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Do Students Really Understand the Difference Between Simulation and Remote Labs?

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ABSTRACT

Laboratory experiments play a crucial role in engineering education as they strongly contribute to the development of important skills for the professional practice. This paper addresses a students' understanding gap between simulations and remote labs. These two resources (and namely the remote laboratory VISIR - Virtual Instrument Systems in Reality) have been commonly used on several didactical implementations, along with other didactical resources in different Engineering degrees at the Federal University of Santa Catarina and Polytechnic of Porto School of Engineering. This work, developed in the scope of the VISIR+ Project, intends to evaluate students' perceptions considering simulation and remote lab results. Quantitative and qualitative data were analyzed to better understand how deeply students realize the differences between these resources and their type of data. Preliminary results indicate that a considerable number of student's don´t have a clear idea of these differences, even though sometimes they know their definition. Furthermore, this gap does not seem to differ much with the context (country, course, academic year, course content), students' final grades, teacher approach or implemented tasks.

CCS Concepts

• **Applied computing→ Physical sciences and engineering→ education**

Keywords

Remote Laboratory; VISIR; Computer Simulation; Contextualization; Learning and Teaching Strategies; Competence Development; Engineering Education.

1 INTRODUCTION

Engineering students need to perform experiments as they allow them to apply theory concepts through the handling of instruments equipment and data, building up and consolidating knowledge and skills, which will be of a vital role after their graduation [1]. These knowledge and competences can be developed not only in traditional laboratories (hands-on), but also using computer simulations and remote laboratories. These on-line resources in addition to allow students to practice some experimental skills activities in a different way, are a stimulus to the younger generations of digital natives [2]. Naturally, students should be aware that they get different experimental results from these resources: real results from remote labs as opposed to computational model results from simulations. A "blended" or "hybrid" approach to laboratory learning - a combination of hands-on labs, simulation and remote labs - seems to be the most effective [3]. Besides the use of manifold techniques and resources may allow teachers to reach more students [4].

Remote labs combine the advantage of both hands-on labs and simulations and they are defined as an educational resource where the user and the instruments are physically apart. The connection between both of them is using the internet and the user interaction with the lab (configuring, controlling and/or monitoring results) is achieved through a computer or smartphone interface [5]. VISIR (Virtual Instrument Systems in Reality) is the most used lab on electric and electronic circuits. Considered, in 2015, the best remote controlled laboratory [6], it started in 2004 by the Blekinge Institute of Technology (BTH). VISIR mimics a typical electric/electronics workbench (Figure 1), with the same instruments and components [7]. By 2015, VISIR systems have been set-up in seven different Higher Education Institutions (HEI), in five different countries [8]. The VISIR Consortium thus created, with the goal of fostering the collaboration within the community and fomenting the dissemination, proposed the VISIR+ Project to EU ERASMUS+ Programme.

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VISIR+ project intends to spread the knowledge around VISIR to Latin America (LA) countries. In fact, in this project, the EU Consortium supports the LA Consortium (Brazilian and Argentinian HEI) sharing their experience and expertise. A VISIR system has been installed in five LA HEI and one of the project outcomes is the development of a set of educational modules comprising the use of hands-on, virtual and VISIR remote lab, combined with calculus, following an enquiry-based teaching and learning methodology, in electrical and electronic circuits' theory and practice.

This work describes several didactical implementations that took place in several courses, under different contexts and with different goals: a calculus course of Computer and Energy Engineering degrees in Federal University of Santa Catarina (Brazil) and a physics course at the Systems Engineering degree at Polytechnic of Porto School of Engineering (Portugal).

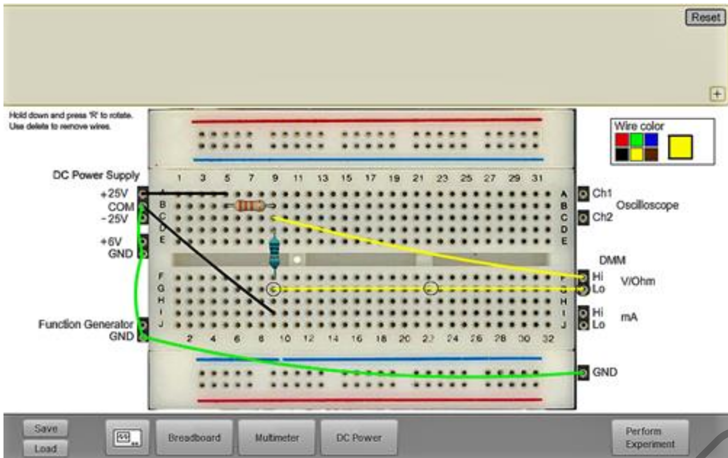

Figure 1. VISIR System

The calculus course covers mainly topics of analytical solutions to differential equations and the teacher used the remote lab VISIR, along with other resources, with the main goal of providing the students a contextualized curriculum (through electric circuits' analysis). Indeed, the teacher had already this desire/concern for a few semesters as he believes (being supported by various authors) that a contextualized curriculum creates interesting mechanisms to transfer the information to students being a more productive approach to learning and exploring science concepts [9], [10]. On the other hand, the physics course has a module of electricity and electric circuits' analysis and the teacher decided to use VISIR with the main goal of helping students to develop experimental skills and competences as has being supported by several authors [11], [12], [13]. While gathering the data from these courses' implementations results, an important gap between the students' understanding of simulation and remote labs was identified.

In order to describe and analyze the identified problem, section 2 describes the learning environment where it took place, including courses' descriptions and resources used with a major emphasis to the activity involving VISIR. Section 3 is devoted to the research methodology and includes a summary of the collected data. Section 4 presents the results and its discussion and finally in section 5 the conclusions arising from this work are presented.

2 DIDATICAL IMPLEMENTATION

The didactic implementations reported in this work are briefly summarized in Table 1. The table includes information which characterizes the implementations through each course name, curricular semester, degree and institution, country, number of teachers (T) and students (S) enrolled in the course and class hours per week (C). All implementations took place from March to July 2017 (1st semester of the academic year 2017 for Brazil and 2nd semester of the academic year 2016/17 for Portugal).

From now on we will use **CE** to refer to the Calculus IV from Computer Engineering course, **EE** to Calculus IV from Energy Engineering course and **SE** to Applied Physics from Systems Engineering course. The CE and EE courses are 5 years' engineering degrees while SE is a 3 years' degree.

Table 1. Course Details

Institution (Country)	Degree	Course	Semester	Number of		
				T	S	C

Federal University of Santa Catarina (BR)	Computer Engineering (CE)	Calculus IV	4th	1	16	4
	Energy Engineering (EE)				27	4
Polytechnic of Porto - School of Engineering (PT)	Systems Engineering (SE)	Applied Physics	2nd	1	50	6

2.1 Course Description

"Calculus IV" course content embraces complex numbers, ordinary differential equations, partial differential equations, Bessel functions, Laplace transforms and Fourier transforms and series. The course overall goal is that students get to know the mathematical functions and equations that are beneath typical physical phenomena.

"Applied Physics" course content covers classical mechanics topics (kinematics, Newton laws, energy, work, and power) and electricity and circuits (Coulombs force, electric field and electric current and circuits). The course general goal is the development of knowledge and understanding in those topics to mobilize and apply it to actual contexts of engineering.

Teachers introduced VISIR to students and used it with different goals designing tasks accordingly. Table 2 summarizes these results and the resources used as well as the period of time students had to deliver the task.

Table 2. Implementation Description

	Description	Course Name		
		CE	EE	SE
General	Resources	VISIR, simulation, graphic tools, calculus	VISIR, simulation, graphic tools, calculus	VISIR, hands-on lab, calculus
	Goal	Contextualize mathematics and develop critical thinking	Contextualize mathematics and develop critical thinking	Develop experimental skills
VISIR	Introduction	Tutorial Video	Tutorial Video	Teacher brief explanation followed by students practice trying to assemble a simple circuit
	Task	Task using VISIR, simulation and calculus	Task using VISIR, simulation and calculus	Task using VISIR and calculus
	Period	6 weeks	6 weeks	1 week

With this implementation in CE and EE, teacher objective was to draw students' attention to applications of the mathematics learned throughout the course and eventually stir their interest in the topics covered. With such activities, the teacher attempts to provide an interdisciplinary learning opportunity where students could link concepts from different topics and develop critical thinking. SE teacher goal was on developing experimental skills and provide the opportunity to practice assembling circuits and using a multimeter on simple measurements before going to the hands-on lab. In all courses, before proposing the task involving VISIR, teachers explained in class the difference between simulation and remote labs, emphasizing the type of results obtained with each resource. SE teacher even took the students to "visit" VISIR in loco.

2.2 VISIR Activity

Teachers from the different courses proposed a unique task/project involving directly VISIR.

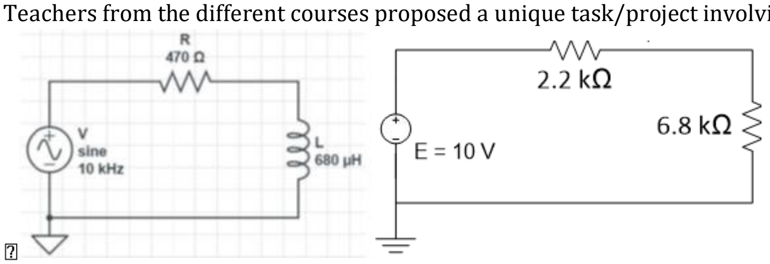

Figure 2. Proposed Task (left: CE and EE; right: SE)

- **CE** and **EE** course: the task consisted on the analysis of one RL circuit (Figure 2, left), using two different voltage sources. Students had to determine the electric current and the voltage drop across the inductor (L) using VISIR, a simulator and calculus. Students worked in pairs and had to submit a report in which they compare the results obtained through calculations and simulations, to the results they have measured in the remote lab. The activity is assessed and corresponds to 1/9th of the final grade.
- **SE** course: the task consisted of assembling a simple circuit with two resistors and a voltage source (Figure 2, right) and measure the current, drop voltage and the resistance. They had to calculate the same parameters and compare the results. They worked in pairs and had to deliver a report for assessment. The following week they had to perform a similar experiment in the hands-on lab (also comparing the results through calculus and delivering a report). The set of both activities had a weight to the lab grade of 25% (corresponding to 10% on the course's final grade). In fact, SE teacher was using VISIR for the first time so he was cautious and intended to explore the resource to see students' satisfaction and acceptance.

In all cases, this was students' first contact with electric circuits and experimental labs.

3 RESEARCH DESIGN

3.1 Research Question and Design

Different resources (remote lab, simulation and hands-on lab) allow students to practice some experimental skills in a different manner, but in order to take the most of it, they need to understand the major differences of the type of measurements gathered while using it. The problematic tackled in this study deals with students' perception about the difference between simulation and remote labs. We intend to answer the question: *"Do students really understand the difference between simulation and remote labs and the different type of results obtained with each of them?"*

The research methodology adopted in this work is a multicase study research [14], in which each case represents a different course where VISIR was implemented, as described in the previous section. A mixed method approach is used to analyze the three course implementations, involving 2 teachers and 93 students.

3.2 Collected Data

The analyzed data included the students' grades, both on VISIRs' task, but also their final grades; the number of accesses to the remote lab VISIR, provided by the log-register, per student and course; the answers to a satisfaction questionnaire; and an interview.

The students' satisfaction questionnaire (built on a validated set of questions, used in VISIR+ Project) [15] was applied at the end of the implementation. This questionnaire intends to infer students' opinions about VISIR and the applied methodology. The questionnaire included twenty closed questions 1-4 Likert scale and two open-answer questions. The two open-answer questions attempt to elicit what the students found as most interesting about the use of the remote laboratory VISIR and which problems they had while using this tool.

Finally, to have a more accurate idea on students' perception about on line resources some interviews were conducted. Teachers asked all enrolled students to participate in a brief interview, either personally or using some internet service, but only some of them showed availability. The interviews conducted and recorded by each teacher, included three main questions:

- Q1 - What is a simulation? Do you know the difference between and remote lab?
- Q2 - When you worked with VISIR did you measure the same parameter several times? If so, did you get the same exact values? Did you find it odd?
- Q3 - How did you access VISIR? In group or individually? Several times or just for performing the requested tasks? At home or at University? Did you explore furthermore the resource after the task has been completed?

4 RESULTS AND DISCUSSION

4.1 Students' Grades

Students' grades are summarized in Table 3. The table includes information, per course, about number of assessed students (the ones who delivered the task involving VISIR and the ones who went to the final exam/test), average VISIR grade, average final grade, and percentage of students who completed the course. Considering SE course, the results in the last two columns may still undergo some minor adjustments, as the results from the resource exam are not yet known.

Table 3. Students' Grades

Course	Assessed students		VISIRs' task grade	Final course grade	Students Completing the Course
	VISIR	Final			
CE	12	16	80%	44.7%	43.8%
EE	26	27	83.5%	61%	74.1%
SE	49	46	70%	52.5%	64%

In the three courses, students achieved a better grade in the task involving VISIR than in the final grade. EE students achieved the best results while CE students reached the worst. It´s curious to remark that these two courses had the same teacher, the same content and have undergone the exact same assessment plan, with the same resources at the same time.

4.2 VISIR Logs

The log-register provides information on the individual access to VISIR, but as the students performed the proposed task in groups we tracked the number of accesses per group. Table 4 summarizes these data per course and includes information about total number of accesses, average accesses' number per group as well as semester length, time period in which VISIR was available and period allocated to deliver the task.

Table 4. VISIR Logs

Course	Number of Accesses		Semester Length (in weeks)	Period of Time (in weeks)	
	Total	Per Group		Availability	Task
CE	25	3.1	18 w	4 - 18 w	6 w
EE	36	2.8	18 w	4 - 18 w	6w
SE	53	2.3	11 w	10 – 11 w	1 w

The average number of accesses per group ranges from 2.3 to 3.1, being the Computer Engineering Calculus IV students the ones who used VISIR the most. Still, if we consider simultaneously the number of accesses with VISIR's availability, the Applied Physics Systems Engineering Course stands out. A statistical analysis (with 95% confidence interval) was performed to assess the significance of this factor – number of accesses to VISIR - in the students' grade obtained in Task using VISIR. We have used a Pearson correlation, as the variables in study followed a normal distribution but no significant correlation was found between these factors. However, it is noteworthy that, for all courses, the students with more accesses were the ones who achieved the best performance in the course. Probably because they are naturally committed and interested, they have just made greater use of the tool.

However, there was a rather low number of accesses to VISIR, even though students found this tool very powerful and interesting and express their will of using remote labs in other courses. In fact, most of the students (in the interviews) refer that they consider VISIR an interesting tool with applicability in other courses and express their interest in exploring it, although most of them state that they didn´t have time to do it; some of them admit they just used the tool to perform the requested task.

4.3 Students' Satisfaction Questionnaire

The EE students were the most receptive to answer the questionnaire (88.9%) and the SE the least receptive (38%); 56.3 % of EC students answered it. Although there are some differences in the 3 courses answers (considering average and mode carried out over the quantitative variables (Questions Q1 to Q20) in the Likert scale) they're not significantly noteworthy.

In the questionnaire results analysis, the questions were grouped in several dimensions. In this work, three dimensions were pertinent to cross-analyze: dimension 1 (**D1**) which deals with students' perception and opinion about learning environments (traditional lab, simulation and remote lab); dimension 2 (**D2**) which intends to infer students' perception about their own development of higher order skills; dimension 3 (**D3**) which evaluates the impact of any technical problems while accessing the remote lab VISIR and the adequacy of the time period devoted to executing the task. These three dimensions as well as the categories (accordingly to three levels) are enumerated in Table 5. The numerical values/ranges corresponding to the categories associated with each of the dimensions were defined considering the number of variables Q (with Likert scale values (1-4 agreement scale), on each D, considering the sum of the answers average on the questions in each dimension). For D1 and D2 (with 3 questions each), the upper category was considered when values were between 10 and 12, the lower category lower than 7 and the medium category in between both. For D3 (with only 2 questions) the upper category was considered when values were between 6 and 8, for the lower category lower than 4 and for the medium category in between both.

Table 5. Dimensions and Categories

Dimension/New variable	Variables that make it up	Categories
D1: Learning Environments (traditional, remote, simulation)	Q3, Q13, Q18	Good
		Fair
		Weak
D2: Development of Higher Order Competences	Q2, Q10, Q16	Good
		Fair
		Weak
D3: Period of Time and Technical Restrictions	Q15, Q19	Few
		Some
		Many

The case summary results obtained for each of the dimensions can be visualized in Tables 6, 7 and 8, which include the number of answers and the mean value for each dimension, calculated from the Q variables that make it up, per course.

Looking in detail at D1 results, regarding the learning environments opinions', summarized in Table 6, the majority of students lies in the category *Fair* (which means students expressed a fair satisfaction and have a fair perception about learning environments)**.** Just the EE course students (about 29%) consider the category *weak*. The SE students are the ones with a better opinion about the learning environments – 31.6% lies in the category *good*.

Table 6. Dimension 1 analysis (D1) by category (per course)

Category	Course	Number of answers			D1 average score		
		CE	EE	SE	CE	EE	SE
	Good	1	4	6	10.00	10.00	10.83
	Fair	8	13	13	7.88	7.62	8.15
	Weak	-	7	-	-	5.43	-

Dimension 2 results (Table 7) shows that most students, in all courses, believe they achieved a *Fair* level of competences development. Students from CE believe none of them lies in the category *Weak*, although three out of the nine (33.3 %) who filled the questionnaire have failed the course. CE teacher considers there were 2 students who achieved higher order competences development but just one of them coincides with students' perception. The same conclusion – students' and teacher' perception differ – can be drawn for the other courses. In EE course, teacher considers 3 students achieved higher order competence development and just one is coincident with students' perception. In SE, teacher considers just two students' have developed higher order competences and belong to the group of 8 students who believes to lie in the *Good* category. Particularly for this course, it seems many students believe to have achieved better results than they in fact had.

Table 7. Dimension 2 analysis (D2) by category (per course)

Category	Course	Number of answers			D2		
		CE	EE	SE	CE	EE	SE
	Good	2	5	8	10.00	10.60	10.25
	Fair	7	12	9	8.43	8.08	8.56
	Weak	-	7	2	-	5.57	5.50

Most students from CE and SE (nearly 90% for both courses) lies in the category *Few,* in the dimension 3 analysis results (Table 8) – they had practically no problems with server connection and consider that the period of time allocated for VISIR tasks was appropriate. The EE students have a very different opinion. In fact, the majority considers they had some or many problems

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connecting to VISIR and the period of time devoted to VISIR tasks was not adequate. These results are quite curious, considering CE and EE teacher was the same and the students (both 4th semester) have undergone with exact the same implementation, with the same resources at the same time.

Table 8. Dimension 3 analysis (D3) by category (per course)

Category	Course	Number of answers			D3		
		CE	EE	SE	CE	EE	SE
	Few	8	10	17	2.75	2.30	2.29
	Some	1	10	2	4.00	4.20	4.50
	Many	-	4	-	-	6.00	-

The two open questions of the questionnaire attempt to elicit what students found more interesting in VISIR as well as the main problems/restrictions they found. In general students' answers point out the most important features about VISIR is its *"practicality"*, *"simplicity"*, *"availability"*, *"ease of use"*, *"being able to practice without the fear of damaging"*. Considering the main problems, lots of them (from all courses) refer "*none*". It was also a frequent answer the ideas such as: *"when I make a mistake, the system doesn´t give me information about the type of mistake"*, *"some bugs, that implied to restart the experiment"*, *"some difficulties at the beginning"*. On the other hand, some statements called our attention: *"the lack of precision on the measures – they vary"*, *"difficulties in understanding what is happening in the simulation"*, *"I downloaded another software"*, *"not being able to save the assembled circuit for a future use"*, for they suggest some students didn´t truly assimilate the difference between simulation and remote lab.

4.4 Students' Interviews

The students' interviews were done to a few students from each HEI (Annex A). Table 9 shows these students background and characteristics. High order skills development was assessed by each teacher.

The interview results show that the difference between a simulation and a remote lab is not clear in every students' mind; apparently, this is independent from the teacher mediation, since different approaches and contexts were analyzed, achieving similar results in this particular issue. It seems also independent of students' maturity and academic experience.

Table 9. Interviewed Students (A-I) Characterization

	A	B	C	D	E	F	G	H	I
Country	BR				PT				
Degree	EE		CE		SE				
Course	Calculus IV				Applied Physics				
Teacher	X				Y				
Semester	4th				2nd				
1st course enrollment?	yes	yes	yes	yes	yes	yes	no	yes	yes
N accesses Personally?	11 no	1 no	2 yes	9 yes	1 no	2 yes	2 no	3 yes	2 no
VISIR task grade (%)	90	80	75	90	70	83	65	65	80
Final grade (%)	85	75	65	80	50	75	Fail	Fail	85
High order skills?	yes	no	no	yes	no	no	no	no	yes

Even students with good grades or being considered by teachers as having developed higher order skills, not always have a clear idea of the difference between simulation and remote labs:

"The **S** is a <u>non-faithful representation of reality</u>; It is only a model that allows to work with situations similar to those of the real life" – student D.

"The advantage of this software, of that learning environment was exactly the issue of not having the danger of burning a lot of boards and things like that, that usually happens when you're in an electrical circuit laboratory. Our biggest fear is to make some wrong connection or anything of the kind and with a **RL** people lose that fear but are still aware that it can happen, right?" – student D.

"I have heard that **RL** it's a development of a graphical interface, however it doesn't use physical connections like wire"; "In the **RL** we can truly make a real circuit"; "**RL** does not require the use of physical means, such as wires" – student B

or not being able to comprehend that the fact that they would get different measures when repeating them:

"Sometimes it would change the decimal places, you know? …everything was due to the control of our variables, so if we put the same variables we would have equal results. But it is very difficult for us to faithfully represent several times the same thing on a device that required rotation of the buttons and everything else… I did not notice something discrepant in the results …and if it was discrepant it is because some parameter (that we had not adjusted) was missing" – student D.

"yes, I measured the same quantity several times to make sure I would get the same result"; "I didn't find it odd because maybe it doesn't work with the results with the same quantity due to some faulty connections" – student B.

"tested it only once and checked with the other instruments that the professor suggested" – student C.

"The **S** is when we do what we do in the laboratory only with the help of something on the computer." – student E.

and even when some students have the right idea, they are not sure, and the way they express it, shows that probably this was not entirely understood:

"The values in some parts I think were the same or very similar at least but I remember that in others they were different and I did not find it very strange because there are always those measurement errors…but I don't know" – student E.

"I measured several times. The results differed a thousandth if I'm not mistaken. I found it normal since it's still a somewhat futuristic thing. I think ... I do not know if it is or not ... but ... it is normal that there is some margin of error that is not exactly the same as the real one." – student H.

Some students totally admit their confusion:

"The difference ... I do not know what the difference is ... because to me they would be very similar." – student E

"But the difference between **RL** and **S** is not clear to me" – student C.

Or they express contradictory ideas:

"A **S**, in this case with VISIR (**RL**), we are basically using a digital platform, we are simulating, that's it ..." – student H

"in my understanding, we used the **RL** to perform a **S**" – student B.

From this analysis, we realize that teachers must be extra careful while planning the activities with RLs and simulations. As shown, even with extreme emphasis on this difference and even showing students the real RL they were accessing, some of them still do not truly assimilate it. Other authors [11], [12] have stated that this must be tackled with some activity where students can see the difference between working with a real experiment or a computer simulation based on a physics model. However, this might not be sufficient since in these simple cases, when students were asked to repeat their measures, most of them did not had perfectly clear that it would be natural to get similar but not equal results.

Since one of the important competences while working with several resources simultaneously, namely RL, S and calculus, is indeed to understand the differences between the data gathered from each one. The comparison and its discussion implies students to fully understand their nature. This work identifies a gap students might be experiencing, which may be undermining their critical thinking while discussing their results. Teachers might gain in taking further actions that may clarify the difference between these resources and the benefits of using them in parallel.

5 CONCLUSION

Although students found VISIR a very powerful and interesting tool and expressed their will of using remote labs in other courses, the results (from VISIR logs and the interviews) showed that they used it very little. In fact, some of them used it in a group, only to perform the required task. Nevertheless, the results in the task were good, suggesting the time spent with VISIR was appropriate.

Most students have a fairly good opinion about VISIR learning environment and believe they achieved an average level of competences development, although some overestimate this development. The majority of students in CE and SE courses report few (or none) problems with server connections and time allocated for the task, while in the EE course several problems were reported.

On the other hand, students from each course showed contradictory ideas (student H from SE and student B from EE), admitted having confused ideas (student E from SE and student C from CE), or expressed a gap in understanding the difference between simulations and remote labs (student B from EE, students C and D from CE and students E and H from SE).

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Answering the research question: "Do students really understand the difference between simulation and remote labs and the different type of results obtained with each of them?", the results, although preliminary, indicate that even with explicit care from the teacher in explaining this difference, some students don´t clearly assimilate it. This difficulty is not even acknowledged by some students, who think they did understood it.

Understanding this difference is crucial, and only then students can get the most of working with simultaneous resources and develop critical thinking while analysing, comparing and discussing the different results, so the benefits of the simultaneous use of resources are more effective.

This conclusion seems to be independent of the context, content, students' level of maturity, assessment or teacher, having only in common the fact of being the students' first contact with remote labs (and electric circuits). Especially for these students working with these topics and resources for the first time, it seems important teachers prepare a simple activity where students can immediately understand this difference, exploring themselves the various results and their meanings. Further studies are needed in order to better understand if this understanding gap substantially decreases with students' practice along their degree.

ACKNOWLEDGMENTS

The authors would like to acknowledge the support of the VISIR Community as well as the financial support provided by the Foundation for Science and Technology Project, FCT UID/EQU/00305/2013.

This research work is made within the University of Salamanca PhD Program on Education in the Knowledge Society.

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Appendix A

• Student • (Country)	• Degree • Course • Curricular year and semester • Teacher	• Number of accesses? • Personally?	• VISIR grade • Final grade • Higher order skills?	Simulation (S) definition	Remote lab (RL) definition	Contradictory ideas	Repeated measures	Exploitation
• A • (BR) • enrolled 1st time	• Energy Engineering • Cálculo IV	• 11 • no	• 9/10 • 8,5/10 • yes	• "is testing something, weather it is physical or done by computer"	• "you truly physically test the circuit"		• "tested it only once and checked with the other instruments that the professor suggested"	• "during and after the task I explored some resources that VISIR had and tested some different ways in which to build the circuit, just by curiosity"
• B • (BR) • enrolled 1st time	• Energy Engineering • Cálculo IV • Teacher X	• 1 registered, but stated 5 for the group • no	• 8/10 • 7,5/10 • no	• "when someone does an exercise, or see a problem and wants to simulate the result"; • "we need to simulate to see if it is going to get a positive result beforehand"; • "you can simulate an electrical circuit in a lab like we did in physics class"	• "I have heard that RL it's a development of a graphical interface, however it doesn't use physical connections like wire"; • "In the RL we can truly make a real circuit"; • "RL does not require the use of physical means, such as wires"	• "in my understanding, we used the RL to perform a S"	• "yes, I measured the same quantity several times to make sure I would get the same result"; • "I didn't find it odd because maybe it doesn't work with the results with the same quantity due to some faulty connections"	• none
• C • (BR) • enrolled 1st time	• Computer Engineering • Cálculo IV • Teacher X	• 2 • yes	• 7,5/10 • 6,5/10 • no	• "S is when one abstracts and models a real-life system through a model. It can be a physical model, mathematical models, etc."	• "with a RL I imagine that the experiments occurring in real time are not simulated mathematically by means of software."	• "But the difference between RL and S is not clear to me"	• "After some training I managed to get the same results and I did not find any problems in VISIR itself"	• "I ended up exploring the other features to see how the lab worked to know a bit more because I had in mind to use it in the next electronic disciplines that I will have ...so I wanted to get used to his interface"
• D • (BR) • enrolled 1st time	• Computer Engineering • Cálculo IV • Teacher X	• 9 • yes	• 9/10 • 8/10 • yes	• "The S is a non-faithful representation of reality; It is only a model that allows to work with situations similar to those of the real life"	• "In the RL you have access to something real" • "The advantage of this software, of that learning environment was exactly the issue of not having the danger of burning a lot of boards and things like that, that usually happens when you're in an electrical circuit laboratory. Our biggest fear is to make some wrong connection or anything of the kind and with a RL people lose that fear but are		• "Sometimes it would change the decimal places, you know? ...everything was due to the control of our variables, so if we put the same variables we would have equal results. But it is very difficult for us to faithfully represent several times the same thing on a device that required rotation of the buttons and everything else... I did not notice something discrepant in the results ...and if it was discrepant it is because some parameter (that we had not adjusted) was missing"	• "I intend to use it as a study tool to be able to understand with more dynamics what is happening"

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					still aware that it can happen, right?"			
• E • (PT) • enrolled 1st time	• Systems Engineering • Applied Physics • 1st year • Teacher Y	• 1 • no	• B • 14/20 • 10/20 • No	• "The S is when we do what we do in the laboratory only with the help of something on the computer."		• "The difference ... I do not know what the difference is ... because to me they would be very similar."	• "The values in some parts I think were the same or very similar at least but I remember that in others they were different and I did not find it very strange because there are always those measurement errors…but I don't know"	• none
• F • (PT) • enrolled 1st time	• Systems Engineering • Applied Physics • 1st year • Teacher Y	• 2 • yes	• A • 16,5/20 • 15/20 • No	• "For me the S is the use of software that allows us to have an idea of how things would happen in reality"	• "In the RL we have access to real measurements. We see that the values oscillate a little: the resistances oscillated a little, the potential differences oscillated a little ... this gives us a greater sense of reality. We have the notion that it is what is happening."		• "The results were not the same, they were close, they were within the same order of magnitude ... But they were not the same and I found this perfectly natural because real measurements were being taken. Not something stipulated theoretically."	• "We ended up playing a little with the tool. Seeing what we can do, we tried to break the machine and we couln't… this was an advantage because we had the notion that we were working…but sure that we could not damage anything."
• G • (PT) • repeating	• Systems Engineering • Applied Physics • 1st year • Teacher Y	• 2 • no	• C • 13/20 • failed the course		• "A RL is a bit more intuitive because we're working directly with things" • "It is easier to check if we have errors and cannot damage the material itself."		• "We measured at least 3 times and usually only one of them would be different ... We chose to measure 3 because the first and second gave equal but the third already gave different, sometimes a thousandth ... I think it is normal because in the laboratory itself we do it with our own tools in our hands sometimes the values also do not give 100% the same. The mistake will be very little but it does not match."	• "my colleague who is a student who is already doing SISEL of the 2nd year ... if he knew that this platform existed before it was presented in class, he would have made use of it ... it is very useful to be able to work at home things we sometimes do in class"
• H • (PT) • repeating	• Systems Engineering • Applied Physics • 1st year • Teacher Y	• 3 • one	• C • 13/20 • failed the course		• "It is much simpler, we run less risk in the use"	• "A S, in this case with VISIR, we are basically using a digital platform, we are simulating, that's it ..."	• "I measured several times. The results differed a thousandth if I'm not mistaken. I found it normal since it's still a somewhat futuristic thing. I think ... I do not know if it is or not ... but ... it is normal that there is some margin of error that is not exactly the same as the real one."	• "…then I went to show it to some of my classmates at home because I found it interesting ... out of curiosity ... basically to show them that it existed."
• I • (PT) • enrolled 1st time	• Systems Engineering • Applied Physics • 1st year • Teacher Y	• 2 • no	• A • 16/20 • 17/20 • Yes	• "S is the representation or pretence of something that does not actually happen"	• "The RL is an experience that although we are doing it in our computers it is physically being done in a laboratory somewhere"		• "We did not find it strange that the values were slightly different since the experience was being physically done in a laboratory somewhere so it was only natural that, as it happened in our classes,	• none

							the values were not exactly the same."	