An Experimental Study of the Inclusion of Technology in Higher Education

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ABSTRACT: This article presents an experimental study of the inclusion of technology in a higher education teaching context that aims at transforming the educational process by making it both more effective and more attractive to students. Portable Pocket PC devices are used to set up and run collaborative work activities in the classroom under the technologically assisted supervision of the professor. The results lead to various findings regarding the technology inclusion process, such as the importance of the underlying educational model and the instruments that provide the technology, and allow us to draw certain conclusions relating to the educational process, in particular that the continued use of ICTs leads to improvements in student performance. Comput Appl Eng Educ 17: 100–107, 2009; Published online in Wiley InterScience (www.interscience.wiley.com); DOI 10.1002/cae.20188

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INTRODUCTION

The growing use of Information and Communication Technologies (ICTs) has had a major impact on society, bringing about important changes in ways of working, relating and communicating. These changes have also been felt in the field of education, where traditional instructor-centered, monomedia methods of teaching in which students are essentially passive and work in isolation are giving way to new types of learner-centered, multimedia learning with active students participating in collaborative activities [1].

The uses of ICTs in education are highly varied, opening up a wide spectrum of options for promoting learning. Thanks to their characteristics, these technologies are particularly well-suited for applications in educational approaches that are based on *constructivism* [2], where open systems guided by the learner are used, and on *socialization* [3], in which an agent promoting development is employed.

Various studies have demonstrated the benefits of ICTs in educational processes, both as support tools and as a preparation for living in today's society.

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Nevertheless, their incorporation into education is neither quick nor easy [4], and ensuring that concrete and desirable results are obtained will require the adoption of technology management processes that are well-managed and based on models that truly reflect the needs and objectives set by the institutions involved [5].

According to Ref. [6], less than 15% of teachers in the United States use ICTs as an integral part of their teaching methodologies. Many studies indicate that the implementation of these technologies by educational practitioners is a complex innovation [7] beset by a number of complicating factors:

(1) Many teachers do not have all the necessary skills to integrate ICTs in teaching processes. To make optimal use of these technologies in the classroom, in many cases changes will have to be made in current pedagogical approaches and classroom management strategies [7].
(2) Students have different ICT abilities and knowledge levels because of various availability and accessibility factors. An increase in ICT use as a learning tool may be problematic for those with less experience with the technologies [8].
(3) Computers are often installed in laboratories rather than the classroom, their natural habitat, thus impeding easy and routine access [9].
(4) The use of ICTs is often made difficult by a series of related factors such as an insufficient number of computers, peripherals or software licenses; slow Internet access; and poor ICT management [10].
(5) ICT training received by teachers tends to focus mainly on the immediate practical or technological aspects such as the use of the computer, word processing, and the Internet rather than how to introduce them into actual teaching activities [11].

What is lacking, therefore, is a plan containing measures for mitigating these complicating factors so that ICTs can be properly integrated into the teaching process.

This study presents the experience and results of a pilot project carried out at the Universidad de Tarapacá in Chile involving the inclusion of portable technology into the classroom as a support tool for instruction and content evaluation. The project's objectives were to boost students' motivation, include technology in the learning process and thereby improve student performance.

DESCRIPTION OF THE TECHNOLOGY AND ITS UNDERLYING PEDAGOGICAL MODEL

The technology used in the project, shown here in Figure 1, consisted of a portable laboratory of PDAs connected via a Wi-Fi LAN that can be easily transported and used in any classroom with an electrical outlet. The laboratory included 50 Pocket PCs with wireless capability using 802.11 $\times$, a router for establishing a network, and two modified suitcases for carrying the devices and the machines battery chargers. This hardware platform provided the base for a set of collaborative applications used in the classroom (Fig. 2).

The first step of the process is to establish a content database of multiple-choice questions, followed by the second step in which a pedagogical activity is created by selecting from the database a set of specific questions. In the third step the created activities are loaded onto the teacher's Pocket PC, which acts as the network server. In the fourth step activities are wirelessly sent to the participating students. The fifth and final step is the activity itself, in which the students work collaboratively in the classroom in randomly selected groups of three [5].

The fifth step, the pedagogical activity, is carried out in the classroom in two stages. The first stage is the *execution* of the activity and the second stage is the *closing*.

Execution

To enable the execution of the activity, each student is given a Pocket PC that acts as a client. The instructor's

Figure 1 Technology used in project. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

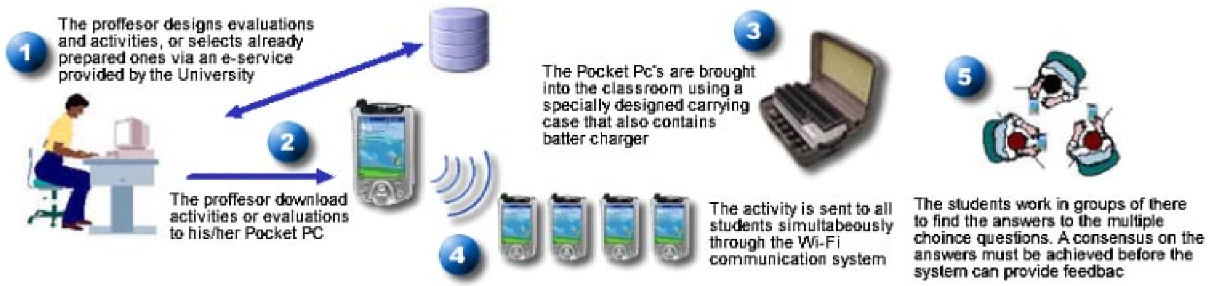

Figure 2 Classroom application. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Pocket PC, in the role of server, organizes the students randomly into groups of three. The instructor then begins the activity by sending an initial question to all of the groups. Each group works on their question collaboratively (through argumentation, discussion, etc.) using their devices until they agree on an answer, which they then submit to the professor's server. If the answer is incorrect, the server instructs the group to reconsider the question; if it is correct, the server sends them another question. The entire process is repeated as many times as the activity calls for [5]. The professor controls the activity via his or her device, and can intervene at any moment to give an explanation or skip to a specific question. The teacher's Pocket PC can display a matrix showing the progress and performance of each group in the activity (Fig. 3).

Closing

The closing stage begins once the execution stage is completed. It involves analyzing the performance data collected during the activity, which is displayed in the matrix view on the teacher's server. The results of this analysis reveal what material needs reinforcement and allow the professor to identify group's with relatively weak performance.

METHODOLOGY

The technology inclusion experiment described above was implemented at the University on a restricted basis as a pilot project applied to the teaching activities of a limited group of academic personnel. A number of measures were taken to mitigate the complicating factors listed in the Introduction Section, and described below.

Selection of Teaching Personnel

To mitigate the first complicating factor on the list, and keeping in mind that to a large extent the inclusion of ICTs will only be effective if there is genuine interest and commitment on the part of the teaching personnel, 12 professors were invited to participate of which 5 accepted. The preselection of the 12 focused on professors teaching high-impact courses which traditionally have a high failure rate, and took into account personal characteristics such as their involvement with, and motivation to use, ICTs.

Training

A training process consisting of two 6-h sessions was set up to cover the various technological and

Figure 3 Online display of group's progress on teacher's machine. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

pedagogical issues involved. The first session aimed at familiarizing the professors with the technology platform and its use in the development of educational content, while the second dealt with the application of the technology in the classroom and its underlying pedagogical model.

The knowledge and skills thus imparted were intended to directly mitigate complicating factors 1 and 5. The problems posed by factor 2 were solved through activities held during a course on computer use included in the degree programs and taken by students in their first semester of study.

Support

To mitigate complicating factors 1, 3, 4, and 5, a series of resources and activities were designed to provide assistance to the professor at all times, both inside and outside the classroom. The fact that the technology is mobile and self-contained automatically mitigated factor 3. As regards factors 1, 4, and 5, the assistance included the following:

- External management of technological resources (scheduling assignments) (factor 4).
- Equipment maintenance (hardware, software installed/configured, battery charged) (factor 4).
- Equipment transported to classroom (factor 3).
- Support for the creation of educational material, development of activities and generation of reports (factors 1 and 5).
- Technical support for the execution of the actual classroom activity (factors 1 and 4).

Application

The professors initiated development of the educational material to be used, and applied the technology once a week. Table 1 summarizes the courses, semesters and years in which the project was implemented, and the number of students enrolled in each course.

RESULTS

Education is a goal-oriented process that focuses on the achievement of a series of objectives in areas such as knowledge acquisition, attitudes and values. Since in the context of our experiment the promotion of the courses by the students is based on their success in acquiring knowledge, the principal parameter to measure was the percentage of students who pass the courses. For reasons having to do both with the academic process and ensuring equal treatment of the participating students, the courses were not divided into experimental and control groups. As shown in Table 2, the statistical analysis of the findings relied on two historical data sets as a basis for comparison: the participating professors' average pass rates for at least three different instances of teaching each course involved in the project (column headed ''Historical pass rate, participating professor'') and the pass rate for all instances of the courses given by all professors over the past 4 years (column headed ''Historical pass rate, course''). The quantity of data used to derive these averages was determined by the minimum number of instances available in the records of the University's computer databases since the year 2000.

The double asterisk in Table 2 indicates deficient course results due to certain disturbances, most notably a strike lasting various months, that impaired the normal functioning of the courses in some semesters and caused abnormally high dropout rates. Thus, for General Chemistry II in the Laboratory

Table 1 Courses in Which Technology Was Applied

Year	Semester	Course	Degree program	Enrolments
2004	II	General Chemistry II	Laboratory Chemistry	41
		Physical Chemistry II	Laboratory Chemistry	27
2005	I	Fundamentals of Programming Languages	Computer Engineering	23
		General Chemistry I	Laboratory Chemistry	27
		General Chemistry I	Chemical Engineering	21
		General Chemistry	Radiology	32
		General Chemistry	Medical Laboratory Technology	46
	II	General Chemistry II	Laboratory Chemistry	42
		Physical Chemistry II	Laboratory Chemistry	36
		General Chemistry II	Chemical Engineering	16
		General Chemistry I	Biology, Chemistry and Natural Sciences Education	48
Total		11	n.a.	359

Table 2 Results Obtained and Historical Comparisons

Course	Degree program	Pass rate using technology (%)	Historical pass rate, participating professor (%)	Historical pass rate, course (%)
Fundamentals of Programming Languages	Computer Engineering	82.6	61.7	65.5
General Chemistry I	Laboratory Chemistry	55.6	37.7	38.8
	Biology, Chemistry and Natural Sciences Education	47.9	20.5	24.4
	Chemical Engineering	76.2	35.7	38.8
General Chemistry II	Laboratory Chemistry	68.3	64.9	64.9
		35.7**	64.9	64.9
	Chemical Engineering	81.3	72.2	64.9
Physical Chemistry II	Laboratory Chemistry	63.0	56.5	56.5
		75.0	56.5	56.5
General Chemistry	Medical Laboratory Technology	76.5	73.3	70.0
		63.0**	73.3	70.0

Double asterisk (**) denotes deficient data excluded from statistical analysis.

Chemistry program, there were 15 dropouts versus a historic average of 1.8. Similarly, in the General Chemistry course in the Medical Laboratory Technology program, 12 dropouts were recorded as against a historical average of 4. With these two exceptions, the data show that all pass rates for courses using the experimental technology were better than the historical results whether measured by course or by individual professor.

Statistical analyses were performed on these results, excluding the deficient data marked with a double asterisk, and are collected here in Table 3. The calculations include significance tests for the comparisons between the experimental and historical results plus the effect size as given by Cohen's *d*.

CONCLUSIONS

This study generated findings at three levels: the process of including collaborative technology into classroom teaching, academic and educational factors, and technological factors. These are summarized below.

Inclusion Process

Institutional phenomena in the areas of internal administration and labor relations were identified that severely limited the success of the project. These included:

- The lack of incentives for professors to use the technology: The initiation of a technology inclusion process requires that professors devote additional hours to activities such as learning the process, preparing materials, etc. No extra remuneration was offered for participating in this project, nor was there any compensating reduction of teaching loads.
- Instability in course assignments: Professors are given no assurances as to which courses they will teach from one semester or year to the next, meaning that any effort to prepare educational material may not be compensated in the future.
- Course scheduling: The mobile technology used in the experiment requires a battery recharge time similar to the maximum battery run time, which is about 1½ h of continuous use. This limitation was not taken into account in the course scheduling process, so that if two participating professors had classes immediately following each other, not to mention simultaneously, only one of them could use the equipment.

It was observed that the support resources and activities played an important role in ensuring the functioning of the project. The quality of this support was fundamental for maintaining participants' interest and motivation.

Academic and Educational Factors

Academic and educational factors were identified that had not been foreseen, which limited the adoption of the experimental technology:

- Disagreement with the educational instruments involved: Five of the preselected professors who

Table 3 Comparison of Experimental Results With Historical Results by Course and by Individual Professors

	Use of technology experiment			Historic control (professor)			*t*-test results					Historic control (course)			*t*-test results				
Degree program (Course)	Pass rate (%)	M	SD	Pass rate (%)	M	SD	*t*	df	*P*	Cohen's *d*	Effect size	Pass rate (%)	M	SD	*t*	df	*P*	Cohen's *d*	Effect size
Computer Engineering (Fundamentals of Programming Languages)	82.6	5.07	1.14	61.7	4.03	1.28	3.68	40.61	0.000337	0.82	Large	65.5	3.79	1.30	4.88	31.84	0.000014	0.99	Large
Laboratory Chemistry (General Chemistry I)	55.6	3.95	1.02	37.7	3.44	0.98	2.44	31.72	0.01022	0.51	Medium	38.8	3.46	0.97	2.41	29.53	0.0113	0.50	Medium
Biology, Chemistry and Natural Sciences Education (General Chemistry I)	47.9	3.73	0.77	20.5	3.15	0.92	3.19	74.53	0.0010	0.70	Medium	24.45	3.15	0.92	3.19	74.53	0.0010	0.70	Medium
Chemical Engineering (General Chemistry I)	76.2	4.57	0.88	35.7	3.61	0.85	4.11	38.61	0.0001	1.11	Very large	38.8	3.46	0.97	5.58	22.82	0.0000058	1.15	Very large
Laboratory Chemistry (General Chemistry II)	68.3	4.19	1.11	64.9	3.94	0.93	1.29	55.79	0.1008	0.25	Small	64.9	3.94	0.93	1.29	55.79	0.1008	0.25	Small
Chemical Engineering (General Chemistry II)	81.3	4.52	1.13	72.2	4.18	0.89	1.06	23.61	0.151	0.35	Small	64.9	3.94	0.93	1.98	17.18	0.03189	0.61	Medium
Laboratory Chemistry (Physical Chemistry II)	63.0	3.86	0.76	56.5	3.53	1.18	1.72	65.80	0.04523	0.30	Small	56.5	3.53	1.18	1.72	65.80	0.04523	0.30	Small
	75.0	4.14	0.58	56.5	3.53	1.18	3.90	119.93	0.00008	0.58	Medium	56.5	3.53	1.18	3.90	119.93	0.00008	0.58	Medium
Medical Laboratory Technology (General Chemistry)	76.47	3.90	1.13	73.34	4.00	0.88	0.38	17.80	0.3546	−0.12	Negligible effect	70.04	3.95	0.98	0.19	17.45	0.424	−0.01	Negligible effect

declined to participate in the project did so because, in their view, it was inconceivable that their course material could be taught using instruments based on multiple-choice questions.

- Rejection of the use of a specific platform: Three of the preselected professors who declined to participate expressed their disapproval of a system that was dependent on a particular technology and its underlying educational model.
- Perceived risk of loss of intellectual property: Three of the preselected professors who declined to participate raised issues relating to ownership of the intellectual property in the educational material generated.

It was observed that the inclusion of the project technology and its systematic application to the courses improved the teaching, both in quantitative and qualitative aspects.

- Quantitative: Academic performance as measured by students' course marks improved (Table 3).
- Qualitative: Improvements were achieved in student communication and knowledge levels [12]. Students found the platform's underlying collaborative learning model to be supportive of their studies, as was corroborated by the global improvements evident in the results, and also showed progress in social skills.

Technological Factors. The lack of maturity of the technology used was identified as a factor that could seriously hinder the success of the project:

- Compatibility problems: As already noted, the Pocket PCs use a network based on the 802.11 × standard. The network that was established did not perform reliably with all routers, and the normal functioning of the platform was therefore sensitive to the use and availability of specific equipment.
- Poor functioning: Uncontrolled expansion and installation of wireless devices caused the platform to malfunction due to signal interference. This initially inexplicable breakdown resulted in a lack of confidence in the technology, which in turn quickly led to frustration and demotivation among the participants.

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