An Innovative Laboratory Physics Course Using Specialized Software and Digital Media: Students' and Instructors' Perspectives

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A laboratory physics course incorporating specialized software and digital media from the students' perspectives

Abstract

At a private Latin American university in the southern hemisphere, efforts were made to move away from traditional physics lab teaching practice during a recent innovation in its academic program. As a result, a physics course was created to be held in the classroom rather than in the physics laboratory, using specialized software and digital media. The laboratory course allows students to collect and analyze data through PhET simulations or videos rather than in a traditional laboratory setting. The aim is to promote agency and participation in all students, make the experimentation process more agile and dynamic, enhance student engagement, and make the experimentation process more flexible.

This study aims to examine student perceptions of their learning experience in a physics laboratory course taught using digital tools instead of traditional laboratory facilities. The central research question being addressed is: How do students perceive active learning in a physics laboratory course prepared using technology?

The is a quantitative research study in which participated over 500 first-year engineering and science major students in a laboratory course. The students completed a pre-and-post survey before and after an 8-week intervention period. The survey collected their perceptions regarding an innovative teaching method used for the laboratory course. The pre-and-post comparison allows for contrasting student opinions in three main areas: type of instruction, teaching strategies, and student response to the instruction. The study presents some of the laboratory activities' outcomes and limitations. One specific activity, the capacitor discharge experiment, will be thoroughly discussed to compare the traditional physical setup with the technology-based version. Findings highlight the pros and cons of the teaching method used and reflect on what has been learned. It also suggests potential next steps for further improvement.

Keywords: Physics laboratory course, PhET, active learning, educational technology, educational innovation, higher education.

Introduction

Current teaching methods in physics laboratories often involve lectures where students are passive participants whose task is to receive information to later repeat procedures without fully grasping underlying concepts. This approach has been demonstrated as ineffective [1]. Education has been under constant change. Consequently, there has been a shift towards active learning methods where students play a more active role in their learning. [2], [3]. Given the above and in line with the changing educational landscape, the private university in which this study took place has adopted an active learning approach in their physics laboratories. This teaching approach offers to the engineering student a shift in their learning process making them more involve and active, challenging them in their reasoning, helping them to make connections, and giving them the opportunity to apply the tools, concepts, and ideas they have learned [1].

The teaching model adopted is based on Sokoloff, Laws, and Thornton [4] which involves incorporating computers in the physics laboratories to collect data through real and virtual experiences using videos or PhET simulations [5], [6]. Moreover, the impact of a lab course is question when final scores of students who took or not a lab course seems not to be significant [7], [8], [9]. Of course, the debate about offering a lab course or not [7] and under what modality (real experiments, with educational technology) [2] or implementing active methodologies continues.

Using videos or simulations may address some of the issues commonly encountered in traditional laboratory settings, such as lack of readiness or limitations in terms of equipment [10]. This approach also enables a larger number of students, 40 or more, to experience laboratory work and the application of laboratory techniques.

One of the major problems presented at the university is the large number of students who must take the experimental physics course in a regular semester. That is, the engineering students taking this lab course are of the order of 1000 students nationwide, concentrating 700 in the city of Santiago. We estimate that the space, instruments, and materials needed will require a significant investment in infrastructure and measuring tools to offer this course in a physical laboratory. This limitation can be attenuated by changing the focus of the laboratory to a more digital environment [11]. Taking into account the lessons learned during the COVID-19 confinement, we incorporate videos and PhET sims [5] allowing us to offer many simultaneous sections of the course to a large number of students while keeping the class size with an average of 38 students.

This teaching method may resemble distance learning [10], [11], [12] except that in our design, students and instructors are physically present in the classroom. This allows the instructors to walk around the classroom and to closely monitor students' work by providing guidance and support when needed. The in-person facilitation of the instructors allows them to get to know their students better and to keep closer contact than in the online learning implemented during the pandemic.

This study aimed to understand student perception regarding their learning in a physics laboratory course using digital tools instead of traditional physics laboratory equipment. The research question is: What is the perception held regarding active learning in a physics laboratory course taught using educational technology from the perspective of students and instructors?

Methodology

This is a quasi-experimental quantitative study with a pre-post test (at the end of the first and third part of the semester, respectively, about 9 classes each third), and intervention with a didactic design (active learning) using technology (see Figure 1). This study aims to know how students perceive the teaching of a physics laboratory course using educational technology instead of actual physics laboratory materials.

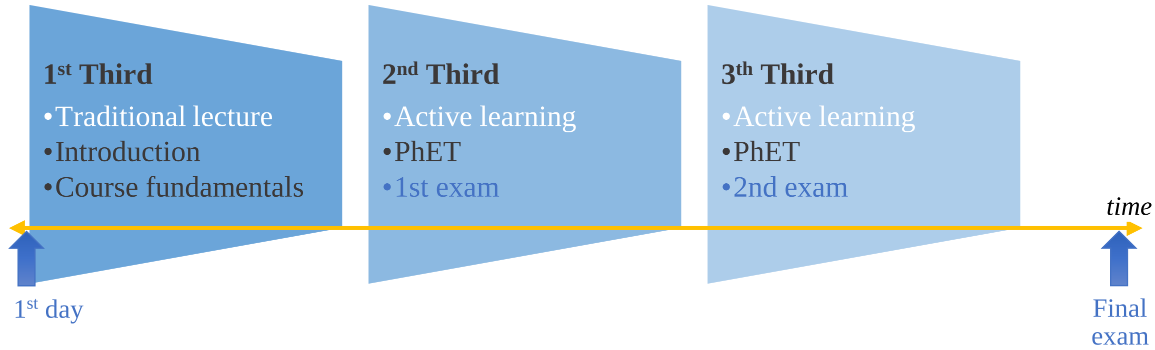

Figure 1. Type of instruction (in white font), educational technology, and course milestones (in blue font) are represented with the semester's timeline. Each third of the semester covers about 9 sessions each, while the semester runs from the beginning of August to the second week of December including the final exams period.

Participants

The students who participated in the study belonged to engineering programs (mining engineering, geology, computer and information engineering, industrial engineering, informatics engineering, merchant marine engineering, and bachelor in science) of a private university in South America. The experimental physics course is located as a course in the second semester of the curriculum (first-year engineering students). The students must take and approve the general physics course, which corresponds to a basic physics course. Since these students are registered in their first year, they are taking a parallel course in calculus, so at this point, they can only work with basic mathematics.

During the semester when the study was conducted, there were 1030 students enrolled in the lab course; of which 572 took the pre-test, and 490 responded to the post-test, representing 56% and 48% of the total enrollment, respectively.

Survey Instrument

To study student perception about the teaching strategy of the physics laboratory course, the instructors ask enrolled students to take a survey. This survey is known as the Student Response to Instructional Practices (StRIP) by [16], the authors implemented the Spanish version as reported by [17]. This quantitative instrument evaluates three dimensions:

- *Student response to instruction* – 15 items asked the student about their response/reaction to the instructions and activities given by the teacher. The subdimension are value, positivity, participation, and distraction. Three more items of this dimension focus on the student's general evaluation of the course and the teacher. 18 items in total
- *Strategies for using in-class activities* – 8 items that focus on the teacher's role. This dimension has two sub-dimensions, namely: explanation and facilitation.
- *Types of instruction* – 21 items that target the type of classroom dynamics and teaching strategies the teacher implements. These items are asked about the actual class and their

ideal scenario. It has four subdimensions: active, passive, interactive, and constructive. 42 items in total (see Appendix)

All items use a frequency scale of five points, from 1-Almost never (<10% of the time) to 5-Very often (>90% of the time).

The StRIP has a total of 68 items, we added on question to enquire the number of courses in which the students have work using technological tools to enhance their learning during the class period in a regular basis (at least once a week). Given the length of the instrument, for this report we focus on the responses regarding the 21-items on the types of instruction only.

Didactic design

The didactic design has two stages. The first stage involves the provision of tools for acquiring and processing data. The second stage involves independent student work.

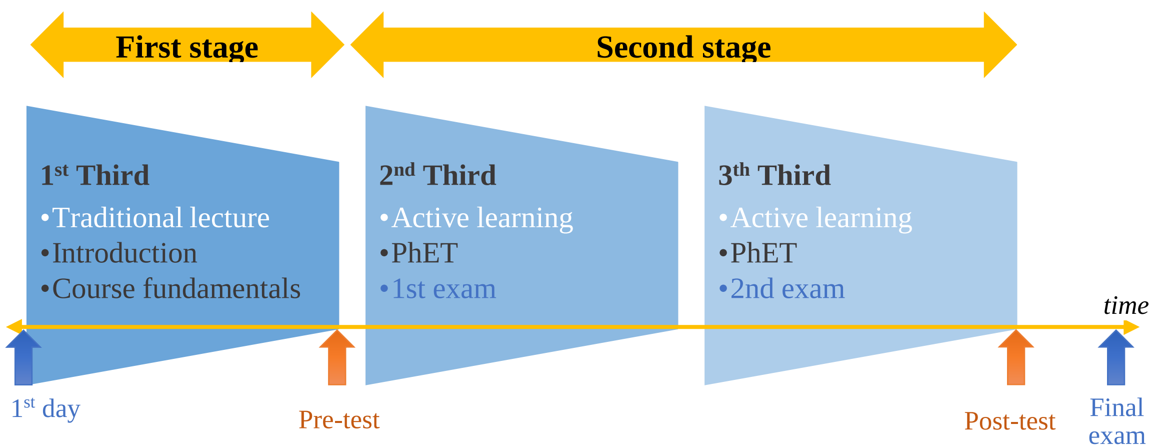

Figure 2. The two stages of the didactic design (yellow arrows), educational technology, course milestones (in blue font), and research study data collection during the semester (in orange font) are represented with the semester's timeline.

In the first stage, the teacher leads the activities, during which digital tools are introduced, such as the basic use and management of Excel (creating a graph, calculating standard deviation, etc.), downloading and using Tracker Video Analysis and Modeling Tool for Physics Education (physlets.org), PhET the Interactive Simulations project from the University of Colorado Boulder (https://phet.colorado.edu/) , mobile apps, and alternative methods for obtaining data (such as watching videos from the web or YouTube). During this stage, students work in three activities, some lasting more than one 90-min session.

In the second stage, the teacher facilitates and supports students' work by answering questions about the use of the educational tools, posing challenging conceptual questions, and monitoring students work. Students work in four activities during this stage, these activities last at least two

90-min sessions. To illustrate this, following is a description of how students actually work, specifically about the discharge of a condenser or capacitor:

There are four main stages in the capacitor discharge activity and lasts for two 90-min sessions. The description is as follows.

1. Introduction (15 min). At the class start, the instructor presents a class guideline and their evaluation rubric, explains the activity's objective, and informs students about the course website with all the resources.
2. Students work (75 min). In the second stage, students read the guide, obtain data from a video previously uploaded to the course website (also available on YouTube, Capacitor discharge resource), and start working on the activity.
3. Students work (90 min). On the second session of the activity, students continue working on the activity performing the necessary analysis with support of the educational technology to achieve the learning objective.
4. Students written report. The activity ends with a written report that students submit. In this report, students give evidence of their solution process, discuss their findings, and reflect upon the learning.

Course evaluation includes four components: a rubric-based assessment of activities, all written reports corresponding to the course activities (7 in total), and related evidence, two experimental tests, and a final written exam.

Results

The analysis focuses on understanding student perceptions of what they are currently engaged in and what they believe is ideal. It also compares students' answers in the mid-semester test (mid-test) and the end-of-semester test (end-test). For this study we are focusing on the items about *types of instruction* (see Appendix) that resulted with a significant difference based on a *t*-test ($p=0.05$). To compute the significant difference, each item response on dimension 3 (21 items on students' perception of their actual course) were compared to the corresponding item on dimension 4 (21 items on students' perception of their ideal course).

To offer a visual representation of the students shift between their perception of the actual type of instruction and the ideal type of instruction, the five-point Likert type scale of the responses was converted into three-point scale by adding responses 1 (almost never) and 2 (rarely) to indicate a type of instruction that the students did not perceive as frequent; and adding responses 4 (frequently) and 5 (very frequently) to indicate that students perceive that type of instruction as occurring in a common bases.

Table 1 summarizes the items of dimensions 3 (actual) and 4 (ideal) that have a significant difference when comparing item by item. Since *Types of instruction* have 4 subdimensions, first we present items with significant difference for the subdimension interactive and constructive type of instruction for the pre-test (mid-test at the beginning of the second stage of the course in Figure 2).

Table 1.

Items from the interactive (highlighted in yellow) and constructive (highlighted in green) subdimensions showing students' perspectives of the type of instruction in their actual class (in blue) and their ideal class (in orange) from the pre-test. The percentage indicates students' responses using the 5-Likert scale, 1&2 means not frequently and 4&5 frequently occurring.

Pre-test items	Actual	1&2	4&5	Ideal	1&2	4&5
Work in assigned groups to complete homework or other projects	3d	5%	84%	4d	9%	78%
Study course content with classmates outside of class	3g	31%	44%	4g	24%	50%
Discuss concepts with classmates during class	3i	11%	67%	4i	8%	73%
Solve problems in a group during class	3n	9%	75%	4n	7%	78%
Do hands-on group activities during class	3u	18%	61%	4u	7%	78%
Brainstorm different possible solutions to a given problem	3b	5%	76%	4b	5%	81%
Find additional information not provided by the instructor to complete assignments	3c	16%	58%	4c	19%	59%
Assume responsibility for learning material on my own	3h	20%	54%	4h	17%	59%
Make and justify assumptions when not enough information is provided	3j	17%	56%	4j	15%	62%
Take initiative for identifying what I need to know	3r	16%	58%	4r	11%	66%
Solve problems that have more than one correct answer	3t	11%	62%	4t	9%	72%

In a graph, the shift from actual to ideal can be represented with a vector. In this representation, a vector moving up indicates that students prefer more of that type of instruction. This is important, since these results correspond to the pre-test, that is, prior to the active learning implementation of the lab practices (beginning of the second stage of the course in Figure 2). Figure 3 below shows student responses to the mid-semester test (pre-test), specific values are presented in Table 1. Notice the shift in item 3g to 4g regarding studying course content with classmates outside of class (interactive), or 3b to 4b about brainstorming different possible solutions to a given problem (constructivist), 3u to 4u regarding doing hands-on group activities during class.

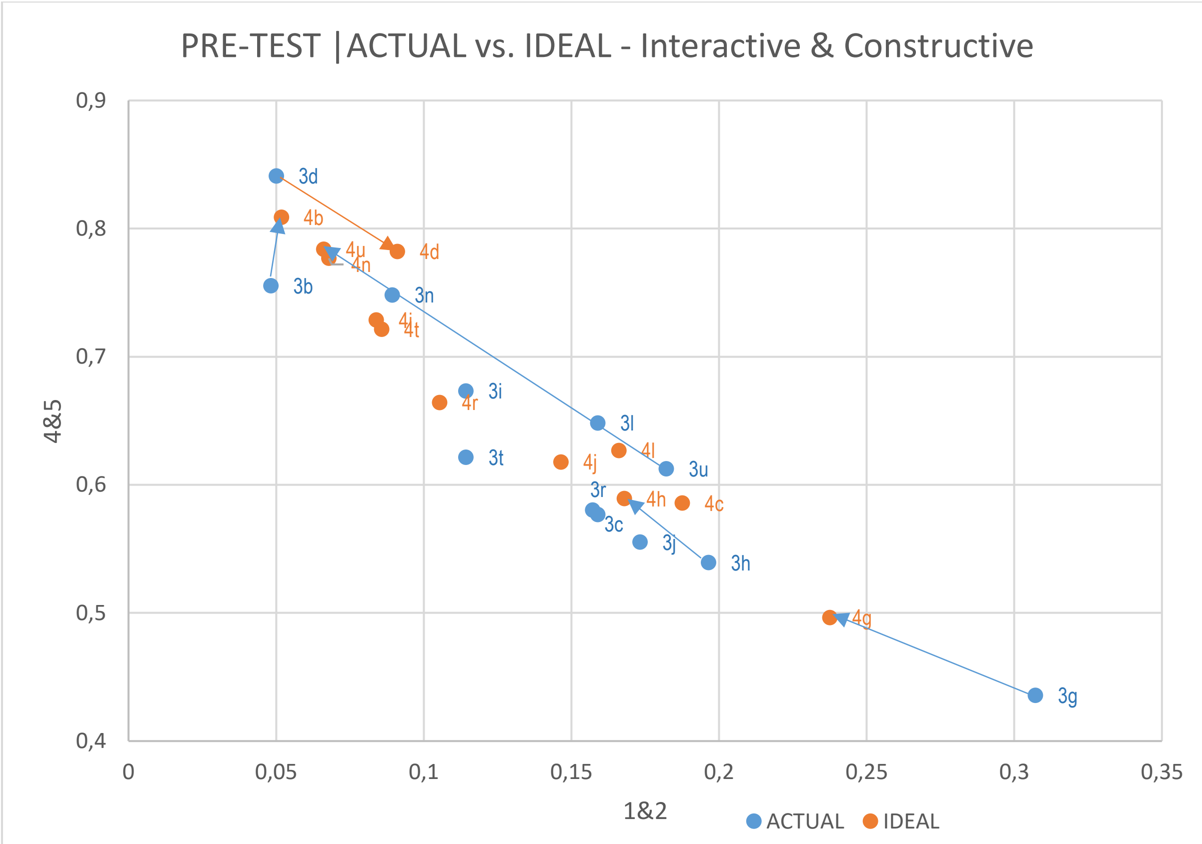

Figure 3. This graph shows items with significant differences between students' perception of their actual class versus their ideal class for the interactive and constructive subdimensions of types of instructions before the intervention (pre-test). Blue dots indicate students' actual perception and orange dots indicate ideal perception of the type of instruction.

Both Table 1 and Figure 3, show students willingness to take responsibility for their own learning, as questions 3u and 4u refer to doing hands-on group activities during class (use equipment, material, sensors, etc.). Students express a desire to undertake more practical activities, as seen in the answers to questions 3h and 4h "Taking the responsibility of studying and learning using other material, on my own."

These answers contrast with those obtained to questions 3d and 4d "Work in groups to complete tasks or other projects", shown with an orange vector in Figure 3. Students indicate that ideally the group work done for each activity should be less.

Regarding passive type of instruction, only items 3k and 4k resulted with significant difference; the other two items of this subdimension (a and s) did not have a significant difference. Being a subdimension of only three items, in which only one indicates a significant shit, it is not possible to conclude anything. However, analyzing the general shifts of each pair we have the following. For 3k and 4k "Get most of the information needed to solve the homework directly from the instructor", marked with an orange vector in the right and lower part of the graph, indicate that students consider that it would be better to get less information from the teacher, as occur in an expository master class. Notice that the shift from 3s and 4s “Watch the instructor demonstrate how to solve problems” has the same direction as “k” but did not result with significant difference; meaning that students are open to less of these passive actions. Whereas the shift from 3a to 4a “Listen to the instructor lecture during class”, moves in the opposite desire direction, it could be interpreted as students having difficulty abandoning the passive learning method of being told. That is, students also resist changes in their learning paradigm when going from passive to active learning items, see Figure 4.

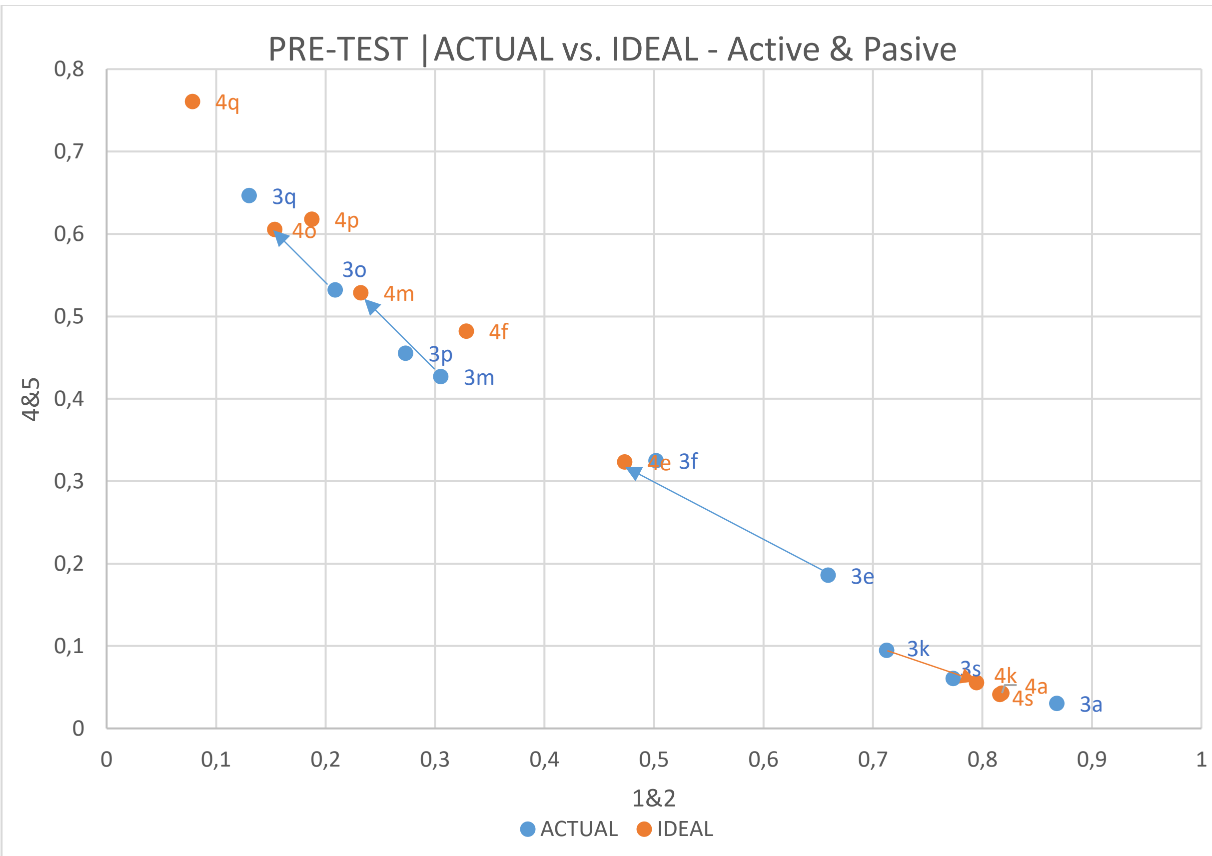

Figure 4. This graph shows items with significant differences between students’ perception of their actual class versus their ideal class for the active and passive subdimensions of types of instructions before the implementation of the didactic methodology. Blue dots indicate students’ actual perception and orange dots indicate ideal perception of the type of instruction.

Regarding the active subdimension, all six items (e, f, m, o, p, q) resulted with significant differences. In Figure 4, the shift of 3m to 4m indicates students’ perception of the need (in their ideal class) to preview concepts before class by reading, watching videos, etc., to solve problems individually during class (items 3o and 4o), or make individual presentations to the class (items (3e and 4e). These subdimensions indicate students’ willingness to active learning.

Figure 5 shows the shift from actual class to ideal class corresponding to the interactive and constructive subdimensions of the types of instructions. As in Figure 3, a vector moving up indicates that students prefer more of that type of instruction (given that these items are positive). Now these results correspond to the post-test, that is, after to the active learning implementation of the lab practices (end of the second stage of the course in Figure 2). Figure 5 shows student responses to the mid-semester test (post-test), and the specific values are presented in Table 2. Notice the shift in the same items discussed in Figure 3, item 3g to 4g regarding studying course content with classmates outside of class (interactive), or 3b to 4b about brainstorming different possible solutions to a given problem (constructivist), 3u to 4u regarding doing hands-on group activities during class, both the shifts are similar.

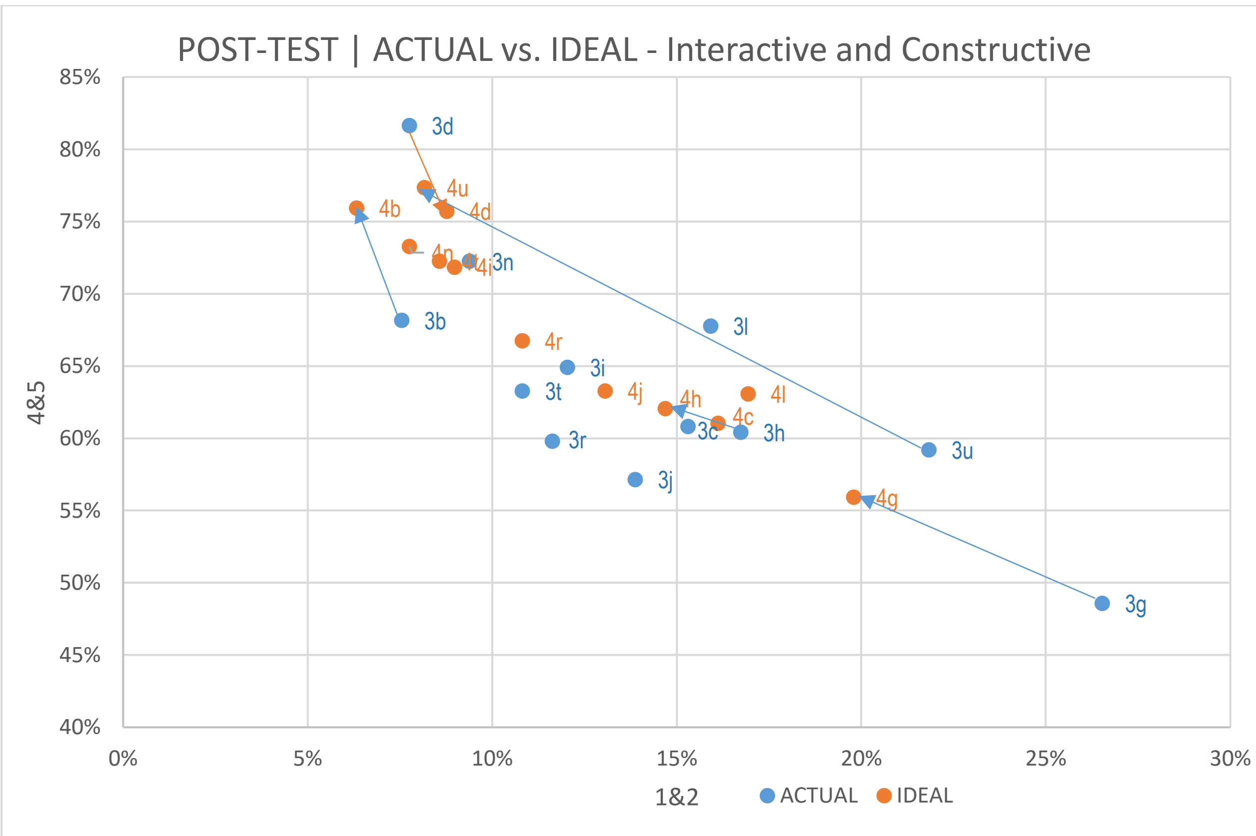

Figure 5. Items with significant differences between students' perception of their actual class (blue dots) versus their ideal class (orange dots) for the interactive and constructive subdimensions of types of instructions after the intervention (post-test).

For the interactive subdimension five out of the six items (d, g, i, n, u) resulted with significant differences. While for the constructive subdimension, all six items (b, c, h, j, r, t) had significant differences when comparing the actual versus the ideal perception of the students for those types of instruction (Table 2).

Table 2.

Items from the interactive (highlighted in yellow) and constructive (highlighted in green) subdimensions showing students' perspectives of the type of instruction in their actual class (in blue) and their ideal class (in orange) from the post-test. The percentage indicates students' responses using the 5-Likert scale, 1&2 means not frequently and 4&5 frequently occurring.

Post-test items	Actual	1&2	4&5	Ideal	1&2	4&5
Work in assigned groups to complete homework or other projects	3d	8%	82%	4d	9%	76%
Study course content with classmates outside of class	3g	27%	49%	4g	20%	56%
Discuss concepts with classmates during class	3i	12%	65%	4i	9%	72%
Solve problems in a group during class	3n	9%	72%	4n	8%	73%
Do hands-on group activities during class	3u	22%	59%	4u	8%	77%
Brainstorm different possible solutions to a given problem	3b	8%	68%	4b	6%	76%
Find additional information not provided by the instructor to complete assignments	3c	15%	61%	4c	16%	61%
Assume responsibility for learning material on my own	3h	17%	60%	4h	15%	62%
Make and justify assumptions when not enough information is provided	3j	14%	57%	4j	13%	63%
Take initiative for identifying what I need to know	3r	12%	60%	4r	11%	67%
Solve problems that have more than one correct answer	3t	11%	63%	4t	9%	72%

Even though, only two of the three items of the passive subdimension (a, k) resulted with significant difference when comparing students' perception of the actual class (after the intervention) and their ideal class, all three pair items 3a and 4a stated as "Listen to the instructor lecture during class", 3k and 4k "Get most of the information needed to solve the homework directly from the instructor", and 3s and 4s "Watch the instructor demonstrate how to solve problems" shown the same shift direction (Figure 6, highlighted in blue). These three items are considered negative, since refer to passive actions of the students. Thus, the tendency indicates that students are moving away from that, asking for less of those actions, and preferring an active role.

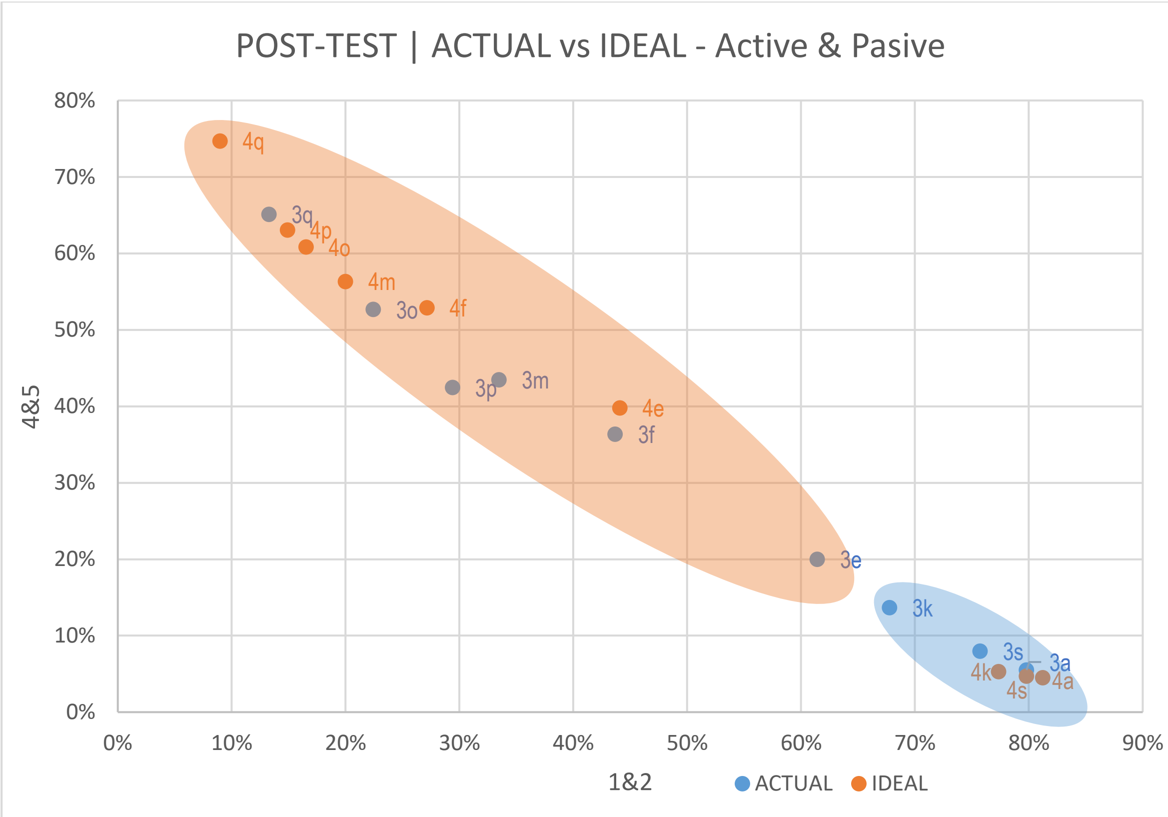

Figure 6. This graph shows items with significant differences between students' perception of their actual class versus their ideal class for the active and passive subdimensions of types of instructions at the end of the semester. Blue dots indicate students' actual perception and orange dots indicate ideal perception of the type of instruction.

Figure 6 shows the responses for the subdimensions of active and passive types of instruction for the post-test. The orange bubble contains all the items corresponding to active instruction, whereas the blue bubble contains all the passive instruction items. This representation elucidates the resistance presented by students to the paradigm shift between active and passive learning. All six items (e, f, m, o, p, q) of the active subdimension (highlighted in orange) resulted with significant difference and the shift from actual to ideal indicate that students would like more of those actions corresponding to an active type of instruction.

Even though, only two of the three items of the passive subdimension (a, k) resulted with significant difference when comparing students' perception of the actual class (after the intervention) and their ideal class, all three pair items 3a and 4a stated as "Listen to the instructor lecture during class", 3k and 4k "Get most of the information needed to solve the homework directly from the instructor", and 3s and 4s "Watch the instructor demonstrate how to solve problems" shown the same shift direction in the opposite desire direction, that is, students have difficulty abandoning a passive type of instruction (Figure 6, highlighted in blue). This indicates a conflict in which students struggle to abandon a passive type of instruction, but at the same time would like to take a more active role in their learning.

When contrasting students' perception of the actual class before the intervention with the didactic strategy (pre-test) and their perception at the end of the semester (post-test) for all four dimensions of the types of instruction we found that 10 out of the 21 items resulted with significant difference (Figure 7 and Table 3). There is a positive shift, meaning students perceiving the actual class at the end of the semester towards a desire type of instruction. This is the case of items h (constructive), g (interactive), e and f (active) and a, k, and s (passive). However, there are three shifts in the negative direction, b (constructive), n and u (interactive). As noted, students' answers given to questions 3u and 4u that refer to doing hands-on group activities during class (use equipment, material, sensors, etc.)," it seems to be a tendency to prefer more practical activities.

Figure 7 shows items with significant differences between students' perception of their actual class before (blue dots) and after (orange dots) of the implementation of the didactic strategy for all four subdimension of the types of instruction, passive (blue bubble), active (orange bubble), interactive (yellow bubble), and constructive (green bubble). Arrows show positive shift (blue arrow pointing up) and negative shifts (orange arrows pointing down).

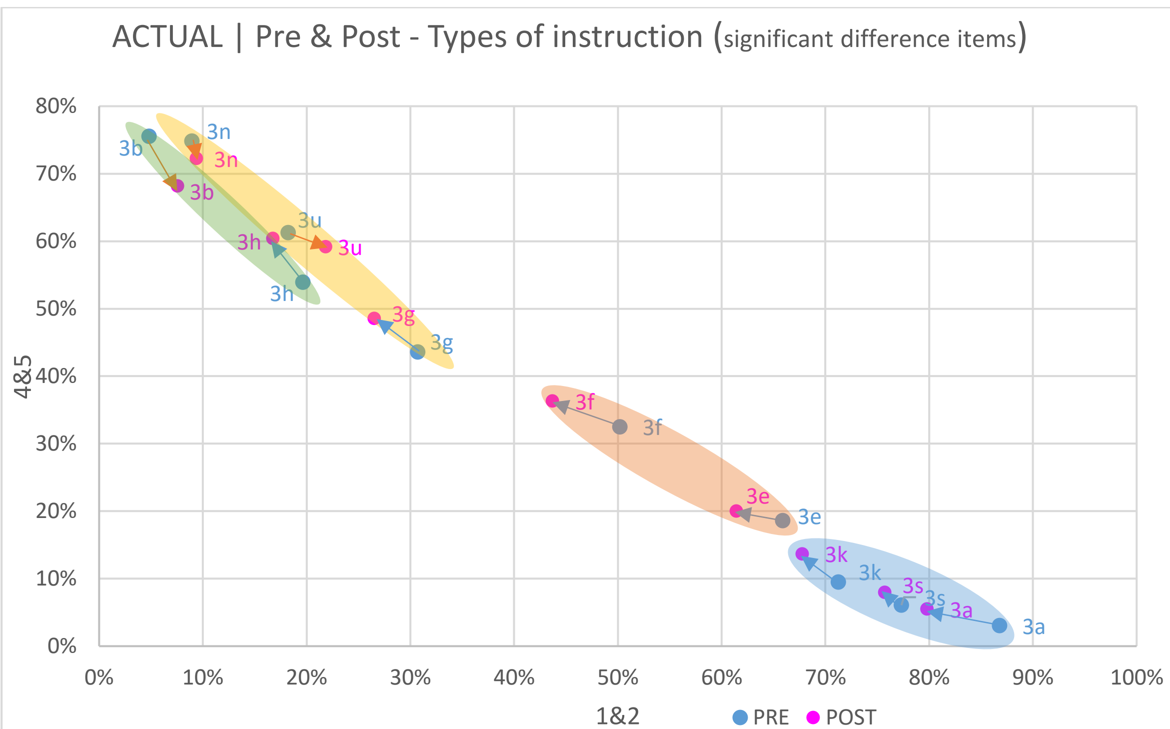

Figure 7. Shifts between actual class before (blue dots) and after (pink dots) the intervention for items with significant differences for all four subdimension of the types of instruction, passive (blue bubble), active (orange bubble), interactive (yellow bubble), and constructive (green bubble).

As indicated in Table 3, all three items of passive instruction move in the desire directions, that is, students perceive that the instructor actions were less passive. Only two items from the active type of instruction resulted with significant differences, “Make individual presentations to the class” and “Be graded on my class participation”, meaning that students perceive the value in their individual participation.

Table 3.

Items with significant differences comparing types of instruction as it was actual perceive by the students before (pre-test) and after (post-test) of the intervention (second stage).

Dimension	Subdimension	items	items with significant difference
Types of instruction	Active	e, f, m, o, p, q	e, f
Types of instruction	Passive	a, k, s	a, k, s
Types of instruction	Interactive	d, g, i, l, n, u	g, n, u
Types of instruction	Constructive	b, c, h, j, r, t	b, h,

The objective of the study was to analyze students’ perception to the type of instruction by collecting data before (pre-test) and after (post-test) the didactic strategy (active learning + educational technology). As a result, we notice that in general students perceive as positive the instructional method. Further discussion is included in the next section.

Conclusions

The study involved administering a test to students at mid-semester (pre-test) and at the end of the semester (post-test) to compare their course perception when a didactic strategy is implemented in a lab course. The didactic strategy consisted in using active learning with educational technology (Phet, Tracker, multimedia, mobile apps, etc) rather than a physical laboratory equipment. To measure this shift of perception we applied the StRIP survey before the intervention occurred and at the end of the semester under the same conditions (pre- and post-test). Given the objective of this study, we are focusing on the *type of instruction* dimension of the instrument. This dimension consists of four subdimensions, interactive, constructive, active, and passive.

The results show that students desire more responsibility in their learning but also reveal that they are deeply ingrained in the traditional passive education system they have experienced throughout their schooling. Students show a strong willingness to embrace active learning. However, they still strongly tend towards the passive learning model they are familiar with. As reported by [22] students struggle to abandon the model they know well and are used to (the traditional model of passive instruction) to completely shift towards a very appealing model of learning that invites more commitment and engagement in their learning.

A reflection to consider for future course teaching is related to the web design of each course, designing a different way to deliver study resources (i.e., notes). These notes were available under a specific activity in former versions of the same lab course. Students indicated that it would be necessary to increase the amount of complementary reading material (questions 3m and 4m). Such an answer shows that students associate the material only with a specific activity rather than as valuable cross-sectional material for all activities.

A "Study Notes" section will be introduced to improve students' perception of the material. This section will be separate from the various activities and contain general study materials. In these activities, the student will be directed toward specific material necessary for the activity, including the work guide and its corresponding rubric.

Other important aspects to consider for further research are the following: Are there any differences among the various sections? Are there differences in the location where the course is taught in the physical organization in which the class takes place? Are there differences attributable to other characteristics, the teacher’s gender, time of the course, infrastructure, class size, etc?

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Appendix

Items corresponding to dimensions 3 and 4 on *types of instruction*, colored by factors, of the Student Response to Instructional Practices (StRIP) [16]. The actual survey format appeared in numerical order without color and in Spanish [17].

Active
Passive
Interactive
Constructive

	Indicate the frequency with which you carried out the following activities during this course. Taking into account that, on average, this course has 30 sessions during the semester counting lectures and workshop.	1. Almost never (<10% of the time) 2. Rarely (~30% of the time) 3. Sometimes (~50% of the time) 4. Frequently (~70% of the time) 5. Very frequently (>90% of the time)				
#	Item					
3e	Make individual presentations to the class	1	2	3	4	5
3f	Be graded on my class participation	1	2	3	4	5
3o	Solve problems individually during class	1	2	3	4	5
3p	Answer questions posed by the instructor during class	1	2	3	4	5
3q	Ask the instructor questions during class	1	2	3	4	5
3m	Preview concepts before class by reading, watching videos, etc.	1	2	3	4	5
3a	Listen to the instructor lecture during class	1	2	3	4	5
3s	Watch the instructor demonstrate how to solve problems	1	2	3	4	5
3k	Get most of the information needed to solve the homework directly from the instructor	1	2	3	4	5
3n	Solve problems in a group during class	1	2	3	4	5
3u	Do hands-on group activities during class	1	2	3	4	5
3i	Discuss concepts with classmates during class	1	2	3	4	5
3d	Work in assigned groups to complete homework or other projects	1	2	3	4	5
3l	Be graded based on the performance of my group	1	2	3	4	5
3g	Study course content with classmates outside of class	1	2	3	4	5
3j	Make and justify assumptions when not enough information is provided	1	2	3	4	5
3c	Find additional information not provided by the instructor to complete assignments	1	2	3	4	5
3r	Take initiative for identifying what I need to know	1	2	3	4	5
3b	Brainstorm different possible solutions to a given problem	1	2	3	4	5
3h	Assume responsibility for learning material on my own	1	2	3	4	5
3t	Solve problems that have more than one correct answer	1	2	3	4	5

	Indicate the frequency with which you would like the following activities to occur during this course. Taking into account that, on average, this course has 30 sessions during the semester counting lectures and workshop.	1. Almost never (<10% of the time) 2. Rarely (~30% of the time) 3. Sometimes (~50% of the time) 4. Frequently (~70% of the time) 5. Very frequently (>90% of the time)				
#	Item					
4e	Make individual presentations to the class	1	2	3	4	5
4f	Be graded on my class participation	1	2	3	4	5
4o	Solve problems individually during class	1	2	3	4	5
4p	Answer questions posed by the instructor during class	1	2	3	4	5
4q	Ask the instructor questions during class	1	2	3	4	5
4m	Preview concepts before class by reading, watching videos, etc.	1	2	3	4	5
4a	Listen to the instructor lecture during class	1	2	3	4	5
4s	Watch the instructor demonstrate how to solve problems	1	2	3	4	5
4k	Get most of the information needed to solve the homework directly from the instructor	1	2	3	4	5
4n	Solve problems in a group during class	1	2	3	4	5
4u	Do hands-on group activities during class	1	2	3	4	5
4i	Discuss concepts with classmates during class	1	2	3	4	5
4d	Work in assigned groups to complete homework or other projects	1	2	3	4	5
4l	Be graded based on the performance of my group	1	2	3	4	5
4g	Study course content with classmates outside of class	1	2	3	4	5
4j	Make and justify assumptions when not enough information is provided	1	2	3	4	5
4c	Find additional information not provided by the instructor to complete assignments	1	2	3	4	5
4r	Take initiative for identifying what I need to know	1	2	3	4	5
4b	Brainstorm different possible solutions to a given problem	1	2	3	4	5
4h	Assume responsibility for learning material on my own	1	2	3	4	5
4t	Solve problems that have more than one correct answer	1	2	3	4	5