly connected to things that would impact their daily lives and future careers. As such, the availability of teaching tools that would vividly illustrate and highlight the fun and practical aspect of science would be highly valuable.

In the area of chemistry, it is common knowledge that the sub-discipline of analytical chemistry is a favourite topic among many undergraduate students (at least in countries such as the U.S. and U.K.), since analytical chemistry is highly practical in nature and can be easily understood by students. What they learned in class can be immediately applied to solve problems encountered in society, enhancing their chances of obtaining fruitful employment (as in many fields of engineering). Unfortunately, in Hong Kong, the fun of learning and employment opportunities associated with the field of analytical chemistry appear to be not very appreciated by the undergraduate chemistry students. It is most likely due to the lack of suitable teaching materials that could be used to properly illustrate the relationship between subject matters taught in class and their practical usefulness in Hong Kong society.

The use of multimedium method has been proven to be an effective approach to assisting and enhancing teaching and learning. Unlike software packages that can be purchased commercially for the teaching of analytical chemistry, the software package developed in the project were unique and important in the sense that the working principles of various essential analytical techniques and chemical instrumentation were presented and explained alongside real-life analytical problems of direct relevance to Hong Kong. The VCDs containing visual images and step-by-step explanations of a real-life chemical analysis (just as that performed in local commercial testing laboratories) of cadmium in oyster, nicotine in cigarettes, metals in green tea leaves and ginsenosides in American Ginseng were produced. With the use of such innovative teaching materials, we hope that students would see more clearly the joy of learning analytical chemistry and that what they learned in class could really help them find jobs after graduation.

Our current undergraduate programme in Chemistry includes three analytical chemistry-related courses, namely *Analytical Chemistry, Instrumental Analysis I & II*, and two laboratories (*Analytical Chemistry Laboratory and Instrumental Analysis Laboratory*). One major objective of developing the innovative multimedium software training package in analytical chemistry was to enhance and stimulate students' interest in learning the course materials, especially in laboratories involving the use of different chemical instruments. Four different instrumental techniques, namely high-performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC-MS), flame atomic absorption spectrometry (FAAS) and inductively coupled plasma-optical emission spectrometry (ICP-OES) techniques were selected. These techniques are among the most commonly used instruments in commercial chemical testing laboratories and they offer wide applications in chemical analysis. Through the multimedium training programme, hopefully the students will be equipped with the knowledge and technical skills to solve their daily chemical analysis problems.

Aims and Objectives

1. Development of the innovative multimedium software training package focusing on the teaching and learning of the working principles of chemical instrumentation and analytical procedures typically employed for the chemical analysis of real-life analytical samples, as illustrated by case studies obtained from local chemical testing laboratories.

2. Dissemination of the training package to undergraduate chemistry students as supplementary teaching materials, with the aim of enhancing and stimulating their interest of learning, as well as providing students with the knowledge concerning employment opportunities associated with analytical chemistry and chemical testing laboratories located in Hong Kong/Mainland China.

Methodology

The Head of the Department served as the Coordinating Investigator for the project. Three other Chemistry faculty members specialising in teaching and research in analytical chemistry were engaged as Co-investigators.

Division of Labour

Team approach was adopted for the planning, selection of teaching materials, script writing, filming of laboratory demonstration, editing of the audio-visual materials, and the production of the VCD package. The Principal Investigator oversaw and coordinated the whole project. Co-investigators were responsible for the production of the VCDs regarding the four chosen instrumental techniques. In addition to recruiting a project assistant for the day-to-day operation of the project development, technical staff members of the Chemistry Department were called on occasionally to provide technical assistance in the handling of the instruments and the laboratory demonstration for video-recording.

Each investigator was responsible for the development of the multimedium package involving the four selected instrumental techniques in tackling of real-life analytical problems:

1. Analysis of Nicotine in Cigarettes
2. Analysis of Ginsenosides in American Ginseng
3. Analysis of Metals in Green Tea Leaves
4. Analysis of Cadmium in Oyster

Contents of the VCDs

A VCD was produced for each of the four selected instrumental techniques, namely HPLC, GC-MS, ICP, and AAS. A common format for each of the techniques was designed covering the following sections:

1. Principle: to provide a brief theoretical background of the instrumental technique (Skoog, et al., 1998).

2. Instrumentation: to provide basic understanding on the operation of the instrument (Currell, 2000).

3. Real-life Applications: the operation of the instrument was illustrated with the chemical analysis encountered in real life. Detailed analytical procedures for tackling daily problems including the sampling, sample pretreatment and analytical measurements were addressed. To consolidate the learning experience of the students, the sample pretreatment procedures were video-taped in the stepwise manner.

The run time for each section of the VCDs is approximately 40 minutes accompanied with English narration. Self-explanatory slides in Powerpoint format were incorporated with each distinctive instrumental technique including sample preparation and data analysis. Each technique was seen with the proper set up of glassware, chemicals and instrument.

Results/Findings

A total of four real-life analytical problems were identified and the quantification of the toxic/bioactive materials from real samples was performed, using the state-of-the-art analytical instruments (Ram, 1999 & Cancilla, 2001). Real-life problems chosen were:

1. Cadmium in oyster obtained from local market: the key question borne in the mind of the students might be whether the toxic metal (i.e. Cd) concentration in oyster is high enough to make it not suitable to be consumed by the public.

2. Nicotine content in a common brand of cigarettes (Marsella, et al., 1999): the results of the finding would provide important data to support the expanding region of "non-smoking zone" in public places.

3. Metal ions content in tea bags: the interesting question borne in the students' mind might be that whether the metal ions leaching from the tea bags are good or bad to our health.

4. Ginsenosides content in American Ginseng: the students should appreciate that the modern day analytical techniques enable TCM manufactures to produce health products with reliable quality assurance measures, they should thank the contribution of analytical chemists.

The VCD production of each of the cases comprised a Powerpoint presentation of 24-36 slides and a number of movie files in MPEG format. Each of the presentations contained the following sections which should have sufficient materials to be presented in one lecture:

1. The operation principle of the instrument was presented with the real instrument housed in our laboratory.

2. The sample pretreatment procedures (i.e. sample digestion, extraction, separation, etc.) were shown in the stepwise manner in the movie files.

3. Actual steps for taking measurements for various instruments were articulated in the presentation.

4. The findings and data treatment methodology were given as the last part of the presentation.

Key experimental findings in the activity were:

1. The mean concentration of Cd in dried oyster sample determined by AAS was 11.65 mg/Kg with a standard deviation of 0.18 mg/kg.

2. The mean nicotine content generated from one piece of cigarette determined by GCMS was 1.07 mg with a standard deviation of 0.031 mg.

3. The selected metal ion contents in a tea package were found by ICP and the results were compiled as below.

Extraction method	Al	Mg	Mn	Ba	Zn	Cu
By brewing (ml/L)	3.69	8.63	1.84	0.038	0.16	0.029
By Acid digestion (mg/Kg)	755.8	2026.5	637.1	22.3	33.4	20.9

4. Seven kinds of Ginsenosides were determined and quantified individually by HPLC. The findings were given as below:

	Ginsenoside	Found in the sample Mg/g	R.S.D. (%) of the determination
1	Rb_1	16.75	1.2
2	Rb_2Rc	0.49	4.5
3	Rc	2.54	3.3
4	Rd	4.53	6.1
5	Re	14.81	1.1
6	Rg_1	1.96	3.8
7	Gypenoside XVII	3.16	1.3
8	Ro	3.65	8.7
9	Fd_{11}	0.65	3.7

Discussion

The VCD production not only assisted our students in consolidating their knowledge of the four core analytical instrumentations (i.e. AAS, ICP, HPLC, GC-MS), but also taught them several common sample extraction techniques such as solvent, ultrasonic and microwave extraction.

In particular, the software emphasised the sample pretreatment techniques for real sample analysis. Such skills were difficult to be acquired through normal lecturing approach. In addition, the major steps in operating these expensive instruments were clearly articulated. The students could take time to review the materials before going to the laboratory and using the instruments to acquire real hands-on experience. Thus, the malpractice by students on the operation of the sophisticated instruments could be greatly reduced.

With the operational principle clearly spelt out in the VCDs of these four important analytical techniques, the software served as an ideal teaching aid for the students before they had the chance to use them in the laboratory class (i.e. *CHEM 2220 Instrumental Analysis Laboratory*). Many commercial testing laboratories in Hong Kong heavily rely on the use of these instruments for their routine operation. It is absolutely essential for our students to fully master the instruments if they aspire to secure a technical job after their graduation. We believe that the VCDs produced by this project can be used to beef-up the background knowledge of the students before they go through the job interview in an analytical laboratory.

Enhancement on Teaching and Learning

A lack of interest in science among undergraduate students is a problem not just prevalent in Hong Kong universities but appears to be a global concern for educationalists worldwide. To motivate the learning attitude of the students is a challenge to all teachers and university faculties. The production of the multimedium learning package was a reasonable solution to enhance students' learning interest. We used the software in our *CHEM 2242 Instrumental Analysis* class. The real-life nature of the cases in the software enabled students to appreciate the powerfulness of the modern day instrumental techniques in protecting the well-being of the public. The movie files made the class presentation more appealing to the students and they started to feel the "fun of learning", especially for students who grew up in the Internet age. To most young students, the fun of learning science appears to be closely related to how well the materials being taught can be directly connected to things that would impact their daily lives and future careers. In this connection, we are pleased to see the availability of this teaching tool through the provision of the TDG. It vividly illustrated and highlighted the fun and practical aspect of science to the students.

To solicit feedback from the students, a questionnaire was drafted and completed by the year-two students. The result of the survey conducted is attached as appendix of the report. In general, the students agreed that the VCDs could

1. strengthen their understanding of the application aspects of analytical chemistry;
2. enhance their appreciation of sample digestion process;
3. extend their knowledge to other real-life case studies;
4. stimulate their interest in learning analytical chemistry;
5. assist them in understanding the proper operation procedure of AA, ICP, GC-MS and HPLC;
6. help them gain confidence in performing experiments more smoothly; and
7. appreciate how the Department's in-house instrumentation can solve real-life analytical problems.

Specifically, the students claimed that after viewing the software, they were more confident in employing sample pretreatment techniques which had appeared to to be very complicated before. As the content of the teaching materials was related strongly to their daily life experience, they recognised that learning analytical chemistry is of practical importance.

The software would be uploaded to the WebCT of other relevant courses of the Department, allowing students to review the materials on their own pace.

Limitation/Difficulties

To implement the development plan of the project, we were fortunate to recruit a fresh M.Phil. graduate of the Department to serve as the project assistant. With sufficient analytical chemistry knowledge, he helped us to prepare most of the content of the package. However, his computing skill is not professional. As a result, the content of the software certainly has room for improvement. If we could secure a bigger budget for the project, we would build up more real-life cases to cover not only these four instrumentation techniques. Nevertheless, we are quite happy with the product generated from the project. For the information of the reviewer, the VCD product derived from the grant is enclosed for viewing.

Conclusion

This multimedium software training package was the first attempt of the Department to provide a multi-purpose teaching aid for both undergraduate and MSc in Analytical Chemistry students. As a follow-up to this teaching development activity, we established a few more real-life cases in environmental chemistry (i.e. Air Pollution by Nitrogen Oxides/Examination of Lead Contamination/Treatment of Industrial copper Wastewater/Degradation of Phenols in Wastewater Samples) so as to enhance the teaching and learning experience of our staff and students.

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Appendix

Results of the student survey on "Advanced Analytical Instrumentation VCDs" conducted in Instrumental Analysis Class, returned by 30 year-two students.

Direction: Please check the appropriate box according to the following descriptions.

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

1. The VCDs produced by the Department were suitable for undergraduate class teaching.

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
0%	0%	60%	33.3%	6.7%

2. The real-life case studies shown in the VCDs could strengthen my understanding in the application aspects of analytical chemistry.

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.7%	56.7%	36.7%	0%	0%

3. The sample digestion process was thorough and easy to follow.

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
13.3%	36.7%	40%	6.7%	3.3%

4. The real-life case studies shown could apply to other similar samples.

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.7%	40%	50%	3.3%	0%

5. I found the VCDs very informative and they stimulated my interest in learning analytical chemistry.

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.7%	30%	33.3%	6.7%	0%

6. Real-life samples (e.g. oysters, cigarettes, green tea leaves & American Ginseng) were used in the demonstration which allowed me to appreciate the practicality of the analytical instruments.

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
13.3%	60%	23.3%	3.53%	0%

7. After viewing the VCDs, I totally understood the proper operation procedure of AA, ICP, GC-Ms and HPLC.

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
3.5%	46.7%	36.7%	13.3%	0%

8. By watching the VCDs before starting a new project which required the use of analytical instruments, it really helped me to perform the necessary experiments smoothly and reduced the amount of frustration.

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.7%	50%	36.7%	6.7%	0%

9. I found the English narration easy to follow.

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
10%	50%	40%	0%	0%

10. I came to appreciate how our in-house instrumentation can solve real-life analytical problems.

1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.7%	40%	53.3%	0%	0%