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INNOVATIVE USE OF A TABLET DEVICE TO DELIVER INSTRUCTION IN UNDERGRADUATE CHEMISTRY LECTURES

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This report describes a simple, inexpensive and highly effective instructional model based on the use of a tablet device to enable the real-time projection of the instructor's digitally handwritten annotations to teach chemistry in undergraduate courses. The projection of digital handwriting allows the instructor to build, present and adapt the class contents in a dynamic fashion and to save anything that is annotated or displayed on the screen for subsequent sharing with students after each session. This method avoids the loss of continuity and information that often occurs when instructors switch between electronic slides and white/chalk board during lessons. Students acknowledged that this methodology allows them to follow the instructor's cognitive process and the progressive development of contents during lectures as the most valuable aspect of the implemented instructional model.

Keywords: instructional model; chemistry education; digital handwriting; learners' active engagement; tablet-based presentations.

INTRODUCTION

For decades, chemistry teachers used multicolor chalk or pens on chalk/white boards to deliver instruction in a classroom setting. Nowadays, most teachers have replaced the use of traditional chalk/white boards by the projection of electronic content, usually in the form of PowerPoint® slides, which allow the teacher to embed schemes, high-quality figures and multimedia animations, and to share the contents of a lecture with their students before or after each session. Even though the visualization of chemistry concepts is enhanced through high-quality images and computer-generated chemical structures, a major drawback of using PowerPoint® slides at the undergraduate level is that students are not encouraged to take their own notes and adopt poorly engaged attitudes towards learning.[1-3] Electronic slides are particularly unfavorable when teachers need to adjust the contents of a class instantly in response to the needs of a particular audience. In that case, teachers must switch between electronic slides and chalk/white boards, which often affects continuity and disorient students within a lecture.

In the past five years, tablet devices have emerged as valuable pedagogical tools in a wide range of applications and educational contexts.[4-9] Particularly, tablet devices have been employed to enable the projection of real-time instructor's handwritten annotations either on pre-developed materials or on a blank screen, showing a positive effect on students' performance compared to traditional teaching methods.[5,10-12] However, to the best of our knowledge, no information has been reported regarding the use of tablet devices to deliver instruction in chemistry courses in the Latin American context, particularly in Chilean universities where the inclusion of technology in teaching activities is still incipient.

This report describes the use of a tablet device to enable the real-time projection of digital handwriting to deliver instruction in undergraduate chemistry courses during the first semester of 2014 at Universidad Andres Bello (Chile). As proposed by Lee and Lim,[5] "digital ink enables more efficient and vivid representation through free handwriting, which leads to focus the students' attention on the key feature of these visuals". Thus, we expected that using a tablet to display handwritten representations of chemical structures and equations helped students to develop better representation skills and conceptual knowledge in chemistry courses. Projection of digital handwriting can also be accomplished through several technologic tools, such as document cameras, pen input SMART screens, digital scribe pens, but these types of equipment are rare and not currently available in our institution. On the other hand, the use of tablet devices has become affordable and more widespread within our faculty members, which constitutes a valuable opportunity to take advantage of this technology for teaching and learning purposes in undergraduate chemistry courses.

METHODS

This study was performed in four undergraduate introductory chemistry courses during the first semester of 2014 at Universidad Andres Bello, Concepción campus (Talcahuano, Chile), using a non-experimental cross-sectional design. The total number of students in the intervened courses is N=137. A non-experimental research is a type of study carried out without any deliberate manipulation of the variables and in which phenomena are only observed in their natural environment. The study was cross-sectional because the data were gathered from four parallel courses during the same academic period.[13]

Students were instructed using a tablet device (iPad2® or iPad Air®) to project the instructor's digital handwriting, using Bamboo Paper® (Wacom Co. Ltd)[14] application and a Bamboo Stylus® (Wacom Co. Ltd) digital pen. The Bamboo Paper® application allows the use of the tablet screen as an electronic paper notebook, capturing high-quality handwritten annotations in different colors and pen styles. Photos and images can also be added, and anything that is annotated on the screen can be easily saved as a PDF file and shared with students after each session. A HDMI or VGA adaptor is required to enable the projection of the tablet screen content to provide instruction during lectures. Other applications, such as Molecules 2.1 (Sunset Lake Software),[15] Mobile Hyperchem® Free (Hypercube Inc.),[16] K12 Periodic Table (K12 Inc.),[17] and Socrative Teacher (Mastery Connect Inc.)[18] were employed to complement digital handwriting with other educational activities during lessons. Molecules 2.1[15] is a free application that allows the view and

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manipulation of three-dimensional molecular renderings. New molecules can be downloaded from the RCSB Protein Data Bank[19] or NCBI's PubChem[20] directly to the handheld device and stored for later viewing. Mobile Hyperchem® Free[16] is an application that allows the user to draw and manipulate simple molecules on a mobile device. The free version includes a model builder along with multiple molecular renderings that can be zoomed, rotated and translated. Selection allows exploration of structural features, such as bond lengths, angles and dihedrals. The K12 Periodic Table[17] application is a simplified electronic version of the periodic table that allows the user to explore the most relevant properties of the chemical elements. Socrative Teacher is an application that allows teachers to engage and assess their students with educational activities on tablets, laptops and smartphones. Through the use of real time questioning, instant result aggregation and visualization, teachers can gauge the whole class' current level of understanding in a particular field. Class and student level reports can be downloaded, emailed or delivered to Google Drive folders at any time.

A web-based perception survey was applied at the end of the semester in order to assess the opinion of students about the instructional method implemented in undergraduate chemistry courses. Students were asked to identify the most favorable and negative aspects about the instruction methodology, choosing one or more options from a series of statements. Favorable aspects considered in the survey about the projection of digital handwriting using a tablet device were: (a) It made me easier to take notes during lectures; (b) I could follow the follow the instructor's cognitive process and the progressive development of contents during lectures; (c) It made me easier to represent chemical structures and chemical processes; (d) It helped me to follow and understand the problem solving strategies presented during chemistry lectures; (e) The contents of each class were available after each session in a web platform; (f) I had the possibility to complete my notes after each session without losing information; (d) None. On the other hand, the potentially negative aspects considered in the survey about the instructional methodology used during chemistry lectures were: (a) It was hard for me to understand the calligraphy of my teacher; (b) My instructor wrote too fast during lectures; (c) I could not see the screen during lectures; (d) It was hard for me to write and pay attention simultaneously during lectures; (e) None. Finally, students were asked to identify whether they prefer tablet-based or PowerPoint®-based presentations as instructional method in chemistry lectures. Survey contents were validated by a panel of three experts who are faculty members and experienced teachers in undergraduate chemistry courses. The survey was implemented and applied using a Moodle platform provided by the institution. All responses were anonymous.

At the end of the semester, teachers were also asked to provide their qualitative opinion about the effect of the presentation mode on students' performance in chemistry lectures. In addition, courses final grades were retrieved from the official university report system in order to evaluate the students' outcomes in the intervened undergraduate chemistry courses. These results were compared with the average grades obtained by students in non-intervened undergraduate chemistry courses during the same academic period. Grades are reported in a 1.0-7.0 scale, with a passing grade of 4.0, which is the most common grading system in Chilean universities. Final grades and percentages of success of students enrolled in intervened and non-intervened introductory chemistry courses were classified according to the students' PSU scores distribution obtained from official institutional sources. PSU (*Prueba de Selección Universitaria*) is a standardized national university selection test that is customarily used as descriptor for the academic profile of first-year undergraduates.[21]

RESULTS AND DISCUSSION

Digital handwriting projection using a tablet device was provided as instructional model in four introductory chemistry courses. The contents of each lecture were built instantly on the tablet screen, using digital ink to create freehand representations of the conceptual aspects, structures, equations and problems corresponding to each session. Handwritten notes were drawn in multiple colors, saved with acceptable quality in PDF files, and shared with students after each class. A key factor in this implementation is that learners can follow the instructor's cognitive process and the progressive development of contents during lectures by reproducing instantly the teacher's drawings and annotations. On the other hand, the tablet enables an instructor to immediately adapt the class contents in response to students' enquiries, and to easily highlight items directly on the screen while retaining facial contact with the audience, which is relevant to engage students and promote motivation during lectures. In addition, the use of a tablet to provide instruction avoids the loss of continuity and information that often occurs when instructors switch between pre-organized electronic slides and white/chalk board during lessons. Instead of that, the use of tablet-based presentations allow students to follow and register the content development during classes, which is guided by the teacher and enriched by students' questions throughout each session. Moreover, if something relevant has been missed by students, they can look up for this information in the corresponding session files and complete their notes after classes. With these qualitative features in mind, we have collected evidence from the intervened courses in order to assess the impact of the implemented pedagogical strategy on the students' perception and academic outcomes, as described in the following sections.

Students' perception about the instructional method

Students' perception about the pedagogical strategy based on the projection of digital handwriting during chemistry lectures was gathered from a web-based perception survey applied at the end of the semester to all students enrolled in the intervened courses (N=137), as summarized in Table 1. According to these results, students show a very positive opinion about the instructional method and acknowledge that the projection of digital handwriting allows them to follow the contents progress during lectures as its most valuable aspect. In addition, students acknowledge that taking notes and understanding problem solving strategies during lectures were facilitated by the projection of digitally handwritten annotations. In addition, almost all students opine that this pedagogical strategy is more preferable than the use of traditional electronic slides during chemistry lectures. These results suggest a positive impact on students' motivation and provide evidence about the favorable pedagogical impact of changing the instructional method from a traditional setting to a more active and process-focused strategy.

Students' academic outcomes

As a means to measure the efficacy of the instructional method on the students' academic outcomes, a comparison of final average grades and percentages of success between students enrolled in intervened and non-intervened introductory chemistry courses is reported in Table 2. Students were classified according to their PSU scores, considering that the results of this standardized national university selection test have been widely employed as descriptors for the academic profile of first-year undergraduates in Chilean[21] PSU data distribution suggests that students enrolled in intervened and non-intervened courses are comparable student populations with similar

Table 1. Summary of students' responses concerning their perception about the pedagogical strategy based on the projection of digital handwriting during chemistry lectures. The survey was gathered from students enrolled in four undergraduate chemistry courses (N=137) at Universidad Andres Bello, Concepcion (Chile) at the end of the first semester of 2014

Item	Percentage of Responses (%)
1. The aspect(s) that I value most about the pedagogical strategy based on the projection of digital handwriting is/are (Please choose one or more options)	
(a) It made me easier to take notes during lectures	54
(b) I could follow the follow the instructor's cognitive process and the progressive development of contents during lectures	84
(c) It made me easier to represent chemical structures and chemical processes	46
(d) It helped me to follow and understand the problem solving strategies presented during chemistry lectures	69
(e) The contents of each class were available after each session in a web platform	77
(f) I had the possibility to complete my notes after each session with no loss of information	69
(d) None	0
2. The most negative aspect(s) about the instructional methodology used during chemistry lectures was/were that (Please choose one or more options)	
(a) I was hard for me to understand the calligraphy of my teacher	0
(b) My instructor wrote too fast during lectures;	15
(c) I could not see the screen during lectures;	0
(d) It was hard for me to write and pay attention simultaneously;	8
(e) None	85
3. I prefer the use of tablet-based presentations instead of PowerPoint®-based presentations during chemistry lectures.	
Yes	92
No	8

academic profiles. In addition, final average grades and percentages of academic success indicate that students enrolled in the intervened courses significantly over-performed compared to non-intervened students, which provides evidence about the benefits of the instructional methodology based on the innovative use of a tablet device to enable the real-time projection of digital handwriting in undergraduate introductory chemistry lectures. As pointed out by O'Malley "As many technological tools become available sound pedagogical reasons for adapting such approaches must be present rather than adopting new technology simply for its own sake".[12] In this sense, the results of the present report support the inclusion of tablets as pedagogical tools in our educational context, where the access and insertion of technology in teaching activities is still incipient.

Teachers' perceptions

From the teachers' point of view, the projection of digital handwriting has a strong impact on undergraduate chemistry lectures. Teachers acknowledge that this method provides flexibility, avoids switching between electronic slides and chalk/white boards, and involves less preparation time compared to the use of traditional electronic slides, without the need of advanced technological skills, which are often an obstacle for the insertion of technology in the classroom, especially for senior teachers. In this sense, the most relevant drawback pointed out by instructors is the need to practice writing with a digital pen until they feel comfortable with the outcome on the projection screen. In addition, teachers perceived a significant improvement in students' attitudes during classroom sessions when instructed with the tablet as a projection device for digital handwriting compared to traditional teaching methods. According to instructors, students retained more attention and were more engaged during the lessons, being reinforced by the permanent face contact with the teacher.

Table 2. Comparison of final average grades and percentages of success between intervened and non-intervened introductory chemistry courses during the first semester of 2014. Data was classified according to the students' PSU scores distribution retrieved from official institutional sources. Average grades are reported in a 1.0-7.0 scale, with a passing grade of 4.0. Percentages of success correspond to the fraction of students that passed introductory chemistry courses within each PSU quartile

PSU Quartile	Number of students	Average final grade	Percentage of success
Intervened courses			
1	27	3.0 ± 1.2	30
2	44	4.3 ± 1.0	70
3	34	4.6 ± 1.0	77
4	32	4.6 ± 1.1	69
Total	137		
Non-intervened courses			
1	90	2.8 ± 1.2	23
2	75	3.4 ± 1.2	41
3	105	4.1 ± 1.1	59
4	139	4.6 ± 0.9	73
Total	409		

CONCLUSIONS

The projection of digital handwriting using a tablet interface constituted a valuable tool for the teaching-learning process in undergraduate chemistry courses at our institution. Preliminary results gathered in the present study suggest that the presentation mode has a strong impact in the academic results and attitudes of students towards learning chemistry. These results are consistent with previously reported evidence, which suggest that learning is improved in environments where students work more actively during classes rather than simply passively listening to lectures. However, it is worth to note that the sole use of digital handwriting projection is not a guaranty for academic success, but provides some valuable technology tools that can help students to engage with the learning of chemistry during lessons. Therefore, it is the role of the teacher to make the most of technology to create educational settings that facilitate learning and to promote the active participation of students during lectures.

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