PERSONAS: RESULTADOS DE INVESTIGACIÓN

Use of a Visual Programming Language and Mobile Devices to Improves Students' Understanding of Process Control Systems

Uso de Lenguajes de Programación Visual y Dispositivos Móviles para Mejorar la Comprensión de los Estudiantes de los Sistemas de Control de Procesos

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Resumen

Nuestra principal contribución es la aplicación del lenguaje de programación visual (VPL, de sus siglas en inglés “Visual Programming Language”) y los dispositivos móviles (MD, de sus siglas en inglés “Mobile Devices”) para el aprendizaje de los sistemas de control, lo cual mejoró la comprensión de estudiantes regulares considerados dentro de un diseño cuasiexperimental. El empleo de un ambiente de enseñanza que emplea VPL y MD para abordar los sistemas de control de procesos fue la clave para resolver las dificultades de aprendizaje que tenían el estudiante con el método de enseñanza tradicional, y que perduraban a pesar de ya que se estaba considerando la alineación constructiva entre instrucción, aprendizaje y evaluación, actividades auténticas y un enfoque de aprendizaje basado en el diseño. Los elementos gráficos utilizados por VPL, tomados de una biblioteca hecha de bloques reutilizables, con diferentes formas y colores, facilitan la comprensión de los sistemas de control de procesos. También VPL muestra todo el sistema de control de procesos de un vistazo a través de los diferentes MD utilizados, que fueron computadoras portátiles, tabletas y teléfonos inteligentes. Ayudó que todos estos MD son bien conocidos y fáciles de usar para los estudiantes. La evaluación comparativa del rendimiento de aprendizaje de los estudiantes, con y sin el uso de VPL y MD, mostró la efectividad del rediseño en el modo de enseñanza. Se facilitó el aprendizaje de los sistemas de control de procesos, reduciendo las dificultades de la enseñanza tradicional y mejorando la comprensión de los estudiantes. Además, la autoeficacia de los estudiantes se vio afectada positivamente.

Palabras clave: Ingeniería eléctrica; sistemas de control; lenguaje de programación visual; dispositivos móviles; educación; instrucción asistida por computadora

Abstract

Our main contribution is the application of visual programing language (VPL) and mobile devices (MDs) to the control systems learning, which improved students' understanding in a quasi-experimental design with regular students. The teaching environment for process control systems that use VPL and MDs was the key to solve the learning difficulties that students had despite considering constructive alignment between instruction, learning and assessment, authentic activities, and design-based learning approach. Graphic elements used by VPL, taken from a library made of reusable blocks, with different shapes and colors make it easier to understand process control systems. Also, VPL showed the entire process control system at a glance through the different MDs used, which were laptops, tablets, and smartphones. All of these MDs are well known and user-friendly to students. Comparative evaluation of the students' learning performance, with and without the use of VPL and MD, showed the effectiveness of the redesign. Process control systems learning were facilitated, reducing the difficulties of traditional teaching, and improving the students´ understanding. Also, students' self-efficacy was positively impacted.

Keywords: Electrical engineering; control systems; visual programming language; mobile devices; education; computer-assisted instruction

1 Introduction

This study was based on previous teaching studies about teaching process control systems by Martín-Ramos et al (2018) and Panoutsopoulos (2011). Martín-Ramos et al (2018) addressed the learning of a programmable controller of the Arduino brand,

and Panoutsopoulos (2011) studied the introduction to robotics as a controlled process. These authors and also Robertson and Howells (2008) proposed learning through practice in realistic scenarios, making students feel a sense of accomplishment, and accumulating experiences. This practical scenario experience can be use repeatedly (De Vries, E., 2006, Fortus, D, et al 2014, and Ke, F., 2014).

Thus, looking for more profound comprehension and application of knowledge, our study addresses process control systems in real-world scenarios (Anna Wiewiora & Anetta Kowalkiewicz, 2019). Also, in this study, students were evaluated in those real-world scenarios (Adie, LE, et al 2010, Anna Wiewiora & Anetta Kowalkiewicz, 2019, Biggs, J, 1996). Increasing the students´ understanding and self-efficacy was expected in our study after involving authentic assessment as in Cronbach (1951), Herrington y Herrington (1998).

It also considers a constructive alignment between instruction, learning and assessment (Biggs, J B, 1993), as suggested by Gulikers et al (2004. Here the instruction, learning and assessment were aligned regarding the task, context (physical and social), and assessment form and criteria.

Taking into account the results from Gulikers et al (2004) and Ke, (2014), we implement all laboratory experiences based on students' design of the process control system. Also, expecting to increase their self-efficacy (Cronbach, LJ, 1951, Ke, F., 2014).

However, after considering constructive alignment between instruction, learning and assessment, authentic activities, and design-based learning approach, students from the base group of this study still had difficulties facing the process control systems concepts. The traditional teaching environment used deals with an electro-mechanical early technology of process control system made up of wiring of control relays and timers. Thus the idea of improving the learning environment came out (Ouahbi, I, et al 2015, Sáez-López, JM, 2016) to improve self-efficacy. It also would increase the students' interest (Bennedsen, J, et al 2008, Chao, PY, 2016) and the learning performance as suggested by Bandura, (1986), Panoutsopoulos (2011), Wilson y Narayan (2016), Yukselturk y Altiok (2017) away from the difficulties of traditional classroom learning (Martín-Ramos et al, 2018, Pintrich, PR y De Groot, EV, 1990) proposed facilitating the learning process and increase the learning motivation integrating VPL tools, thus improving the learning environment. Graphic elements are used by VPL to develop the program (Sáez-López, JM, 2016).

These elements are taken from a library made of reusable blocks. In the end, there are different shapes and colors, making it easier to identify proper programing. VPL can also increase the learners' self-efficacy (Chao, PY, 2016) and success (Yukselturk, E, y Altiok, S, 2017). Nowadays, these VPL tools are displayed in MDs, such as laptops, tablets, and smartphones. All of these MDs are well known and user-friendly to students.

Our main contribution is the use of VPL and MDs for control systems teaching. Our study moved away from traditional education of the process control system, improving the learning environment and also the self-efficacy. In our study, both teaching environments are compared, with and without the use of VPL and MDs. Using VPL and MDs was the improvement key, not achieved despite considering design-based learning (Ke, F., 2014), authentic assessment, and a constructive alignment between instruction, knowledge, and evaluation.

This paper is organized as follows: the methodology used is described in Section 2. It considers the redesign of laboratory experiences of process control systems using VPL and MD. Design-based learning and authentic assessments with constructive alignment are also involved. A discussion of the results is included in Section 3. Finally, in Section 4, some conclusions are drawn.

2 Methodology

Based on the previous literature discussion, this study was made upon the laboratory experiences of the Command and Regulation course of 17-weeks of duration at the Department of Industrial Technologies of the Technological Faculty of our University. The same instructions, activities, and instruments described in the next sections, were applied during two semesters. Students attending the first semester were named the base group, with no use of VPL and MD technology, while these were bought and implemented. The experimental group was of the students attending the second semester, using a VPL and MD learning environment.

2.1 Instructional Activities

Below are the given the instructions in this study, including pre-test, implementation, and post-test. They are also considering the five steps of Fortus et al (2004), Fortus et al (2005) and Fortus et al (2014).

Pre-Test, Evaluating:

(Step 1) Identification and Definition of Context: Here, the student prepares the implementation, based on the related concepts and skills introduced by the teacher in the previous weekly class of 130 min, where the teacher has explained the unit subject and demonstrated similar examples of process control system design. An introduction to the practical context of the laboratory experience is described by the students, giving examples of applications and a description of the process to be controlled, detailing:

• Physical framework: describing examples of facilities using the process control system and its weather and geographical characteristics, such as a mining site at 3,500 meters above sea level; a fishing industry (Brown, JS, et al 1989, Herrington, J y Oliver, R, 2000, Gulikers, TMJ, et al 2004),

• Social context: describing whether the design will be done individually, competing with other individuals of the laboratory group, or as a team; identifying the division of responsibilities (Herrington, J y Herrington, A, 1998, Gulikers, TMJ, et al 2004),

• Early and modern technologies background,

(Step 2) Background Research: students search and collect information about possible solutions. The students design the process control system to be implemented based on the laboratory guideline given by the teacher, describing the instructional activities and showing:

• Bill of materials, including measuring equipment, tools, wiring, control tech, etc.

• Wiring design.

• Programming design.

The students should respond to a self-efficacy survey at this point.

(Step 3) Development of Personal and Group Ideas: A group of at least two students implements it. Based on each student's design, students discuss, provide suggestions, and define the final solution.

Implementation, considering:

(Step 4) Artifact Construction: Students construct the process control system based on the final solution and acquire experience. It constitutes the result of the assessment, evaluated against the completion of the following tasks (Gulikers, TMJ, et al 2004, Moerkerke, G, et al 1999):

• Wiring and pre-commissioning: students shall develop control and power wiring. Then, they test each part independently first, and as a whole at the end.

• Programming and commissioning: students shall control programming. Then, they check each programming segment separately first, and as a whole at the end, together with the wiring.

• Operating: the students should operate the process control system taking into account the commands and monitoring.

Post-Test, including:

(Step 5) Feedback: Students have to update the pre-test with the implementation results. Particularly, the background research (bill of material, wiring, and programming) shall detail every deviation (identifying and discussing) between the implementation and the design.

These were the given instructions for the experiment described in the next section.

2.2 Experimental Design

The quasi-experimental design shown in Table 1 was used in this study, allowing collecting data.

Table 1: Experimental design of this study.

Group	Lab Experience	Pre-test	Implementation	Post-test
Base group	1	$Ti_{1.1}$	$I_{1.1}$	$Tf_{1.1}$
	2	$Ti_{1.2}$	$I_{1.2}$	$Tf_{1.2}$
	3	$Ti_{1.3}$	$I_{2.1}$	$Tf_{1.3}$
	4	$Ti_{1.4}$	$I_{2.2}$	$Tf_{1.4}$
	5	$Ti_{1.5}$	$I_{3.1}$	$Tf_{1.5}$
Experimental group	1	$Ti_{2.1}$	$I_{3.2}$	$Tf_{2.1}$
	2	$Ti_{2.2}$	$I_{4.1}$	$Tf_{2.2}$
	3	$Ti_{2.3}$	$I_{4.2}$	$Tf_{2.3}$
	4	$Ti_{2.4}$	$I_{5.1}$	$Tf_{2.4}$
	5	$Ti_{2.5}$	$I_{5.2}$	$Tf_{2.5}$

The Tests T_1, T_2, T_3, T_4, T_5, including a self-efficacy survey, were applied initially (i), and at the finale (f). It considers the base group (1), and the experimental group (2) for comparison purposes. The two compared groups made the Implementations I_1, I_2, I_3, I_4, I_5 of the process control systems (artifacts construction).

Students had the same teacher and applied the same methodology through all labs for each process control subject treated: processes rotating in forward and backward directions, processes involving induction motor starting, pneumatic processes, oleo-hydraulic processes, and processes involving variable speed drive.
In the next section, the participants in this experiment are described.

2.3 Participants

The experiment was implemented for two semesters. The participants shown in Table 2 were regular students of the Command and Regulation course of the 17-weeks, for the track of "Industrial Maintenance Technologist" (IMT). The average age of students was 22 years of age for the base group (Semester 1), aged between 19 and 24 years, and 21.9 years old for the experimental group (Semester 2), aged between 21 and 26 years.

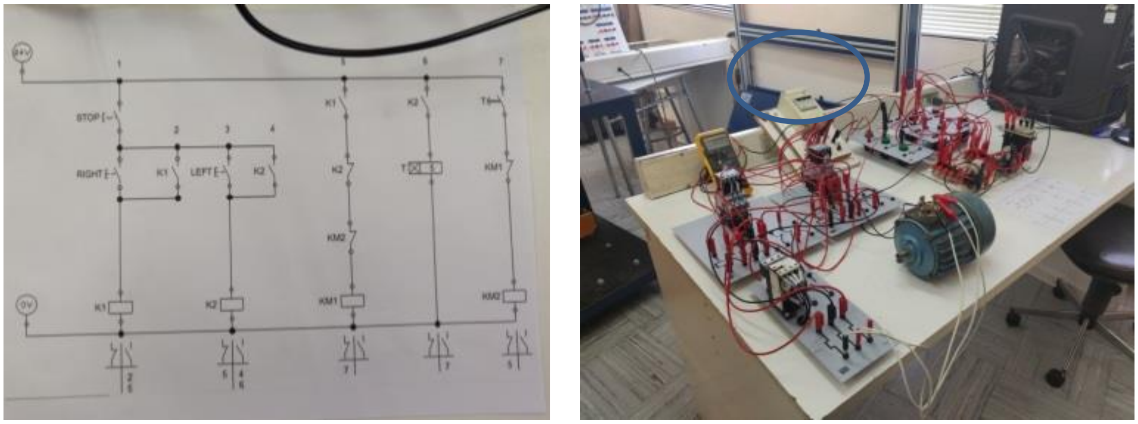
Table 2: Participants.

	Base group (SEMESTER 1)		Experimental group (Semester 2)	
Categories	Quantity	Percentage	Quantity	Percentage
Total	9		9	
Female	1	11.1%	0	00.0%
Male	8	88.9%	9	100.0%
21 year olds	4	44.4%	6	66.7%
22 year olds	3	33.3%	1	11.1%
23 year olds	1	11.1%	1	11.1%
24 year olds	1	11.1%		00.0%
25 year olds		00.0%		00.0%
26 year olds		00.0%	1	11.1%
Age range	21 24		21 26	
Average age	22		21.9	

Participants faced the learning environment described below.

2.4 VPL and MD Learning Environment

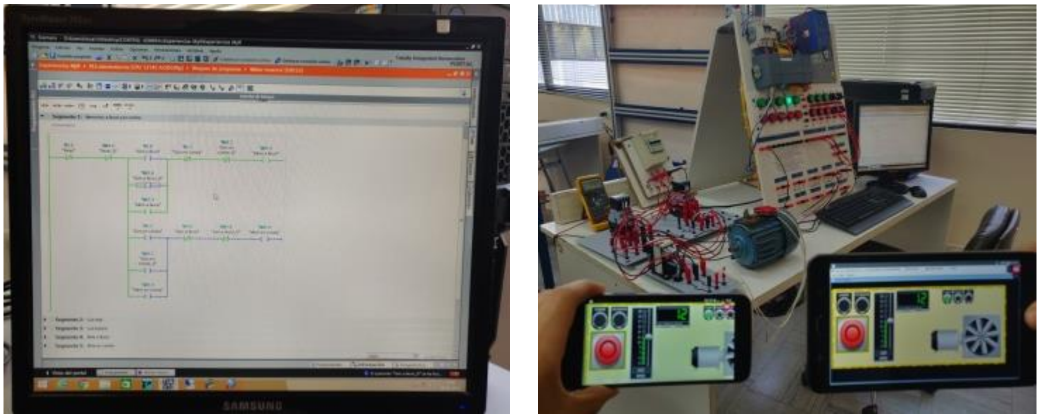
Traditional teaching environment studied for comparison purposes during semester 1, deals with an electro-mechanical early technology of process control system made up of wiring of control relays and timers, which are unknown to students. Figure 1 shows an example. Here students designed the process control wiring drawing of Figure 1.a) to be implemented as shown in Figure 1.b), with the control logic wiring identified inside a circle. While building, monitoring, and commissioning through wiring, students have to deal with safety issues due to the presence of control voltage.



a) b)

Figure 1: Traditional learning environment: a) Process control drawing, b) Wiring

The proposed VPL and MDs teaching environment, implemented during semester 2, deals with a modern programmable electronic technology. Figure 2 shows the same example from previous Figure 1, but with the new technology. Here students built, monitored, and commissioned in a safer environment. They do it through the program of Figure 2.a), to be implemented as shown in Figure 2.b) with the control logic programmed with VPL in a PC (or a laptop), and also operated via VPL running in MDs. Almost all the elements in the VPL and MDs learning environment are known to the students (PC, laptop, tablet, smartphone, with the latter even belonging to the students). These are user-friendly for process control system beginners, similar to those used in Ke (2014) and Sáez-López (2016).



a) b)

Figure 2: VPL and MD learning environment learning environment: a) Programming instead of drawing, b) Wiring reduction of VPL and MD

2.5 Instruments Validity

The pre-test, the implementation, and the post-test, were evaluated for each group, and for each lab experience (from 1 to 5), obtaining the following results:

Table 3: Validity and reliability of the technical assessment.

Group	Charact.	T_i (1 to 5)	I (1 to 5)	T_f (1 to 5)
2	Reliability	0.76	0.73	0.77
	Difficulty	-0.9 to -1.3	-0.6 to -1.3	-1.0 to -1.4
	MNSQ	0.89	0.90	0.90
1	Reliability	0.66	0.66	0.67
	Difficulty	-0.53 to -0.79	-0.51 to -0.79	-0.61 to -0.84
	MNSQ	0.87	0.93	0.91

In all cases, implementation, pre-test, and post-test have a similar degree of difficulty, with the lower value indicating a lower degree of difficulty. The instrument was analyzed considering the Rasch model (Rasch, G, 1960). Reliability improved from group 1 to group 2, showing the latter a higher value than 0.7, which is established by [Duncan, P W, at al 2003] as an acceptable cutoff. The mean square error (MNSQ) of the fit index is higher than 0.87, which fell within the acceptable cutoff of 0.6–1.4 (Wright, BD y Linacre, JM, 1994). Thus, satisfactory results of the made technical assessments are obtained.

A self-efficacy survey (Pintrich, PR y De Groot, EV, 1990), with five subscales, was used during this study pre-test to measure learners' self-efficacy (1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree; 5 = strongly agree). The obtained results are next shown:

Table 4: Validity of the self-assessment survey.

Group	Cronbach's alpha
2	0.89
1	0.87 to 0.89

3 Results

Table 5 and Table 6 show the comparative results obtained after the teaching process control system with early technology (base group) and through the VPL and MD environment (experimental group).

Table 5: Reliability and difficulty of the tests through Labs for Group 1.

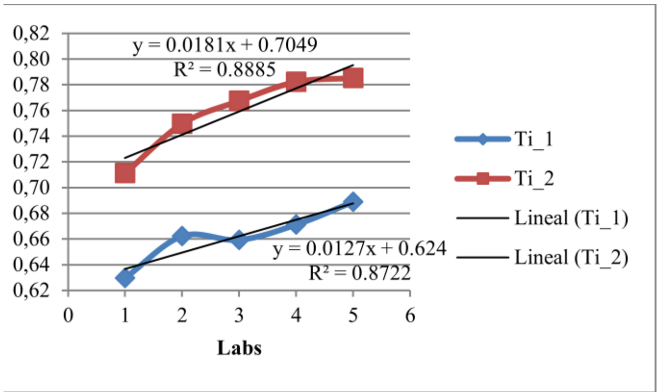
Labs	Description	Ti	I	Tf
Lab 1	Reliability	0.63	0.62	0.65
	Difficulty Logit	-0.53	-0.51	-0.61
Lab 2	Reliability	0.66	0.65	0.67
	Difficulty Logit	-0.67	-0.64	-0.71
Lab 3	Reliability	0.66	0.65	0.67
	Difficulty Logit	-0.67	-0.64	-0.71
Lab 4	Reliability	0.67	0.68	0.68
	Difficulty Logit	-0.71	-0.74	-0.75

Lab 5	Reliability	0.69	0.69	0.70
	Difficulty Logit	-0.79	-0.79	-0.84

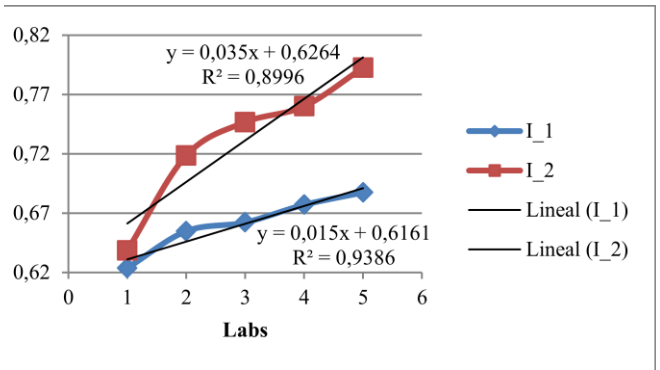
Table 6: Reliability and difficulty of the tests through Labs for Group 2.

Labs	Description	Ti	I	Tf
Lab 1	Reliability	0.71	0.64	0.73
	Difficulty Logit	-0.9	-0.6	-1
Lab 2	Reliability	0.75	0.72	0.75
	Difficulty Logit	-1.1	-0.9	-1.1
Lab 3	Reliability	0.77	0.75	0.78
	Difficulty Logit	-1.2	-1.1	-1.3
Lab 4	Reliability	0.78	0.76	0.8
	Difficulty Logit	-1.3	-1.2	-1.4
Lab 5	Reliability	0.79	0.79	0.80
	Difficulty Logit	-1.3	-1.3	-1.4

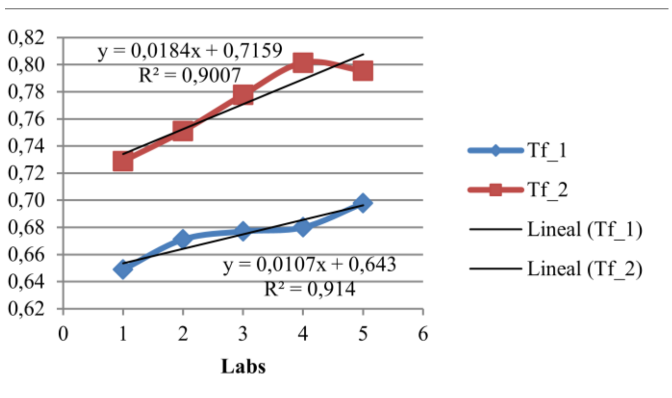
In general, results from Table 5 and Table 6 show that pre-test, implementation, and post-test have a similar degree of difficulty. However, in the beginning the application is slightly more difficult for students. The experimental group, with the use of VPL and MD, found the labs easier than the base group without the use of VPL and MD. Next, Figure 3 shows these results graphically.



a) Pre-test reliability evolution.



b) Implementation reliability evolution.



c) Post-test reliability evolution.

Figure 3: Tests reliability from lab 1 to lab 5 a) Pre-test, b) Implementation, c) Post-test.

The test's reliability increased with the use of VPL and MDs (Group 2). It happened in all cases for the pre-test, the implementation, and post-test. Also, the tendency to find all these tests easier increased from Lab 1 to Lab 5. The difficulty-logit decreased with the use of VPL and MD.

Table 7 shows the self-efficacy results obtained. The self-efficacy increased from Lab 1 to Lab 5, while students acquired experience. Also, it is higher after using of the VPL and MDs learning environment.

Table 7: Results and reliability of the self-efficacy survey

Group	Description	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5
1	Cronbach's alpha	0.87	0.87	0.82	0.89	0.89
	Quantities	121	121	140	150	150
2	Cronbach's alpha	0.89	0.89	0.89	0.89	0.89
	Quantities	144	144	156	168	168

The use of VPL and MDs also solved the issue about the learner's concern due to the presence of control voltage. With the use of VPL and MDs, there was no voltage, but software involved in the implementation and commissioning of the process control logic.

Regarding the students' results, Figure 4 shows the logits for the group 1 and the group 2.

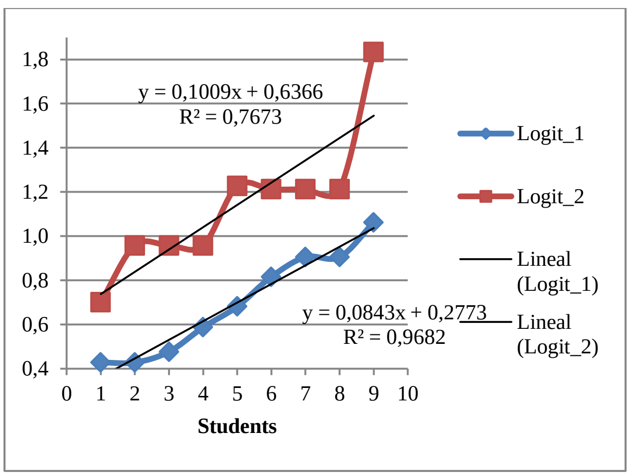


Figure 4. Logit evolution for students of group 1 and group 2.

It can be seen that the logit increased with the use of VPL and MDs, improving students' learning.

4 Conclusion

The main contribution of this work is using VPL and MDs as the improvement key for process control system teaching, joint to the constructive alignment between instruction, learning, and assessment, authentic activities, and design-based learning approach. Considering these last educational elements only, was not enough, not compensating the high degree of new aspects to students related to the control system subject, nor their concern due to the presence of control voltage.

It helped, increasing the amount known and user-friendly elements for students with the different MDs used, which were laptops, tablets, and smartphones. Also, having a safer environment, after eliminating the presence of control voltage with the use of control programming language.

Initially, students had difficulties facing the process control systems concepts with the traditional teaching environment. It happened despite using a constructive alignment between instruction, learning, and assessment, authentic activities, and design-based learning approach. The results were below the expected as verified with students from a base group. These learners were facing for their first time the control wiring of relays and timers, interacting with processes through sensors and actuators. Repeatedly, students expressed their concern due to the presence of the control voltage, related to this electro-mechanical early technology.

Latter, an additional improvement of the teaching environment was considered, the use of VPL and MD. Graphic elements used by VPL, taken from a library made of reusable blocks, with different shapes and colors, make it easier to understand process control systems. Also, VPL showed the entire process control system at a glance through the different MD used, which were laptops, tablets, and smartphones. All of these MDs are well known and user-friendly to students. These changes were applied to an experimental group of students.

Also, an issue solved with the use of VPL and MD was the learners' concern regarding the presence of control voltage. With the use of VPL and MD, there was no voltage, but software involved in the implementation and commissioning of the process control logic.

As a result, the situation changed for students from the experimental group. They considered their environment to be safe while building, modifying, monitoring, and commissioning control systems through programming via VPL and MD. Students from the experimental group acquired a better understanding of process control systems than those from the base group. Also, the reliability of the tests increased with the use of VPL and MD, joint with the tendency of finding each next test easier than previously. The difficulty-logit decreased with the use of VPL and MD. VPL and MD teaching environment is perceived as user-friendly by learners, increased their self-efficacy, encouraged them to sidestep the obstacles to finish projects, and led them to a better understanding.

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