

Educational Digital Games integrated into Remote Labs: systematic and mapping reviews

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Abstract

Remote laboratories and digital games are consolidated learning technologies. Recent works have demonstrated synergistic effects when these technologies are integrated. In this work, we performed systematic and mapping reviews to determine how is the state of the art of the integration process of remote labs and educational digital games. The reviews were carried out by using interdisciplinary databases following well established reviewing protocols. We found 13 papers with the systematic review and 20 with the mapping review. These papers were organized into four groups: (1) Theoretical, (2) Proposal, (3) Prototype, (4) Validation. Our findings showed the integration of these technologies is still in the beginning, since most of the sum of works on theoretical concepts, initial propositions or prototypes is still large than the works on validated results. We found trends towards integrated learning tools based on remote laboratories and digital games but these works are scarce, spatially concentrated and, in most cases, unavailable for massive use.

Keywords: Remote experimentation, game based learning, taxonomy, STEM.

1 Introduction

Science, Technology, Engineering and Mathematics (STEM) education requires practical experiences during the learning process (Nedic, Machotka, & Nafalski, 2003). Usually provided by universities, experiments and demonstrations in science laboratories are used to encourage practical tasks and to teach technical skills. However, high-quality science laboratories are normally expensive to build and to keep for most universities in underdeveloped and developing countries. On the other hand, information and communication technologies have emerged as facilitating tools and become important educational technologies.

Introduced in the '90s, remote laboratories allow the interaction with real experiments located in another place through the internet (Müller & Erbe, 2007). Remote laboratories are online platforms from which the users can control parameters, run the experiment and see the results in real time by video streaming, and download data for post-processing (Casini, Prattichizzo, & Vicino, 2003). Depending on the teacher's need, different activities may be proposed in the same remote experiment, enabling use at various educational levels. Differently from simulations and virtual laboratories, remote labs use a real equipment and, therefore, they are influenced by the surrounding environment, giving to students a virtual presence in the laboratory (Nedic et al., 2003). Because of their characteristics, the remote labs are very appropriate for realization of practical activities in hybrid teaching. The manipulation of the experiment can happen through different ways as, for instance, directly from an online platform, through virtual worlds or virtual reality. Also, the experiment can be responsive and visualized through computers and smartphones.

Digital games are also consolidated technologies used in many contexts, from just entertainment to learning. In education, games appear as alternatives or support to traditional methods. Good learning experience for students (players) and interest to the game is achieved with a balance of didactic features and game elements (Iturrate et al., 2013). Moreover, interaction characteristics of games such as instant feedback and rewards for success also help motivating students during the learning process (Pivec & Kearney, 2007).

In 2001, Prensky *et al.* used for the first time *Digital Game Based Learning* (DGBL) to express the combination of the motivation of games and curricular contents (Papastergiou, 2009). The new generation of students, called digital native, interacts with technologies at an early age and 20% of them have their first contact with technologies between the ages of 5 and 8 years (Oblinger, 2004). Therefore, the students assumed that it was natural to use technologies during the daily activities, including in the school. DGBL is an approach to satisfy the student's interests and habits, exploring the possibility to make the learning process more motivational instead of "dry" and "technical" (Prensky, 2003).

Remote laboratories and digital games can be initially thought as separate learning technologies but recent works have demonstrated synergistic effects when these technologies are integrated (Callaghan, McCusker, Losada, Harkin, & Wilson, 2013), (Hoffmann et al., 2016), (Zualkernan, Hussein, Loughlin, Mohebzada, & El Gaml, 2013). Figure 1 illustrates screenshots of educational games that are integrated with remote labs. Despite the increase of the integrated use of remote laboratories and digital games, systematic reviews of this theme are lacking. Thus, this work presents a systematic and a mapping reviews of the integrated use of remote laboratories and digital games. Our main goal was to answer the following questions: (i) *Is it possible to*

effectively integrate STEM remote laboratories and digital games? (ii) Is there any standard integration methodology? (iii) Are there real cases of the use of remote labs and digital games in class?

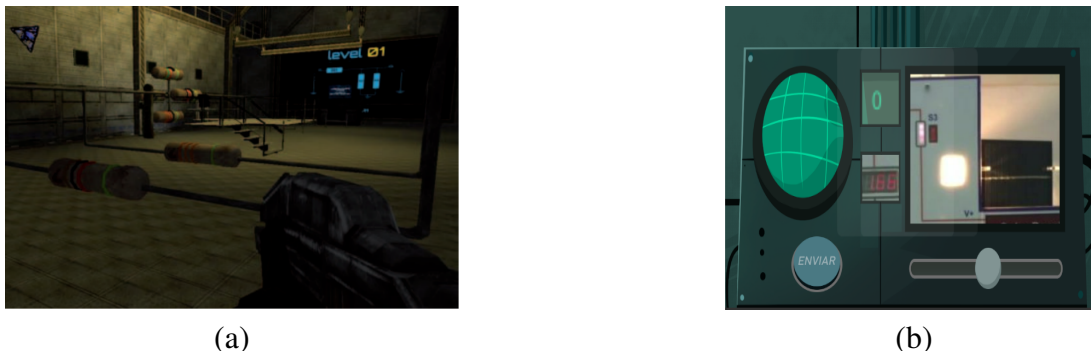


Figure 1: Example of digital games integrated to remote laboratories: (a) Circuit Warz first level (series/parallel circuit). Source: (Callaghan et al., 2013). (b) Fotovolt sixth phase (remote experiment manipulation). Source: (Tulha et al., 2019).

To accomplish our goal we performed a systematic and a mapping reviews using several databases. Systematic and mapping reviews are survey methods with different focuses, specific protocols, and different execution phases. A systematic review is a survey technique of papers, aiming to identify the existence of studies and findings of some subject available in the literature. In these reviews, the study admits the summary of evidence according to a specific strategy (Sampaio & Marcini, 2007). On the other hand, a mapping review allows identifying quantity, types, and results of an available literature finding. The difference between mapping review from the other models is that no specific outcomes or experimental designs in the studies are considered but it helps to create a classification that yields to a systematic map (Petersen, Feldt, Mujtaba, & Mattsson, 2008). Therefore, the use of the same search terms in each method is expected to find different studies.

We expect that our paper can contribute to:

- determine the state of the art and trends of the integration of remote laboratories and digital games through systematic and mapping reviews;
- overview of remote laboratories merged with digital games focused on STEM area;
- group the main findings of the integration of remote laboratories and digital games based in the contributions facet and categories of research descriptions;
- overview the open challenges of the integration methods.

The rest of this paper is organized as follows: section 2 presents the systematic and mapping review protocols, section 3 shows the results and discussions considering their outcomes; finally, section 4 presents some conclusions.

2 Methodology

The following subsections describes the systematic and mapping reviews protocol used during our work. The free software START (State of the Art Through Systematic Review)¹ was used in the selection and extraction phases. START aims to support the application of systematic review based on Kitchenham's outlines and allows the users to fill in the information of the review protocol (Fabbri et al., 2016).

2.1 Systematic Review

We used the protocol proposed by Kitchenham (Kitchenham, 2004) to carry out our systematic review. The protocol is organized into three phases: planning, conduction, and extraction. We chose remote laboratory, game, and game-based learning as the controllers and remote labs and remote experimentation as the non-controllers. Thus, a search was performed by using the research query: (("remote experiment" OR "remote experimentation" OR "remote laboratory" OR "remote lab") AND (game OR "game based learning")). This query was applied on the interdisciplinary databases SciELO, Web of Science, Scopus, Proquest, Engineering Village, Science Direct, IEEE, and Learn Tech Lib. The screening process was based on the inclusion criteria that considered only researches that explicitly mentioned the integration between remote laboratory and games and availability of access, excluding proceedings papers, meeting abstracts, editorial materials, papers which the terms appear only as keywords, and papers found in different bases. In order to collect the maximum of papers on the subject, neither the publication year nor the educational level which the technologies were applied were specified.

2.2 Systematic Mapping

We applied a systematic mapping review based on the methodology suggested by Bailey (Bailey et al., 2007), which involves four phases. First, the definition of the research question. Second, the definition of the research strategy which includes the conducted search and paper screening. Third, the keywording of abstracts, a process that facilitates the classification of the papers. And, fourth, the data extraction and the creation of a map to summarize the evidences found.

To obtain an overview of the research area, the terms 'remote laboratories' and 'game' and their writing variations were considered in the research strategy to produce the following search query: (("remote experiment" OR "remote experimentation" OR "remote laboratory" OR "remote lab") AND ("game")). According to Bailey, the query should contain no terms related to methods or theories, which made us to exclude terms like "game-based learning" in the query. The same databases and inclusion/exclusion criteria used for the systematic review were also used for the systematic mapping review.

¹http://lapes.dc.ufscar.br/tools/start_tool

3 Results

The following subsections present the survey articles outcomes. After the systematic review the papers were organized chronologically, considering the description of collected papers objectives, didactic focus, and enhancement. The systematic mapping outcomes were organized into four groups, summarized as tables, and reflected at a bubble plot.

3.1 Systematic Review Outcomes

The primary research of the systematic review yields 458 papers, 404 not duplicated. Table 1 presents the number of papers surveyed in each phase of the review. Most of them (261) were obtained from the Web of Science database. After applying the inclusion and exclusion criteria, based on the analysis of the title, keywords, and abstract, the number of relevant papers was reduced to 19. After the extraction phase, when all sections of the papers were read, only 13 papers were accepted, most of them (7) found in IEEE.

Table 1: Number of papers found during the systematic review.

Database	Primary Survey	Selection	Extraction
SciELO	-	-	-
Engineering Village	24	3	-
IEEE	23	7	7
Learn Tech Lib	15	1	1
Proquest	58	1	-
Science Direct	31	-	-
Scopus	46	12	5
Web of Science	261	1	-
Total	458 papers	19 papers	13 papers

Most of the researches groups of the accepted papers are in Europe, especially in Spain, where 5 papers were produced in the University of Deusto (Table 2). The most cited article has 36 citations, out of the average of 4 citations per article. The oldest study found was from 2011. It was a paper that provides guidelines for the integration process, including a gaming model, elements of learning, and challenges, and that makes evident the possibility to effectively integrate remote laboratories into educational digital games (Dziabenko & García-Zubia, 2011). In this paper, Dziabenko & Garcia-Zúbia describe how remote laboratories works, the definition of the game-based learning model and the main aspects to design an educational game. They concluded that elements such as the pedagogical approach, the tasks, the pedagogical support, the storytelling, the balance of challenges and the motivation should be considered during the development of a educational game.

Among the accepted papers, three present ideas of future works, including two proposals of a new remote labs architecture. Gil *et al.* (Rodríguez-Gil, García-Zubia, & Orduña, 2016) propose a generic architecture of online labs models as a dissertation theme. The proposal is based on collaborative gamified remote lab immersed into Learning Management Systems. The dissertation aimed to provide support to modern features into remote labs, the development of complex labs, and a collaborative environment. Cano *et al.* (Cano, Hernández, Ros, & Tobarra, 2016) proposed an architecture of a distributed remote lab combining game and instructional supplements

Table 2: Papers chronologically.

Year	Objective	Didactic Focus	Enhancement	Times cited*	Source
2011	Review of principles to guide the integration process (Dziabenko & García-Zubia, 2011)	-	-	10	[A]
2011	Implemented a competition game, evaluating the technical and pedagogical efficiency (Atanasijevic et al., 2011)	Multivariable control	ECHO learning	12	[A]
2012	Describes the validation of a methodology to the use of game-based remote labs (Zualkernan et al., 2012)	Proportional integral	-	1	[A]
2013	Validation of a collaborative remote lab (Zualkernan et al., 2013)	Proportional integral	-	3	[B]
2013	Describes a robot platform prototype to multidisciplinary school applications (Iturrate et al., 2013)	Basic programming, algorithm	<i>Google Blockly</i>	8	[A]
2013	Development and tests of Circuit Warz project: virtual world with AC remote panel challenges (Callaghan et al., 2013)	Circuit theory	-	36	[A]
2014	Implementation and layout of a remote robot integrate into a logic puzzle (Guenaga et al., 2014)	Programming, logic and debugging	Augmented reality	3	[C]
2015	Implement a robot and evaluated the preferences during the use of a game control (Hoffmann et al., 2016)	Engineering practice	Virtual Reality Gamepad control	4	[C]
2015	Evaluation of LaboREM: a robot arm controlled through a collaborative game-like environment (Luthon & Larroque, 2015a)	Build circuits	-	11	[A]
2016	Propose a distributed remote lab based in an instructional and motivational game design (Cano et al, 2016)	Cybersecurity	-	2	[C]
2016	Propose an generic remote lab architecture as a dissertation theme (Rodriguez-Gil et al., 2016)	-	-	-	[C]
2016	Describes the RALfie project and the proposal of a peer-to-peer architecture through quest-based learning (Kist et al., 2016)	-	-	1	[C]
2019	Describes the development and implementation of Fotovolt, based on Photovoltaic effect (Tulha et al., 2019)	-	-	-	[A]

[A] IEEE [B] Learn Tech Lib [C]Scopus

The number of citations were obtained until Fev/2021

using puzzle pieces. The architecture is based on Gagne's event model² to support cybersecurity and protection systems. To evaluate the student's motivation, the ARCS (Attention, Relevance, Confidence, and Satisfaction) model³ will be used as the basis for creating user experience questionnaires. In another context, Kist *et al.* (Kist et al., 2016) propose the structure of the RALfie (Remote Access Laboratories for Fun, Innovation, and Education) project. RALfie allows the development of remote experiments by the users themselves and validates experiments or activities through gamification and quest-based learning methods. The control of the experiment request programming skills of the user. RALfie uses a peer-to-peer architecture that makes possible users to build remote laboratories knowing the basic underline technology.

In 2013, Callaghan (Callaghan et al., 2013) described the initial version of Circuit Warz, a game based learning merge with virtual worlds aiming the support of STEAM area education. The virtual world was created in Second Life and is also integrated into a Learning Management

²<http://epubstep.info/conditions-of-learning-written-content-ebook-robert-m-gagne.pdf>

³<https://files.eric.ed.gov/fulltext/ED436181.pdf>

System (Moodle). At the beginning of the activity the students must full fill an initial quiz about circuit theory. The game starts in a collaborative activity, the students can manipulate an AC panel experiment selecting resistor/capacitor values into a pre-defined circuit output, working with resistors in series and in parallel. The team that first finish correctly the puzzles win the game. The integration with the remote lab is implicit in the user interface, a game based layer was implemented inside the virtual world based on the remote experiment design. The controller occurs through an external hardware that sends data to the virtual objects inside the virtual world. The management of the data and communication is made through the SLOODE, a modified version of Moodle. Practical tests were made based on the user (students and educators) acceptance of the game. The validation showed positives responses from students acceptance of the collaborative aspect, as well as the interaction with the simulations and visualization of the circuit theory and operation. It was not specified in what context the game was applied or qualitative results.

Another integration technique is using augmented reality and virtual reality technologies. Hoffmann *et al.* (Hoffmann et al., 2016) designed a remote laboratory for engineering practices that can be manipulated by using virtual reality and gamepad controllers. The user is immersed in a virtual reality interface which allows the manipulation of the real robot arms. The user can control two cooperating six-axis robots to perform the tasks that they are ask for. The robots are controlled by two manual control panel and computers, that run the virtual reality simulation. The Nintendo Wii control is used to interact with the experiment. The validation of the game was made with engineering students of the RWTH Aachen University. Six questionnaires were applied during two practical tests: (1) theoretical, (2) pre-questionnaire of game experiences and spatial abilities, (3) first experiment, (4) questionnaire of the previous test, (5) second experiment, (6) questionnaire of the previous test. The tests include the evaluation of the correlation between the weekly gaming hours and the mechanism preferences of Wii control (direct or inverse kinematics). After the tests, it is possible to assume that the control mechanism is chosen depending on the task of the learning experience. The first and second experiments that the students performed were not described.

Other papers also described the application of questionnaires to evaluate the students experience using the integrated remote lab/game. The evaluations focused not only on the motivational and learning gains but also on entertainment and performance aspects of the game. Using learning management, Maja Atanasijević-Kunc *et al.* implemented a competition game in a remote laboratory device to teach multivariable control design (Atanasijevic-Kunc, Logar, Karba, Papic, & Kos, 2011). Their work was based on the ECHO-system learning environment to the e-learning management, and on Matlab software to control design and simulation. The game is separated into three phases representing levels with a conceptual quiz, manipulation of a virtual laboratory simulation and remote experiment. In the first level, a questionnaire with three questions about multivariable systems is made available to the student. In the second level, the student must design a controller based on the rotation velocity and tension of an elastic band, and test the results using the simulation. Afterwards, the activity is reapplied using the remote experiment. The project occured during a three years at the Faculty of Electrical Engineering, at the University of Ljubljana, and in the final week of each semester a Likert questionnaire with 16 questions about technical efficiency and pedagogical aspects was applied. During these years the numbers of the students that used/do not used the e-learning and the percent of how many passed exams were accounted for. The results were satisfactory: all students that used the e-learning passed the exams, 50% of the students believed that the e-learning increased the freedom to organize the

work and 42% that increased the studying efficacy.

In 2019, Tulha *et al* design and evaluated a digital game that provides real-time visualization and manipulation of the remote experiment "Conversion of Light Energy into Electrical Energy" (Tulha et al., 2019). The game is organized into six phases, each one about one concept of the photovoltaic effect, being: properties of light as electromagnetic radiation, electric energy with a circuit challenge, conductive materials concepts, and the relation between tension and angulation. During the last phase the student can manipulate the remote lab through the game interface. The game was applied Juan Orobio Goitia BHI School + Iurreta/Spain and was performed by 24 senior year students. After the use of the game the students full fill an inquiry based on MEEGA + (Model for the Evaluation of Educational Games). The question were organized based on the Likert model. Their implementation had positive outcomes, making possible to conclude that the students believes the game provides challenges, the contents helped them to become more confident about the subject and the game promotes cooperation.

Virtual instruments are also used in a game-like scenario such as LaboREM, a remote laboratory for electronics training (Luthon & Larroque, 2015a). LaboREM enables to manipulate a robotic arm for placement of components in a gamified platform enabling collaborative work and learning itinerary adapted for training in electronics. The integration is made through a virtual manager that stores the data of the experiment, and schedules the queue of connected clients. This management enables the user to switch to other activities while is waiting, and to initialize the system. The proposed scenario follows various stages of lessons: including quizzes, remote labwork and a comparison with a simulator. Each lesson has a difficulty level. During the practical activities, a circuit must be build and tested at the simulator and the remote experiment with a limited time and trials. The activity can be done collaboratively, through chats and forum. The student can accumulate points and the best scores are published at the hall of fame with a Top 10. The evaluation was conducted during four years, each one with a class of science degree in an industrial engineering course. Two anonymous questionnaires were applied during each year, with 70 Likert questions about usability, student motivation and satisfaction. The result shows that 75% approves the platform as an effective educational strategy.

Zualkernan described the implementation of remote labs and game-based learning based on problem posing and problem-solving pedagogical methodology *et al.* (Zualkernan, Al Husaini, Loughlin, Mohebzada, & El Gaml, 2012; Zualkernan et al., 2013). The collaborative experiment consists of two identical tanks of water, controlled through a digital interface. The player must try to keep his/her tank stable into a predefined setpoint, while attacks oscillating the opponent tank. The login to the game is made on Facebook, connected to the game as a socket client. The user can join or create his/her own room of the game. To validate the game, a case study was conducted with 12 chemistry students. The control group did not play the game, while the gaming group was divided into two teams. A quiz about the proportional integral control was applied before and after the activity. After the activity, the students also filled a Likert questionnaire about the aspects of the game were evaluated through were applied. The results indicated that 10 students felt immersive and motivated by the game, 11 believed the game improved the knowledge, and 10 would recommend the game. However, after playing the game once, the student performance in conceptual tests was not directly influenced.

3.2 Systematic Mapping Outcomes

This subsection aims to group the papers surveyed and perform a brief analysis of the trends found. Data extraction of the mapping review yields 324 papers for the primary survey and 20 after the keywording phase (Table 3). Although most of the papers were found in Science Direct in the primary survey, all the accepted papers (10) were found in Scopus. Most papers surveyed in the mapped review were also found in the systematic review. Thus, we described the main characteristics, defined by the authors, related to the group in which the article is classified.

Table 3: Number of papers found during the mapping review..

Data Base	Primary Survey	Keywording
SciELO	-	-
Engineering Village	15	2
IEEE	9	4
Learn Tech Lib	50	-
Proquest	76	-
Science Direct	95	-
Scopus	53	10
Web of Science	27	4
Total	325 papers	20 papers

Based on the research type facet, the keywording yield 4 groups. We classify the papers according to their research aims. The *Theoretical Research* group comprises all the conceptual works that describe theories or reviews. The *Proposal Research* group comprises all the studies that have already a development plan without implementation. The *Prototype* group are the papers that have a first implementation without evaluation data. Finally, the *Validation Research* group contains the papers that show some implementation and evaluation data, including usability tests or application in a classroom.

Three works surveyed were classified as *Theoretical Research* (Table 4). The theme of the papers can be summarized as reviews about the challenges and methodologies of the integration process. While Arango *et al.* (Arango, Aziz, Esche, & Chassapis, 2008) describe the classification of games and the state of art of educational and training implementations, Orwin *et al.* (Orwin, Kist, Maxwell, & Maiti, 2016) focus on the state of methodologies and theories of gamification elements into remote labs to provide foundations to the RALfie (Remote Access Laboratories for Fun, Innovation, and Education) project. Dziabenko *et al.* (Dziabenko & García-Zubia, 2011) reviewed of technical concepts about the development of an educational game and the integration process with remote labs. The paper includes the description of necessary characteristics to integrate them efficiently.

Table 4: Theoretical Research.

Year	Main Contribution	Reference	Source
2008	Review of education application of digital games, including the integration with remote labs	(Arango et al., 2008)	[B]
2011	Review of principles and theories to guide during the integration of remotes labs into games	(Dziabenko & García-Zubia, 2011)	[C]
2016	Review of theoretical educational foundations, gamification design, in the context of RALfie project	(Orwin et al., 2016)	[D]

[A] Engineering Village [B] IEEE [C]Scopus [D] Web of Science

Five proposal works were surveyed, listed in Table 5, of which three approaches the conception of architectures to structure the integration of the remote lab and the games. The proposals include design collaborative environments and an attractive interface. Cano *et al.* (Cano et al., 2016) propose a game-piece-based distributed architecture for remote laboratories. The laboratory space will support cybersecurity training based on instructional and motivational concepts. Kist *et al.* (Kist et al., 2016) propose a peer-to-peer approach based on gamification and quest-based learning. The proposed activities enable the user to build his/her remote lab with Matlab software support. Gil *et al.* (Rodriguez-Gil et al., 2016) proposes a generic architecture that can support the existing online laboratories paradigms and increase with serious-gaming elements. Arango *et al.* (Arango, Chang, Esche, & Chassapis, 2007) and Aziz *et al.* (Aziz, Chang, Arango, Esche, & Chassapis, 2007) are complementary research that discuss, respectively, the game design/pedagogical theories and existent methods to transfer information between the remote lab and the game.

Table 5: Proposal Research.

Year	Proposal	Reference	Source
2007	Data transfer data methods between the game and the remote lab	(Aziz et al., 2007)	[A]
2007	Pedagogical script for the use of remote lab at a mechanical engineering course	(Arango et al., 2007)	[B]
2016	Architecture for the game as lab resources and the use of a remote lab in class	(Cano et al., 2016)	[C]
2016	Dissertation theme approaching an architecture to support new online labs paradigms	(Rodriguez-Gil et al., 2016)	[C]
2016	Collaborative organization and architecture of RALfie project	(Kist et al., 2016)	[C]

[A] Engineering Village [B] IEEE [C]Scopus [D] Web of Science

Two of the researches classified as *Prototype* propose solutions for the support of programming classes, including logic, algorithm and writing and debugging programs (Table 6). Guenaga *et al.* (Guenaga et al., 2014) and Iturrute *et al.* (Iturrute et al., 2013) described the incremental of the game with an augmented gamified world interface and the *Google Blockly* graphical programming language, respectively. Tumkor *et al.* (Tumkor et al., 2012) described a multiplayer game laboratory environment that combines a remote lab with the virtual lab, enabling the share of variations.

Table 6: Prototype.

Year	Educational Context	Didactic Focus	Remote Experiment	Enhancement	Reference	Source
2013	Multidisciplinary school	Basic programming Algorithm Logic principles	Robot	<i>Google Blockly</i>	(Iturrute et al., 2013)	[C]
2013	Engineering University	Basic fluid mechanisms	Flow rig experiment	-	(Tumkor et al., 2012)	[C]
2014	Engineering University	Programming logic and debugging	Robot	Augmented reality	(Guenaga et al., 2014)	[C]

[A] Engineering Village [B] IEEE [C]Scopus [D] Web of Science

In the *Validation Research* group, two institutions were highlighted during the survey (Table 7). Luthon *et al.* (Luthon & Larroque, 2015a), (Luthon, Petre, Steriu, & Besleaga, 2009), (Luthon & Larroque, 2015b), from the University of Pau, described in three papers researches made during 2009 to 2015 using LaboREM (Remote Laboratory) platform. LaboREM is a robot arm developed for training in electronics, including signal, circuits and system testing. The platform was

tested in different scenarios during the years. Throughout the years, questionnaires were applied to verify the impact on student motivation, the experience during the activity and the platform usability. Mostly of the works describes the use of the Likert model as an evaluation methodology. Zualkernan *et al.* (Zualkernan et al., 2012), (Zualkernan et al., 2013), from the American University of Sharjah, described a collaborative methodology using problem posing for game-based learning in remote labs for proportional integral (PI) concepts. Twenty-two students were chosen randomly during the validation process, and a pre-quiz on PI controller was applied. After the use of the technology, the students fill out a survey about the student motivation and about the experience of playing the game. Maja Atanasijević-Kunc *et al.* (Atanasijevic-Kunc et al., 2011) focus on technical efficiency and the learning experience of competition game about multivariable control. Andrés-Gutiérrez *et al.* (Andrés-Gutiérrez, González, & Gómez, 2010) made practical tests to analyze the performance of a solid motion game. The evaluation occurs through 16 questions based on Likert model. The enhancement of the integration process using other technological objects, like virtual reality or gamepad controller, is also a trend. Hoffmann *et al.* (Hoffmann et al., 2016), for example, focused on the evaluation of the use of a gamepad controller and the mechanisms preference of the user during the manipulation of a robot arm in a virtual gamified reality. Their work implemented two different experiences using kinematics into groups, giving to the participants questionnaires before and after the experiment. The conclusion was that the technical mechanism depends on the practical activity. Tulha *et al.* focus on the students perception of usability, learning and experience after used the game. The students were requested to the fill out a inquire based on MEEGA+ (Model for the Evaluation of Educational Games) organized based on the Likert model.

Table 7: Validation Research .

Year	Educational Context	Didactic Focus	Enhancement	Evaluation	Reference	Source
2009	Technological University	Signal Circuits Systems testing	-	Student Motivation Usability Satisfaction	(Luthon et al., 2009)	[D]
2010	Engineering University	Solid motion	Gamepad control	Practical test	(Andrés-Gutiérrez et al., 2010)	[D]
2011	Engineering University	Multivariable Systems	Matlab	Practical test	(Atanasijevic-Kunc et al., 2011)	[C]
2012	Chemical University	Proportional integral	-	User experience	(Zualkernan et al., 2012)	[C]
2013	Chemical University	Proportional integral	-	Student Motivation Experience	(Zualkernan et al., 2013)	[B]
2015	Engineering University	Robot control	Virtual Reality Gamepad control	Mechanisms preference	(Hoffmann et al., 2016)	[C]
2015	Technological University	Basic electronic	-	Student Motivation	(Luthon & Larroque, 2015b)	[D]
2015	Technological University	Circuits	-	Student Motivation Platform Usability	(Luthon & Larroque, 2015a)	[A]
2019	High School	Photovoltaic Effect	-	User Experience	(Tulha et al., 2019)	[B]

[A] Engineering Village [B] IEEE [C]Scopus [D] Web of Science

The last phase of the systematic mapping review include the creation of a plot based on the papers found. Associating groups trend researches topics with the contributions facet we produced the mapping plot (Fig. 2). To reach our goal, we used a bubble plot based on the frequency of publications. The horizontal axes represent the research categories, respectively, (i) *Theoretical*, (ii) *Proposal*, (iii) *Prototype*, and (iv) *Validation*, previously described. The vertical axes repre-

sent the contributions facet. We organize the contributions facet in 3 categories: (i) *Integration process*, including innovative architecture propose, (ii) *Didactic*, description of didactic activities, (iii) *Design*, description of interface design, including enhancements as virtual reality (listed in Fig. 2 respectively from the base to the top). The bubbles organization were based on the focus of papers surveyed, for example, if the research is theoretical and presents a review of integration guidelines is classify as *integration*.

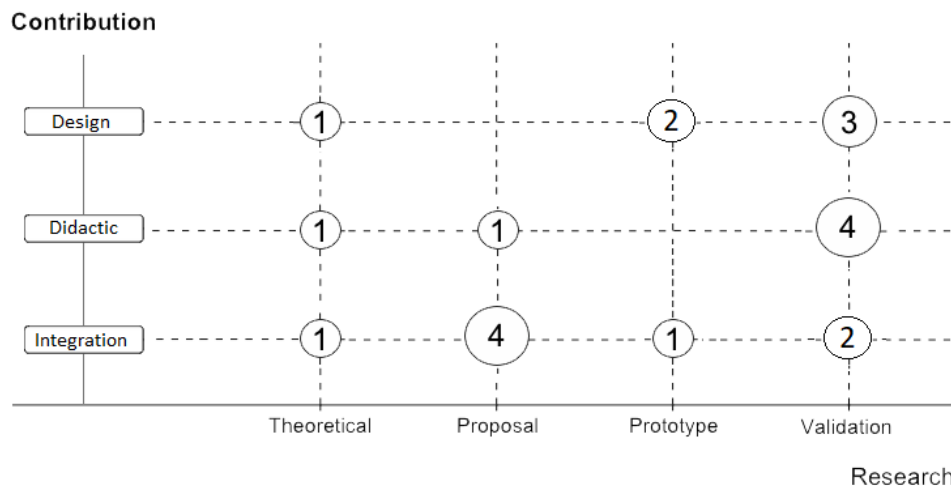


Figure 2: Categorical bubble plot for the systematic mapping. The horizontal axes represent the research categories proposed by our survey and the vertical axes the contributions facet, based on the description focus of the paper survey. .

Analyzing the bubble plot (Fig.2) is possible to regard that the *Validation Research* group is the large one, with 9 surveyed papers, however the sum of works on theoretical concepts, initial propositions or prototypes is still large than the works on validated results. The *Theoretical group* is formed with one literature review about each subject. The *Proposal* group has three researches describing new architectures to structure the integration process, one pedagogical script proposing activities and one dissertation theme. The *Prototype* group has one research describing simple implementation, and two describing design enhancements with others technologies. The *Validation* researches focus on student motivation, pedagogical impact was classify as *didactic* contribution, the usability evaluation as *design* contribution, and practical tests as *integration* contribution.

4 Final Considerations

The systematic review, as a summarizing process, makes possible deep verification and critical evaluation of different works in the literature. Our study aimed to find studies on the integration of remote laboratories and digital games, using a specific game based learning term. In contrast, the research tendency of the educational area was made clear with the mapping review.

During the research, we propose to answer questions to a better comprehension the integration of remote laboratories and digital games, including protocols, methodologies, and real cases of the use of remote labs and digital games in class.

After the survey papers analysis, we conclude that although remote laboratories and digital games are separately consolidated tools, the integration of these tools is still its earlier phase. We found that it is possible to effectively integrate these objects and works describing implementation and data evaluation. However, the sum of papers on theoretical concepts, initial propositions or prototypes exceeds the number of validated works. Although six papers quantitatively describe the implementation and use of remote labs integrated into games in classes, only the game Circuit Warz was found available online.

Our systematic and mapping reviews showed no standard but different methods for integrating remote laboratories and digital games, probably because of the large diversity of digital games. The use of game elements design to manipulate the remote experiment is a trend of integration methods. Furthermore the use of "game based lab design" or "remote laboratory game" terms to refer to educational games based on remote laboratory architectures is common. Also, the most common integration methods found were the enhancement of remote laboratories and remote control by virtual or augmented reality. Whereas the former allows creating competition challenges, pointing out to the correct manipulations or gaming the interface, the latter allows manipulating the remote experiment by, for example, joysticks or gamepad support.

To evaluate the use of remote lab merged into games, 87.5% of works in the *Validation Research* group uses a Likert scale, which allow the students measure of their level of agreement with affirmations was a trend. The evaluation of experience after the use of the technologies shows positive results of enjoyed and motivational learning.

Although no limitation was applied to the publication year, 58% of the survey papers are dated before 2013. This rise some questions about why the research in this subject has decreased since them.

It is also noted that most of the papers were found in conference proceedings which suggests that the researches are not complete with technology assessments. This makes clear that integration of remote labs and digital games is still in the beginning.

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