LABORATORY EXPERIMENT EDUCATION VIA VIRTUAL SIMULATION DEMONSTRATION DURING COVID-19 PANDEMIC

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ABSTRACT

Considering the COVID-19 pandemic, distance teaching has become a necessity. In some cases, laboratory experiments can be replaced by simulated ones. In this study, virtual simulation experiments were designed for students due to COVID-19 to enhance their learning outcomes. A detailed description of a virtual drug manufacturing process is described. Finally, a survey conducted on undergraduate students' understanding of the process confirmed that the method met their expectations in terms of the knowledge and skills for good manufacturing practice (GMP). *[African Journal of Chemical Education—AJCE 12(2), July 2022]*

INTRODUCTION

The SARS-CoV-2 virus has caused the global COVID-19 pandemic. According to the UNESCO [1], close to half of the world's students are still affected by partial or full school closures. In the past year, approximately 60% of the universities were closed and another 30% experienced major disruptions. In China, distance teaching replaced university face-to-face teaching for around two years, thus affecting nearly 90% of teaching activities across the country. To provide distance learning for theoretical courses, most universities relied on videoconferencing software or on recorded audiovisual materials [2]. Unlike such courses, distance learning in disciplines requiring access to laboratories was not as easy [3,4]. For this, most laboratory experiments were replaced by simulation practices, and the students processed and discussed the obtained data [5-9].

In this report, virtual simulation experiment was conducted for chemical and pharmaceutical engineering majors (www.ilab-x.com) and the method used in this teaching innovation was approved by Zhejiang University of Science and Technology. In addition to this and in accordance with the evolution of the pandemic, the teaching guidelines for chemical engineering degrees have been revised. The practices designed in this study can be used for distance learning during the academic years 2020–21 and 2021–22. The enhancement of virtual simulation experiments will be continued so that they can be used when needed.

In this project, with the aim of familiarizing new engineering talents with the information technology and optimizing the sharing of teaching resources, the whole process of aspirin production

was selected to be performed as a virtual simulation experiment. Three independent parts of the experiment were systematically carried out: aspirin synthesis, tablet preparation, and quality assessment. The application of virtual simulation technology in chemical engineering teaching system allows the virtual visualization of different steps during the process. According to teaching guidelines of the subject, students should master the following points: the common reactions and operations involved in aspirin synthesis, the good manufacturing practice (GMP) requirements for crystallinity, and the requirements of the Chinese pharmacopoeia for the drug quality control. This class aims at developing the students' overall engineering practice ability: their ability to deal with unexpected accidents in the experiment and to understand the GMP standard process, their ability to monitor drug quality and the concept of quality control.

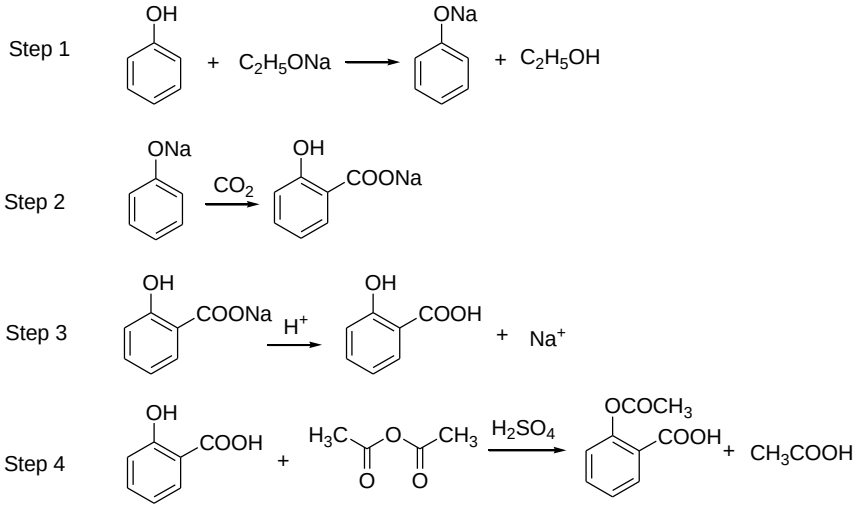
METHODOLOGY

1) Principle of the experiment

The full process of aspirin production by virtual simulation is an experimental project designed to systematically train chemical engineering students. This project uses virtual simulation technology to realize the full production of aspirin. All scenes of the process are virtualized as three operations:

1. Aspirin synthesis. This includes (1) salicylic acid synthesis from sodium phenolate, (2) salicylic acid precipitation, decolorization, and crystallization, and (3) aspirin synthesis and re-crystallization

in ethanol for purification. A variety of organic synthesis techniques, such as filtration, distillation, extraction, and crystallization, are used. The detailed procedure according to the Kolbe-Schimitt reaction is as follows: phenol, the starting material, undergoes a reaction with sodium hydroxide to generate sodium phenolate, and then it is heated under pressure with CO_2 to produce sodium salicylate, which is subsequently acidified, recrystallized, and dried to obtain salicylic acid. Thereafter, salicylic acid undergoes an acetylation reaction, followed by decolorization, recrystallization, drying, and other refining processes to obtain pure acetylsalicylic acid, which is the active pharmaceutical ingredient (API) in aspirin. The chemical reaction processes are described in Scheme 1:



Scheme 1 Reaction processes for aspirin synthesis.

2. Tablet preparation. There are various steps in tablet formulation: drying, crushing, screening, mixing, granulation, and compression into tablets. The tablet compression procedure is divided into four stages: filling, dosing (metering), compression, and ejection. A tablet press is the device that compresses the powder into uniform tablets. The filling stage involves placing the blended granules into the punch-die cavity, which is composed of two punches and a die. The two punches are then pressed together with a great force, and the material is combined. In the dosing section, the overfilled or excess granule is removed from the machine, thus the exact weight of the granule is compressed. This exact weight is determined by the lower punch's height, which in turn is determined by the filling can. The dosing scraper scrapes the excess granule from the surface of the die table. In the compression phase, the tablet is formed. The upper and lower punches are brought together within the die under pressure. They move between two wheels, known as the pressure rolls. These rolls push the punches together, resulting in tablet formation. In the final stage, the ejection stage, the tablet is removed from lower punch. The upper punch rises above, thus the lower punch rises in the die. The tablet is pushed outside the die cavity and the takeoff scraper pushes the tablet into the collection container.

3. Quality assessment: As required during tablet preparation, the manufactured tablet undergoes several quality control tests to ensure that it meets certain requirements. The tablets should be complete and clean, with uniform color and appropriate hardness (to avoid fragmentation during packaging, storage, and transportation). They should also have uniform mass, disintegration time,

dissolution, and friability. In some cases, the country's pharmacopoeia determines further quality specifications. The drug should comply with GMP specifications.

The basic principle of this experiment is based on the central idea of GMP, aiming at covering teaching needs, professional knowledge, industry terminology and engineering concepts. Modern information technologies are used to promote the actual operations, effectively expand and extend the content of experimental teaching. Modules, including equipment simulation and online learning ones can simulate the whole process of aspirin from production to inspection. Parts of the software operation are shown in Figure 1.

Figure 1. Examples of virtual experimentation.

Students need to complete the synthesis workshop (9 sections, 22 steps), preparation workshop (5 sections, 18 steps), and quality inspection workshop (31 working sections, 16-step operations). A virtualized scene of the whole process of aspirin production on computer has been

established to achieve social sharing and maximize the scope of educational audience by independent assessment through internet.

2) Assessment requirements

The assessment is divided into two parts: extended learning and centralized experiment, as showed in Table 1, which are used for the assessment of the step operation and quality control of the simulation software. The assessment requirements of each training program can be customized. Students' performance of specific training programs is evaluated by a scoring system. During the running of training projects, the scoring system will evaluate the corresponding test papers in real time. When the training program is terminated, the scoring system can print out the specific operation details of the corresponding assessment.

Table 1. Assessment requirements

Assessment forms	Assessment contents	Assessment requirements
Extended learning	Aspirin API preparation, tablets, quality check	Pass the relevant test based on GMP of pharmaceutical factory in the text question bank
	SOP operation of formulation workshop	Complete the workshop operation questions in the preparation part of experimental project, and achieve a score of 70 or above in the final assessment
Centralized experiment	Understanding preparation equipment and production operation of API	Time-limited operation: the final completion score is more than 70 points
	Master the standard operation of equipment and production process	GMP related text examination: the final score is 70 points or above

Students can download the experimental client through the experimental website, use their spare time to complete all steps, and synchronize with the online experimental data, finish the text and operation assessment tests under assessment mode. The final score is reflected in the experimental assessment management data, in order to ensure that students have the controllable and executive power to expand knowledge learning.

3) Student survey questionnaire about the virtual simulation experiment in COVID-19 time

To obtain a more objective understanding of how students can better perform virtual simulations, a survey was conducted at the end of the semester to find out what students thought about this kind of education. A total of 120 students enrolled in the course and participated in this online survey and presented their suggestions on this learning method.

Question 1

What do you think are the factors affecting teaching in virtual simulation experiments?

a) Experimental scenario design
b) Experimental teaching content
c) Experimental system stability

Question 2

Do you think that the effect of learning through virtual simulation experiments is better than that through traditional classroom teaching?

a) Better than classroom teaching
b) Similar to classroom teaching
c) Worse than classroom teaching

Question 3

How difficult for the content covered in this experiment?

a) Very difficult
b) Just OK
c) Very simple

Question 4

Do you think that your learning efficiency can be improved by learning through this virtual simulation?

a) Very efficient
b) Just OK
c) Below Average

Question 5

Are you satisfied with the evaluation system of this experiment?

a) Very satisfied
b) Just OK
c) Very dissatisfied

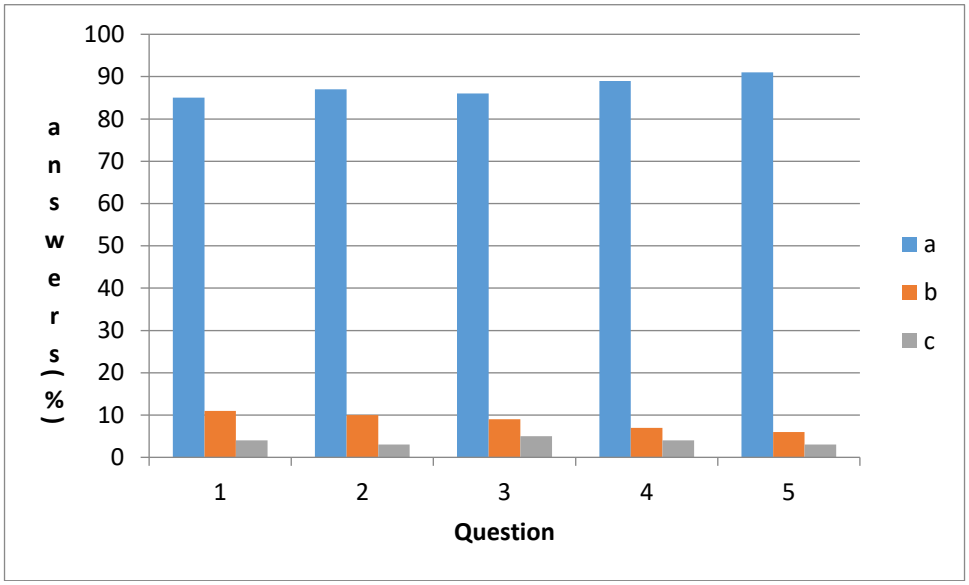


Fig. 2. Results obtained from the survey

These results of the survey revealed that more than 80% of the students were satisfied with this teaching method. Nearly 90% of students believed that virtual simulation experiments were better than traditional classroom teaching. This study

also showed the feasibility to replace traditional face-to-face experiments by virtual simulation when needed.

RESULTS AND DISCUSSION

The introduction of virtual simulation experiments in Chemical engineering education greatly affects the learning process of students. Design and application of the virtual simulation teaching technique is fruitful in promoting chemical engineering students' education. However, it is necessary to further optimize the teaching, enrich the content, and build an evaluation system.

Chemical engineering education requires the combination of both theory and application, knowledge transfer and training ability, production practice and scientific research, in addition to compound talent. Therefore, taking advantage of the virtual simulation technology to continuously improve the experimental teaching part is a long-term work, which requires continuous improvement. With the development of the epidemic, especially the rapid spread of the Omicron variant virus, this virtual simulation method will become more and more popular in future education.

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