

Implementing and Assessing the ABC² Constructivist Model in Chemistry for Engineering Undergraduate Classes*

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This paper shows the results of testing the effectiveness of a constructivist model called ABC² in a chemistry class for engineering majors. Its success was measured using qualitative and quantitative techniques (e.g. observation, interviews, tests and final projects). The results were then compared with a traditional teacher-learning model employed by a separate university, which employed experimentation and control groups to test students' ability to solve problems.

INTRODUCTION

TEACHING BASIC sciences presents a big challenge for instructors. Alumni from a variety of teaching centers using different learning models often find it difficult to adapt quickly to the pace demanded by a new university. Students taking Industrial Engineering and Computer Sciences find it particularly hard to recognize the importance of this subject within the context of their majors.

One measure for teacher-learning effectiveness is student motivation. Until recently, teaching techniques have been based on the assumption that knowledge can be directly delivered from teacher to student [1]. The teacher plays the central role, the student is merely the recipient. This does not present much of a challenge to the student, causing poor motivation. Only 5% of what is presented in a class can be recalled at its end [2]. To solve this problem, several alternatives have been developed, some of which have been successful: Problem-based learning (PBL), used in medical schools since the mid-70s, is a pedagogical approach drawing on recent developments in the cognitive human learning sciences [3]; project-oriented learning (POL) focuses on a finished product or presentation, organizing itself around design activities, problem-solving, decision-making and research [4]; and the case-based learning method (CBL).

All learning activities prepared in conjunction with the aforementioned models must address the importance of student knowledge-building [5]. This implies a move away from traditional education: the student now takes responsibility for the learning process through self-study and teamwork. Although the models have shown very good results, they have been unable to achieve maximum

effectiveness within traditional course programs. At the Tec de Monterrey Veracruz Campus, ABC², an acronym of the Spanish 'Aprendizaje Basado en la Construcción del Conocimiento' (Constructivist Knowledge-Based Learning), was first applied in the second semester of the year 2000. Its flexibility lies in designing several courses with a combination of activities from all three models (PBL, POL, and CBL) [6].

The objectives of the projects are: to create and implement learning activities in a general chemistry course that covers all syllabus topics and at the same time capture the fundamental ideas of the constructivist model; and to make a qualitative and quantitative evaluation of the proposed model and subsequently compare the performance of an experimental group using the ABC² model with a control group using a traditional learning scheme.

METHODOLOGY

Three steps are necessary for the design, implementation and evaluation of an ABC² chemistry class. The first is the structuring and compiling of material for the course, bearing in mind that learning activities center more around problem-solving than cases or projects. The course is designed using the Lotus Notes Learning Space technological platforms. The second is monitoring students' performance through observation, interviewing and written exams. This was done in two groups: the experimental (n=37) and the control group (n=23). The third step is evaluation through the following qualitative techniques:

- observation by the teacher of the students' behavior and performance; and
- student opinions about the model used and the applied activities.

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Table 1. Description of problems, case and project

Problem title	Description
Automatic doors	This problem covers the fundamental concepts of the atom and its behavior
Dry or wet ice	This covers the concepts of states of matter, energetic calculations in physic processes, interactions between substances and polarity in atomic bonds
Edible nitrogen	In this problem, the student is asked to analyze factors that affect reaction velocities and chemical equilibrium by means of a typical reaction used in nature for the fixation of nitrogen
Oxygenated water	This covers reaction velocities, with practical experience using potatoes and oxygenated water
Dental voltaic cell	The use of electrochemical concepts in a fixed tooth cavity
Case title	Description
Salted icecream	This case deals with icecream-making, taking advantage of the low temperatures obtained with salt and ice mixtures; it requires specific calculations using formulas of thermochemistry, coligative properties and states of matter
Problem title	Description
Sulphuric acid production	This project involves practical application and covers many concepts that students need to know and apply to have a general knowledge of chemistry

Table 2. Descriptions and preferences of the three session categories developed for the course

Category	Place	Activities	Teacher role	Preferences
Problem-solving	Team rooms equipped with a table, computer network and blackboard	Following methodology to solve problems and send schedule	Tutor	42%
Result presentation & discussion	Classroom	Result presentation and problem conclusions; reading analysis	Facilitator and evaluator	25%
Lecture	Classroom	Presentation of concepts and analytical problems; collaborative activities	Facilitator	33%

The following quantitative techniques were also used:

- a multiple-choice exam designed by the teacher, applied at the start of the process, containing 38 chemistry questions and assessing the student's chemistry knowledge; and
- a final project done in previously selected teams that takes up 60% of the learning objectives of the course.

Criteria for analysis

Students are organized into teams at the start of the semester. Final projects are given to Mexico City Tec de Monterrey industrial engineering ABC² students, and to a control group (from a university with a traditional learning scheme and a similar academic program). This methodology was proposed by Boaler [8] for a high school math course. The control group was given a multiple-choice exam on the first day, and another a month prior to the end of the course. The same project

with a similar explanation was given to both of them. They were given the same time to complete the project, and it contributed a percentage towards the control group's final grade. The evaluation was based on corresponding information handed in by both groups.

FINDINGS AND DISCUSSION

The teacher is responsible for choosing problems, cases and projects for a course. This takes up considerable time, as he/she must use real, relevant and understandable problems for the student. To encourage more student usage of analytical skills and creativity, problems should not be obviously aimed at course objectives. The combination of all planned problems must, however, cover the course completely. One way to achieve this is by planning the course in two stages: the use of problems and cases for part of the syllabus; and a project that integrates the remainder. A curricular matrix, as in Barrows [8], is useful to relate the problem components with the themes/sub-themes of the course.

The course was divided into 7 modules: 5 problems, 1 case and 1 project. Details of each activity are described in Table 1.

Three alternating session categories were developed, bearing in mind student characteristics

Table 3. Course initiation multiple-choice exam results

	ABC ² group	Control group	6-year total at ITESM CCV
Average	40.1	30.2	42.7
Standard deviation	12.1	9.0	13.5

Table 4. Team project report analysis for the ABC² and control groups

	ABC ² group	Control group
Structure	Adequate	Too many theoretical principles and confused logic in sections
Use of principles & calculations	Concrete application of simple calculation, but little analysis of points requiring more mathematical evaluation	Some did not do any calculations at all, others only simple ones
Analytical activities	Adequate	Very superficial
Development of experimental prototype	Variety of proposals, many based on solutions from the Internet	Repeated proposals, coming from more traditional sources
Conclusions	Relevant and acceptable conclusions	Very poor or no conclusions at all

and preferences (Table 2). This respected partial evaluations and a final exam (consisting of individual solutions to analytical problems).

A survey of student opinion at the end of the semester showed a similar preference concerning the difficulty level of the problems. However, 45% thought that the project was more difficult, as they found it a complex activity with considerable student participation. 90% felt that the methodology used increased their level of motivation and interest in chemistry. This is a sizeable improvement over the findings of seven years ago.

Fifty percent of the students understood how to plan and solve a problem after the first such activity. The other 50% caught on during the second or third exercise. It is important, therefore, to dedicate a complete session at the beginning of the semester to providing an extensive framework for solving problems and activities.

From observations during work sessions, we saw that ABC² teams maintained an environment of freedom, responsibility and order. Students are able to concentrate on understanding and solving a problem and they develop activities without the help of the teacher. On the other hand, although the control group tried to organize themselves, they tended to divide the activities of the project between team members, allowing limited opportunity for developing teamwork.

Preliminary interviews with students showed some concern over the validity of the methodology. Nevertheless, as the course progressed, changing attitudes of higher acceptance and more confidence came hand in hand with greater acquired knowledge. Students in the control group, however, said that the project was overly complex and complained of their inability to report it effectively.

Model effectiveness measure

Table 3 summarizes the results of the initial multiple-choice exam. The control group achieved a lower grade than the ABC² group. It is also lower

than the Mexico City Tec de Monterrey total (taken over the last 6 years, totalling 310 students). The difference is not, however, great enough to have any real impact on final project performance.

The project for both the ABC² and the control group contained six of the 10 themes of the course and included activities that require the application of principles/calculations and the development of an experimental prototype. The project reports are analyzed in Table 4.

Despite project-solving training and greater availability of resources from a university that offers a Chemical Engineering program, the control group was unable to solve the project effectively. The ABC² group, by contrast, took advantage of their previous experience in problem-solving to cover the project objectives completely.

CONCLUSIONS

The success or failure of this kind of course depends on the teacher's ability to select and create relevant problems, cases and projects that cover all the course objectives. The teacher must, therefore, constantly do research work and revise bibliographies.

The ABC² model enables the student to develop capabilities far beyond those defined in the course learning objectives. This is attributed to the student's responsibility to build his/her own knowledge with the help of other team members and the teacher. Chemistry students who are now using ABC² are showing more motivation and satisfaction in studying the subject than they did a few years ago.

In the resolution of a project containing 60% of the course topics, there is evidence to support the effectiveness of ABC², as clear-cut behavioral differences were observed between the development group members of the proposed model and those of the control group.

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