Didactical use of a remote lab: a qualitative reflection of a teacher

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ABSTRACT

This work describes the teacher reflections about a didactical implementation using a remote laboratory and their impact on his practice. These reflections are analyzed from three different perspectives: how the literature review influenced the design of the didactical implementation (namely the first); how his reflection upon his practice influenced its modifications; how his research activity impacted and affected his teaching practices in the subsequent implementations and guided the modifications made. The remote lab was introduced in a Physics Course in an Engineering degree and was intended to be a learning space where students had the opportunity to practice before the lab class, supporting the development of experimental competences, fundamental in an engineer profile. After the first implementation in 2016/17 academic year it has undergone two subsequent editions with adjustments and modifications.

Some features previously reported in literature such as: teacher's experience with VISIR, the importance of an introductory activity and defining VISIR tasks objectives, were corroborated by the teacher during his practice and research. Others, such as the difficulty some students have in understanding the difference between simulation and remote labs appeared directly from his practice and were pursued in his research in order to deeply understand its implications.

CCS CONCEPTS

• Applied computing • Physical sciences and engineering

• Education

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1 Introduction

Education – promotion of knowledge construction and skills (competences) development in a formal or informal way – has undergone considerable changes in the last decades, especially since the 80´s, including the Bologna Process in the beginning of this century. In about 30 years one goes from almost no internet in the beginning of the 80's to a time where ICT (Information and Communication Technology) becomes part of the classroom. This situation affects learning and teaching in different ways leading to a change in students' and teachers' roles. In fact, back in the 80's it was common belief teachers already knew everything, in opposition to the present time, where teachers are committed to lifelong learning, professional reading/research and collaboration [1], [2]. Nowadays, teachers are expected to learn throughout their career and are permanently challenged to revise their practices and adapt them to students' needs [3]. Teachers, individually, often seek immediate resolution to context specific issues, planning and implementing appropriate didactical strategies. Didactical strategies are accordingly to Valcke et al. *concrete teaching approaches, consciously selected and implemented teacher actions in view of attaining learning objectives in students* [4]. These, if well succeeded, have a major contribution in transforming knowledge. From a historical point of view, it is observed a shift from teacher-oriented (theory-oriented) to student-centered didactical strategies [4]. To make the most of these didactical strategies, teachers should focus on planning tasks accordingly to the competences they want their students to develop, apply these practices in the classroom and then reflect about it. The developed learning activities may lose their intrinsic meaning without reflection on the experience. Núñez et al. consider *reflecting is a vital activity for professional and personal development since it leads the teacher to a process of self-recognition of his performance and to a self-evaluation that simultaneously allows him to make changes and implement innovations not only to the methodological approach, but also to the selection and development of meaningful contextualized materials* [5]. Refection refers to teachers discerning about their practice both during the teaching process (in the classroom) and outside the learning environment. [2]. Reflection is a key aspect in teachers' professional development, allowing them to use their observations to initiate the process of transformation. While reflecting on the teaching context, they are focused in what really happens in the classroom and not in what they hoped to happen. The reflection process allows teachers to devote time to learn and inquiry about their practices and didactical approaches leading them to assume a dual role: Teacher-Researcher (TR) [1]. The reflective inquiry about their practice gives them the opportunity to move from reflection (on the experience), to description, analysis and finally to action [1], contributing to classroom/school change and ultimately to the education reform. Teachers should regard reflection as a learning opportunity to develop effective learning strategies, considering students' necessities, [2], [3], [5]. Reflection allows teachers to take more informed and conscious decisions regarding their practices and the resources they use and tasks they design and implement and is also a strategic aspect of a teachers' professional development [3].

The fusion of ICT into Engineering Education, includes simulation and remote labs usage as an alternative and/or complementary way to hands-on labs (traditional labs). Nowadays, many teachers are using a combination of these resources with the aim of facilitating students learning and improve educational performance. These resources allow students to efficiently apply theoretical concepts to practical situations, as well as handling instruments, equipment and data, contributing to build and consolidate knowledge and competences [6]. Remote labs have the advantage of allowing students self-directed learning - practice autonomously and at their own pace - but teacher/tutor support and assistance is a crucial factor to the learning process [7], [8], [9], [10], [11]. In fact, the lack of a motivated and experienced teacher to support students may compromise students interest engagement, particularly in their first contact with the tool and ultimately their learning outcomes [8], [11], [12]. Indeed, the pedagogical and didactical value of this type of resource can be lost and even be inhibitor of students learning [13] as some of these tools are quite complex and not immediately understandable to students, leading them to frustration and dropping out the task [14], [15]. The underlying technology of the laboratory (interface of the equipment) also plays an important role in the sense of immersion students should get to understand remote labs are real labs (physically apart) in which they get real experimental results in opposition to simulations [13], [16].

Teachers, while using these resources, need to make an effort to design the tasks accordingly to the type of competences they want their students to develop, assuming an effective mediation role in the learning process [17]. With adequate tasks, these resources may boost students' interaction, cooperation, teamwork, communication and critical thinking and they also allow students to practice at their own pace, contributing to the development of soft skills like time management and responsibility [13], [18]. The tasks, involving these resources, should contribute to the final grade – most students tend not to make an effort if they do not see immediate results [8], [11].

In the electric and electronic circuit's topic, VISIR (Virtual Instrument Systems in Reality) is amongst the most used labs, being recognized in 2015, as the best remote controlled laboratory in this area [19]. It emulates a remote workbench with the same instruments and components that are available on a hands-on electric and electronic circuits lab [20]. Since its launch in 2004, in Blekinge Institute of Technology (BTH), several VISIR systems have been installed in Europe, India, Morocco [21] and in the scope of the VISIR+ Project [22] in Argentina and Brazil (in 2016 and 2017). The VISIR+ Project intended to disseminate VISIR to Latin America Higher Education Institutions, sharing experiences with the European Partners, installing VISIR systems and performing their own didactical implementations.

This work is organized in 6 sections and its aim is to understand how teachers' reflection on his practice/methodology has shaped his subsequent didactical implementations, by literature review and considering the results from its own practice and research. Teacher research activity about VISIR lead to the introduction of this resource in his practices: The reflection and research about his practices lead teacher (TR) to adjust and reformulate his practices to content students' needs. Section 2 describes the didactical implementation and the adjustments occurred in the successive iterations. Section 3 describes the research methodology used to address the problematic tackled in this work and includes a summary of the analyzed data. Section 4 presents the results: from planning the implementation to observe and analyze class/students' performance and take decisions to make the necessary adjustments. In section 5 these results are discussed and the preliminary conclusions arising from this study are presented in section 6.

2 Didactical Implementation Description

The didactical implementation reported in this work was done within a course entitled "Applied Physics", which is part of the 1st-year, 2nd-semester of a 3-years degree on Systems Engineering, following the Bologna model (180 ECTS), in the Polytechnic of Porto, School of Engineering (PT). The course has 5 ECTS and comprises 2 hours of recitation classes (lectures, T classes), 2 hours of calculus practice classes (TP classes) and 2 hours of lab classes (PL classes) per week, during 11 weeks. "Applied Physics" course covers, classical mechanics topics (kinematics, Newton laws, energy, work, and power) and, since the academic year

2016/17, also electricity and circuits (Coulombs force, electric field and electric current and circuits (DC)), being students' first contact with electric circuits and experimental labs. The course general goal is the development of knowledge and understanding in those topics to mobilize and apply it to actual contexts of engineering. The electricity and circuits module had the short-term objective of providing students with the knowledge and competences in DC circuits. And explicitly, the ability to assemble DC circuits and use a multimeter to measure electrical parameters, as these are required previous skills to two subsequent courses. When the electricity module was incorporated in the course syllabus, the teacher (TR), who has 25 years' experience in teaching physics courses for engineering students decided to use it in his practices. The first didactical implementation occurred in 2016/17 academic year and the TR has been using it since then. He is responsible for all types of classes, being the only teacher in the course.

Table 1 summarizes some course data and didactical implementation details including the number of students enrolled in the course and the resources used. Considering VISIR, it condenses the way VISIR was introduced to students (including the week of the semester), the type of task, its weight in the final grade and deadline to deliver it. It also considers the moment (week) in which students performed an electrical experiment in the hands-on lab and the instant in which they filled up a Students Satisfaction Questionnaire (SSQ).

Table 1. Didactical Implementation (using VISIR) Description

	Description	Applied Physics		
		2016/17	**2017/18**	**2018/19**
General Characteristics	**Students**	76	62	61
	Number of PL classes	4	3	3
	Resources	VISIR, hands-on lab, calculus		
	Goal	Develop experimental skills		
	VISIR's Introduction (week)	10 w	9 w	9 w
	Introduction Activity	Teacher brief explanation followed by students practice trying to assemble a simple circuit and using a multimeter		
	Task type	Series and Parallel Circuits	Series, Parallel and Combination Circuits	
	Task deliver	11 w	11 w	10 w- part 1 11 w- part 2
	Task weight in final grade	5 %	10 %	
	Hands–on Experiment	11 w	10 w	
Data	**SSQ**	After the course has finished	10 w	11 w

Teacher introduced VISIR in his practices with the main goal of developing experimental skills and provide students the opportunity to practice assembling basic electric circuits (resistors and a voltage source) and the usage of a multimeter on simple measurements before going to the hands-on lab. VISIR was intended to be a learning space where students had the opportunity to practice before the lab class, so it was introduced in the week before the hands-on lab, where they had to perform a quite similar experiment. That way students had time to practice and learn how to use a multimeter to measure resistance, current and drop voltage, without the fear of burning/damaging the equipment. Teacher expected that in the hands-on lab students were more at ease and autonomous with the circuits assembling and the multimeter usage. Also that they could be more motivated and engaged, benefitting more from the lab experiment.

He prepared an introduction activity to VISIR, where students had the opportunity to try themselves the tool for circuits assembling and some parameters measurements, after teacher brief explanation. Taking into account students needed time to overcome their eventual initial difficulties with the tool, this introduction activity was fully developed during class time. Teacher had time to go, one by one, to each student and in the remain class time students started to make the proposed task. As they had some time (1 week in the first implementation and two weeks in the subsequent ones) to complete the proposed task, teacher hoped that students used VISIR and practiced accordingly to their own learning needs and at their own pace hoping that they would interiorize the concepts.

2.1 First Implementation (2016/17)

Teacher is involved in Engineering Education research, including the use of remote labs, as VISIR, in engineering courses, since 2014. Teacher was also one of the researchers involved in the VISIR+ Project (November 2015 – Abril 2018), in which there were plenty opportunities to discuss and share practice insights involving VISIR. So teacher was aware VISIR is a valuable resource in engineering education [8], [9] although more adequate to introductory courses [10], [11], [23], and conscious of several aspects of these didactical implementations, even if he has never used it before in his practices. In 2016/17, he decided to use it. He introduced it to his students, in the second to last week of the semester, after electric circuits topics were introduced in the recitation class.

The VISIR introductory activity carried on in a 2h PL class was conducted in a suitable computer room, with adequate internet connection and during its execution there were no server problems connecting to VISIR. The 4 PL classes were distributed by 2 week days and although the students were not equally distributed by them (varied from 9 to 18 students), that was not an issue. He briefly introduced VISIR in class, starting by emphasizing VISIR was a remote lab (an actual lab, physically apart) and not a simulation. As VISIR was not very far away from the room they were using, he took students there. Then he started showing students how to drag the components and wires to the breadboard and how to feed the circuit and use a multimeter. As he was explaining and doing it, students were doing the same in their own computers. After, students had the opportunity to try themselves circuits assembling with a resistor and a source voltage (in the breadboard) and use the multimeter to measure resistance, voltage and currents. Although at PL classes they work in pairs, most students brought their own computers so they had the opportunity to practice on their own. While students were trying VISIR, teacher was around the class explaining and replying to students' doubts. When he considered students were already familiar with the basics of VISIR, he proposed a task consisting of assembling a simple circuit with two resistors and a voltage source, in series and parallel, measure the current, drop voltage and the resistance. They had to calculate the same physical quantities, applying Ohm law and Kirchhoff's laws and compare the results. The remaining class time was used for starting the task. They worked in pairs and had to deliver a report for assessment (that should include "print screens" of the assembled circuits as well as connections to the multimeter with the measured values), with 5% weight in final grade, in the following week, before the lab class. The following week, they performed a similar experiment (series and parallel circuit) in the hands-on lab (also comparing the results through calculus and delivering a report).

Students were asked to fill up a SSQ short after the course has finished (during the evaluation period). The questionnaire was sent by mail - only 19 students answered it and from these very few answered the open questions. Some students were also interviewed.

2.2 Second Implementation (2017/18)

As the teacher considered VISIR a valuable resource, he decided continuing using it, with some minor, but not negligible adjustments. He decided to introduce it a week before (in the semester), also in a 2h PL class, so students had more time to practice, although the gap between VISIR introduction and the lab experiment was the same. He also made an adjustment in the introduction activity, to take the most of one of VISIR advantages: allow students to try and practice at their own rate. Teacher started to emphasize the difference between a simulation and a remote lab and the results obtained by these two resources. He even added to his presentation a slide with it; he also took the students to see VISIR. He then demonstrated how to use VISIR (while students were trying the same procedures in their computers) and made available, via a LMS (Learning Management System), the task students had to perform immediately after his brief explanation. Then students started using VISIR in their own computers with teacher support. Teacher was going around class, helping the students that were struggling with difficulties, while the others were going on and moving on to the task, each at his own pace. The 3 PL classes, distributed by 2 week days, with students equally distributed by them (16 to 17 students), were conducted in a suitable computer room, with adequate internet connection and during its execution there were no server problems connecting to VISIR.

He also increased task complexity: students had to assemble a series, a parallel and also a combination circuit and he also included some theoretical aspects that students should consider in their report. He increased this task weight in final grade to 10%, to stimulate students to accomplish it. He also changed the deadline to task deliver – students had two weeks to deliver the task - using VISIR for a longer period. The lab class was also in the week after VISIR introduction activity, and the lab guide and experiment were exactly the same as the first edition. At the end of this PL class, teacher delivered the SSQ in paper - there were 38 answers and students took time to answer the open questions – in fact most of them expressed their opinions, some of them "exhaustively".

2.3 Third Implementation (2018/19)

In the 2018/19 didactical implementation, although teacher had the same main goal using VISIR he also intended to increase students access to VISIR – more accesses and for a longer time period - and articulate VISIR usage pre and post lab classes. He introduced VISIR replicating the introductory activity he did the previous year with the same features. Teacher started to highlight the differences between remote labs, hands-on labs and simulation and the difference between the results obtained with hands-on labs and remote labs (real physical results) and simulations (computational model results) – he added a slide, to his presentation, to illustrate it. He did not take the students to observe VISIR. Then, he conducted the introduction activity exactly like the year before, stimulating students to work on their own pace. The 3 PL classes were in the same week day and students were not equally distributed between them (12 to 19 students). The computer room, where the activity was performed, was not appropriate: the data show was not working properly, having some failures, obliging the students to get out of their places and get near teacher computer to observe VISIR procedures and then go back to their places to do the same. Students were getting frustrated and to make things worse there were some internet problems and even some server problems when connecting to VISIR. The first two classes were in the same computer room, in similar conditions, although in the second things went a little better as there were less students and also the best and more interested course students. In the third class, teacher managed to change to a better computer room, nevertheless there were also some internet problems. In the first PL class (19 students), most students were not enthusiastic about VISIR activity and teacher had to make a huge effort to "force" students to explore the tool - the majority of students did not manage to start the proposed task (to be deliver in the 2 following weeks), unlike previous years. In the other PL classes, most students started the proposed task.

Although he proposed a similar task with a similar weight in final grade, this time he split the task in two parts: part 1 (series and parallel circuit) should be delivered in the following week, just before the hands-on class. And part 2 (combination circuit) two weeks after the VISIR introduction activity. That way, students were forced to use VISIR before the hands-on lab and so practice for it and also indulged to use it after the hands-on class to complete the second part of the task.

The lab class was also in the week after VISIR introduction activity, and the experiment was exactly the same as in the previous editions. Still the lab guide underwent some minor changes. The lab guide was less structured: in the preceding editions it was a set of very precise instructions students had to carry out, almost without thinking. This time, there were less instruction and they were not so meticulous obliging the students to think and take decisions.

The SSQ was delivered, also in paper and during class time, in the last week of the semester, week eleven. As it was the last class, several students missed and just 25 answered the SSQ; about half of them took time to answer the open questions, expressing their opinions.

3 Methodology

In this study the teacher assumes a dual role of teacher researcher (TR). After getting to know VISIR from literature and research, he decided to implement it in a course he was teaching during 2016/17 academic year. His reflection about his first didactical implementation, considering his own observations and reflections as well as students' perception about VISIR, led him to make some adjustments in the subsequent editions. His purpose was to find more effective ways of implementing VISIR in the teaching process towards better learning achievements. So, the problematic tackled in this work is to understand how teacher reflection – upon literature review, his didactical practice and his research results upon his and other teachers' practices – shaped his teaching adjustments in the subsequent didactical implementations.

3.1 Research Methodology

In order to conduct this study, an action research methodology was adopted. This methodology is a powerful tool, as it combines action and reflection with the purpose of improving practice [24]. It is particularly useful at a local level – a change in a particular feature, in a given context - to achieve a better outcome.

The participants in this study are the respective academic community involved in "Applied Physics" course during the 2016/17, 2017/18, 2018/19 academic years. Qualitative data includes teachers' observations, reflections and analysis of class/task performances and the subsequent actions. Teacher also had the opportunity to gather some students' informal comments and to conduct some interviews. At the end of each didactical implementation, students were asked to fill a questionnaire (SSQ). This questionnaire (built on a validated set of questions [22]) intended to evaluate students' perception about the tool. Besides the closed questions (not analysed in this work), there were 2 open questions where students were asked to highlight positive or negative aspects about VISIR or their experience with it which provided some data about student perceptions.

3.2 Research Context

The teacher's involvement in Engineering Education, including research upon remote experimentation usage, began in 2014. He incorporated a team that has been developing work in the didactical implementation analysis and students' learning outcomes of incorporating VISIR, along with other resources, in Engineering Courses. His involvement in the VISIR+ project also allowed him to share ideas, discuss and research upon VISIR practices: 39 didactical implementations involving VISIR in higher education engineering courses (and at lower extent some secondary/ professional courses).

4 Results

In section 2, the didactical implementations characteristics were described, and its modifications were explained but not justified nor analyzed, including the decisions for the first implementation. In this section they are addressed again but focusing on explaining the influence the literature (studies from other researchers), teacher's reflection upon his didactical practice and his research upon his and other teachers' similar practices (studies in which the RT was involved) had in his decisions.

This section describes this evolutionary process from planning, practicing, decisions making and producing adjustments.

4.1 Reflections from Literature

The careful analysis of other researchers' practice and results gave the TR insight inputs which played a crucial role particularly in the planning phase of his first didactical implementation.

Using this knowledge, the teacher carefully planned a didactical implementation using VISIR along with hands-on lab and supported by calculus. He introduced it in his practices, giving special attention to the aspects that had caught his attention:

- *Get familiarized with VISIR*: he spent some time getting familiarized with it to be able to give assistance to his students to overcome their eventual initial difficulties and to arouse students' perception of VISIR utility and their enthusiasm [8], [11], [12].
- *Prepare an introductory activity*: which focus was to help students get familiarized with the tool and to be developed during class time [8], [11], [12].
- *Prepare support material*: a guide explaining the basis of VISIR and made it available in a LMS [8], [11], [12].
- *Define VISIR task objectives*: taking into account his main goal was to develop experimental skills – he mainly intended for students to use VISIR before the hands-on lab - to increase their confidence and performance [10], [23].
- *Incorporate course assessment*: the proposed task was assessed and contributed for students' final grade [11].
- *Ensure students support*: considering it was students first time with VISIR (and electricity and electric circuits topics) he gave them support not only during the

introductory activity but also during the task execution period [11].

4.2 Reflection about Teachers' practice

The three didactical implementations occurred in successive years and the teacher also used his reflection upon his practice to adjust and improve it. Teacher perception and observations about students' involvement, students' performance in the hands-on class and VISIR task results/grades analysis were the factors that most contributed to the modifications he made. So, analyzing by factor:

- *Students' involvement*: VISIR was well accepted by students. The teacher percept they were motivated and engaged. Still there was a difference in this acceptance and engagement from the first two editions to the third one. In the first two editions, students' acceptance and motivation to use VISIR was very good since its introduction. On the other hand, in the third edition, some students were not particularly motivated to use it in the introductory activity, but as they got to explore VISIR and understand its' potentialities, their enthusiasm and motivation raised. Students from the third implementation were, generally, less interested and motivated in all semester (not only in VISIR) and there were also some problems with server connection to VISIR and VISIR system itself, which may have contributed to this initial resistance.
- *Hands-on class performance*: in the week following VISIR introduction, students performed a series and a parallel circuit (the same in all editions) similar to the one included in VISIR task. Typically, in this type of class, students are very cautious while using the multimeter (specially to measure currents), calling the teacher all the time, fearing to turn on the power source and usually the multimeter blowned fuses are quite a few! In the first two editions, students were quite at ease in the hands-on lab, assembling and measuring the parameters autonomously, without fear of burning the equipment. They brought the "print screens" they had taken from VISIR and used them to discuss with each other how to use the multimeter and to check any doubt they had (but none of them actually accessed VISIR, during hands-on classes). The hands-on classes were really productive and peaceful – with only 5 fuses blown in the first edition and none in the second. In the third implementation, teacher perception was that students were not as autonomous or at ease as students were in previous years, especially in the first PL class. They repeated the former usual students' behavior: were very cautious, especially when using the multimeter to measure currents and asked more for teacher help/support. The teacher only observed 3 students (in one of the classes) looking to VISIR "print screens" they had from the VISIR activity. In total, 5 fuses were burn.
- *VISIR student's results/grades*: in the first edition students did well in the VISIR task. In the subsequent editions, where the task complexity was increased, although students achieved good results, they were qualitatively different. In the second edition, some students did not manage to complete successfully the combination circuit (current measurement in the branches). In the third implementation students achieved better results in the second part of the task (although this part was more complex and demanding and not executed in the hands-on lab) than in the first part.

Taking into account these results as well as teacher's experience with VISIR, which allowed him to quickly acknowledge any doubts/problems, he decided to make some adjustments to the second and third implementations. These were:

- *Enlarge the usage period*: in the first edition, teacher introduced VISIR in the last but one week of the semester, but realizing students could profit more with the tool if they had more time to practice and learn by themselves, in the subsequent editions he managed to introduce it the week before.
- *Adjust students support*: in the first introductory activity edition, while students were trying VISIR on their own, with teacher support, teacher noticed not all students worked on the same pace. Some had difficulties with very simple issues like dragging the components and wires while others quickly completed the introductory activity and were waiting for the next activity (start the proposed task). As teacher was really eager about VISIR, he considered he gave too much support to students in this introductory class: when they were taking too long to overcome their difficulties, he just showed them how to do it, instead of helping them to solve the problem, at their own pace. Although teacher had that perception, he was having some difficulties as some students were already over the introduction activity and were waiting to know what the subsequent task was, so he did not have much time to really respect it. Thus, in the following editions, after his brief explanation, he made immediately available the proposed task via LMS. That simple modification allowed teacher going around class, helping the students that were struggling with difficulties, giving them time and tutoring them (instead of pointing the solution) while the others were going on and moving on to the task, each at his own speed.
- *Emphasize the difference between resources/type of results*: in the second edition, teacher highlighted this difference and the different results obtained. In the third edition, he even added the hands-on labs to his explanation, making the comparison between hands-on labs/remote labs considering the type of experimental result and simulation/hands-on labs considering the access through an interface. Clearly it was not sufficient as this misperception still subsisted for some students.
- *Increase task complexity*: the proposed task also changed, from the first edition to the subsequent ones. Teacher decided to include some theoretical aspects - so

students could reflect and apply the theory to a combination circuit (not done in the hands-on lab)– while assembling and measuring electrical quantities such as current, resistance and drop voltage. In this type of circuit, students need to have a solid understanding of the concepts that pertain to both series circuits and parallel circuits. This change was intended to be a step forward in helping students to consolidate the theoretical concepts and further apply it to a new situation. Teacher did not had time to explore the combination circuit in the hands-on lab, but VISIR allowed it.

- *Increase task weigh in final grade*: considering task complexity increased he also modified its weight accordingly from 5 to 10%, to encourage students to accomplish it.
- *Expand task delivery time*: in the first edition teacher gave students one week to deliver the task forcing them to deliver it before the lab class. His purpose was to make sure students practiced how to assemble circuits and use a multimeter, to guarantee in PL class students knew what to do. During his mediation with students he considered this period was not enough, especially for those students who experienced some difficulties with the tool (and also considering he increased its complexity) in the subsequent editions he increased it to two weeks. In the second edition, teacher considered that although students had two weeks to deliver the task and practiced before going to the hands-on lab (at least, in the class where VISIR was introduced) and again after the hands-on class, his intent – students using more VISIR and for a longer period in time – was not fully accomplished. Most students tend to deliver their assignments as late as possible, so although they had the possibility of using VISIR in different moments, accordingly to their learning needs, the majority used it nearly at the due time (focusing their efforts in a very short period).
- *Split the task in two parts*: in the third implementation teacher formally made this separation visible to students, with two parts delivered in different dates. That way he compelled students to practice series and parallel circuits assembling and parameters measurement in VISIR before the hands-on class, in which they would execute a similar activity. And afterwards, he wanted them to go a step further assembling and measuring some parameters in VISIR, taking advantage from the hands-on experiment and VISIR experience.
- *Lab guide adaptation*: teachers experience led him to consider that VISIR usage allowed students to understand the basis of assembling a circuit and using a multimeter; so he adapted the lab guide in the third edition – it was still a set of instructions, but they were not so directive as before - allowing students autonomy to make some decisions. An important change in the usual students' behavior, from the previous editions was observed: students were very cautious and asked more for teacher support.

Problems with server connection to VISIR and VISIR system itself (instability), which happened in the third implementation can compromise not only students' acceptance of VISIR but also teacher will to use in subsequent editions/course. In fact, if these problems have happened in his first edition, in which teacher was still insecure, probably he would reconsider using it again.

4.3 Reflections from Research

Since 2014, the TR was involved in several research works related with VISIR's didactical implementations of his or other teachers' practice (most under the VISIR+ project, but some also in his own Institution). The SSQ open question answers and some interviews were considered for some of this research. In all editions, "availability, accessibility and practicing without the fear of damaging or burning the equipment" were the features students considered more interesting about VISIR. Some also pointed VISIR made them "more at ease in the hands-on lab class". Considering VISIR disadvantages, the answers differed, amongst editions, although in overall it was mentioned "it does not replace the hands-on lab" and "none". In the first implementation the most referred factor was students felt "some difficulties in the beginning". In the second implementation, just one student mentioned he felt "some difficulties with the tool at the beginning" and several mentioned VISIR interface was a "bit too simple" and/or "old fashionable" and the disadvantage of "being in English". In the third implementation some students mentioned VISIR "showed some incompatibilities with Mac computers". But the more referred disadvantage was that they had "some problems/errors when trying to do some measurements" and sometimes even the "components (resistors) disappeared". In fact, during the third implementation there were some problems with server connection to VISIR and VISIR system itself. The system had to be rebooted twice. The interviews also showed some students didn´t clearly assimilate VISIR was a remote lab or the difference between simulation and remote labs.

The reflection upon these works have also influenced his practice These are the factors that stood out:

- *Importance of teachers experience with VISIR*: plays a crucial role in students' satisfaction (acceptance and performance) with the tool [25], [26], [27]. More, considering courses with several subsequent editions, students' level of satisfaction increases with the number of course implementation edition [28]. Teachers experience using VISIR tend to lead to (students) higher levels of satisfaction.
- *Task characteristics adaptation*: TR was also particularly cautious in planning a task accordingly to the level/type of competences he wanted his students to develop, particularly in the third implementation. This consolidated result came from a study in the end of 2018 [26] which reported (for several didactical implementations) a mismatch between the type of task

and the level/type of competences teachers wanted their students to develop.

- *Students working regime importance*: students' acceptance of VISIR is higher when the proposed tasks are developed in group [26].
- *The importance of using different resources - VISIR/ simulation/hands-on* - some studies using these three resources simultaneously along with calculus, both in classes and assessment advertised the importance of students understanding the difference between the type of results obtained with each resource [29]. On the other hand, the undertake of cautions in order to do not overload students with too much novelty to overcome at once: *students might be overwhelmed if teachers give them too many resources to freely explore* [30]. A study in 2017 [31], which involved the TR and his first course implementation edition as well as another teacher/courses shows some students do not really understand the difference between simulation and remote labs and the different type of results obtained with each of them. Even more, it fact, it complements that *this difficulty is not even acknowledged by some students, who think they did understood it* [31].This conscience made TR make some adjustments in his practice, even though achieving more or less the same results.

Several other minor aspects such as: students achieved good results in the VISIR task [26], [31]; VISIR increases student confidence and performance in lab, being considered by several teachers as an hands-on facilitator [26] were also established. Last but not least, external factors like limited internet connection, computer rooms not adequate/available and/or VISIR instability were also reported (both by students and teachers) as factors that could compromise the implementation success [26], [27]. These factors assumed a special importance in the 3rd edition. In fact, in the previous editions, VISIR system worked perfectly as well as the internet. That motivated the teacher to go on using VISIR and even increase its importance both in course contents and contribution to final grade. But if VISIR instability would have happened in his first edition, probably he would think twice before using it again and definitely would not increase VISIRs' task complexity and weight in final grade. Teachers familiarity and proficiency with the tool in the third implementation allowed him to quickly adapt and overcome the problems caused by VISIR instability.

5 Discussion

The factors that were considered in the implementations characteristics, including its modifications in subsequent editions are briefly summarized in Table 2. They are listed accordingly to the three main focus of influence in teacher's decisions: literature, teacher's reflection upon his practice and his research upon his and other teachers' similar practices. These factors are grouped into three main categories: teacher mediation; tasks and student results.

Table 2. Summary of most influent factors based on reflection

	Category	Factors identified by refection upon		
		Literature	Practice	Research
Teacher Mediation	Teacher's Experience with VISIR	Important to be able to motivate students	Important to allow him to quickly acknowledge any doubts/ problems	Students satisfaction increases with the number of course implementation edition
	Teacher's Support	Ensure students' support (namely overcoming initial difficulties)	Importance of giving students time to overcome problems for themselves	
Tasks	Introductory Activity	Importance of preparing an introductory activity and guide	Importance of emphasizing the differences between resources/type of results	Some students do not really understand the difference between resources/ results
	Task Characteristics	Importance of defining VISIR tasks objectives; Incorporate course assessment	Supporting the increasing of task complexity and weigh in final grade; Split in 2 parts	Alert for a mismatch between the type of task and the type of competences
	Task Regime			Students acceptance of VISIR is higher when the tasks are in group
	Time Available		Supporting the extension of the usage period; Expand task delivery time	
Student Results	VISIR task results		Students achieve good grades; Some problems in 2nd and 3rd editions	Students achieve good grades
	Experimental Performance	Increases lab confidence, performance and autonomy		
	Student Perceptions	Useful resource. Practicing without the fear of burning		Accessibility; Availability; Practicing without the fear of burning

Literature stated teachers experience with VISIR was important to motivate students and arouse their perception of VISIR utility. From his practices, in the subsequent course editions, teacher considers his experience allowed him to rapidly acknowledge and solve any doubts/problems. This was corroborated by his research that claims teachers experience leads to (students) higher levels of satisfaction.

Teachers support both in the introductory activity and task phase are considered fundamental, by literature. Still teachers practice took him to adjust this support, giving students more time to overcome, autonomously and/or minimal teacher's guidance, their problems.

From literature, teacher concluded it was important that an introductory activity existed for students understanding and training the basis of VISIR. From his practice and research, he considers that this activity should also emphasize the differences between remote labs/simulation/hands-on labs as well as the type of results obtained with each resource.

Considering his revision from literature he proposed a task that accounted for students' final grade, and defined task goals accordingly to competences he wanted students to develop. His practice led him to increase task complexity as well as its weigh in students' final grade and to split the task in two parts, in the third edition. His research alerted him to the fact that teachers should be extra careful when designing VISIR tasks as some mismatch was found between the learning goals and the type of tasks proposed.

From his research he accomplished students' acceptance of VISIR was higher when the tasks were developed in group.

In his first implementation teacher set a deadline for students to submit the VISIR task, but the reflection upon his practices made him expand the task delivery time as well as to enlarge the VISIR usage period.

VISIR grades were generally good, but from his practice he sensed students had some problems in the second and third course editions. In the second edition some students had problems with measuring current in the combination circuit. In the third edition students achieved better results in the second part of the task (although this part was more complex and demanding and not executed in the hands-on lab) than in the first part. Splitting the task in two parts, compelling students to use VISIR more and for a longer period of time and forcing them to reflect in two distinct moments along with the lab guide adaptation seem to be the causes for this change.

The three perspectives of TR reflection (literature, practice and research) confirm VISIR increases students' lab confidence, performance and autonomy and ultimately their experimental skills.

6 Conclusion

This study is based on teacher observations and reflections upon his practice, including reflective writing and analysis of students' perception of the learning activity. This work also takes into account teacher reflections upon literature and the incorporation of identified important features into his practice. And lastly, while becoming a researcher of this problematic, teacher was able to better comprehend some of the aspects reported in literature or better understand some results of his own practice.

This work shows the importance teacher reflection has upon his practice in order to pursue the continuum improvement of student achievements and how these three perspectives complement each other. In fact, some features reported in literature were corroborated by the teacher during his practice and research (such as: teacher's experience with VISIR, the importance of an introductory activity and defining VISIR tasks objectives), others appeared directly from his practice and were pursued in his research in order to deeply understand its implications (like the importance of emphasizing the differences between resources/type of results).

Considering mainly reflections from his practice, RT considers that splitting the task in several parts (with different deliver dates) or propose several tasks can be the solution to compel students to truly explore VISIR and be able to make the most of it. If teacher really considers VISIR usage contributes to students learning, he should introduce it as soon as possible in the semester, to allow its usage for a longer period of time, contributing to the development of experimental competences essential in the engineering profile. A practical aspect that also should be considered is the attention that must be given to VISIR system, during the period students are developing the task in order to avoid students' frustration and dropouts. Teachers and/or technical staff should use it (trying the components/circuits students have to use) to make sure everything is working properly. And, in case, a student reports something is not working properly, examine its legitimacy as soon as possible. Sometimes the system has some instability that with a fast resolution avoids other students of feeling it.

An aspect from his practice, corroborated by his research, that teacher intends to explore more in the future, is the difficulty some students have in understanding the difference between resources/type of results. An activity involving the three resource (simulation, remote labs and hands-on) may be a way for students better understand these differences/resemblances.

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