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Original scientific paper

COLLABORATIVE LEARNING PLATFORM WITH INTEGRATED REMOTE LABORATORY ENVIRONMENT IN VOCATIONAL EDUCATION

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A b s t r a c t: In this paper, the design and evaluation of a computer-based remote virtual laboratory with an integrated collaborative environment in vocational education have been presented. The remote virtual laboratory was implemented as a joined effort of several participating institutions from universities and vocational education in the framework of the Erasmus+ project CORELA. The paper summarizes the design and implementation concepts and presents the user experience evaluation results obtained from students from vocational education. The results presented in the paper suggest that the CORELA platform provides a good professional user space for remote laboratory experimentation but also give insight where the virtual platform could be improved.

Key words;; remote laboratory; collaborative learning; virtual laboratory; vocational education

ПЛАТФОРМА ЗА КОЛАБОРАТИВНО УЧЕЊЕ СО ИНТЕГРИРАНА ДАЛЕЧИНСКА ЛАБОРАТОРИСКА ОКОЛИНА ЗА СРЕДНО СТРУЧНО ОБРАЗОВАНИЕ

А п с т р а к т: Во овој труд се претставени дизајнот и евалуацијата на компјутерски базирана далечинска виртуелна лабораторија со интегрирана колаборативна околина наменета за средно стручно образование. Имплементацијата на далечинската виртуелна лабораторија е резултат на заедничкиот труд на неколку универзитети и средни стручни училишта, учесници во проектот Еразмус + CORELA. Трудот ги претставува концептите за дизајн и имплементација на платформата и ги прикажува резултатите од оценувањето на корисничкото искуство добиени од учениците во средното стручно образование. Резултатите презентирани во трудот сугерираат дека платформата CORELA претставува добра професионална корисничка околина за далечинско лабораториско експериментирање, но исто така даваат увид во областите каде таа може да се подобри.

Клучни зборови: далечинска лабораторија; колаборативно учење; виртуелна лабораторија; стручно образование

1. INTRODUCTION

In order to be competitive in the global economy, Europe tends to be most highly skilled region in the world. Recent study shows that the occupational structure of EU employment of the engineering sector tends to shift towards knowledge and skills-intensive jobs from 27.3% in 2007 to 32.4% in 2020 [1]. Industry requires well educated science, technology, engineering and mathematics (STEM) professionals at all education levels. However, at the same time the reduction of professionals in STEM is very high –- 30% for the science education and 50% for the engineering. Such technical and educational demands could be met by introducing innovative learning methodologies that include class instructions, practical assignments, laboratory work and extracurricular activities. Vocational education and training (VET) teaching staff have the central role in reaching these goals. On the other hand, they must have access to high quality resources to support student's curiosity with state-of-the-art research and developments in STEM, and supported interactive instruments including an experimental laboratory.

The Erasmus+ project CORELA [2] introduces innovative, integrated Tailor-made platform intended for VET education. The platform improves the remote laboratory concept that has been used in higher education institutions. Usually, this concept is broadly accepted at the technical universities, where remote experiments are implemented to support student's curriculum. Most of the experiments are not widely disseminated and exist side by side with the known remote laboratories such as iLAB (MIT, USA) [3], LabShare (UTS, Australia) [4], VISIR (BTH, Sweden) [5], WebLab-Deusto (Spain) [6]. Moreover, conceptual designs of remote laboratories are presented in numerous research papers [7, 8].

In the last few years, simple versions of those laboratory experiments have been proposed to the STEM school teachers' community. However, there is much less experience of implementing such technologies in the secondary vocational education. This project was aimed to channel this effort into the development of internet-based software platform which supports international collaboration through forming groups with pupils from different countries and different cultures while collaborating on remote experiments using remote virtual laboratories (RVL). Unlike in real laboratories, where pupils are often confined to a limited time, closely monitored by a supervisor and without an option to repeat experiment, the RVL platform offer unlimited access and freedom to explore. This can be also extremely important in cases of restricted student mobility such as the COVID-19 pandemic situation that we are currently facing.

This paper elaborates the design and implementation of the virtual remote environment with integrated collaborative learning focusing on the virtual instrumentation design. On the other hand, the paper summarizes the quality control evaluation report that has been done by using a large group of VET students which took part in the practical experiments. We believe that the results reported herein are widely relevant having in mind the international mix of student working groups and VET schools from different partner institutions.

2. COLABORATIVE REMOTE VIRTUAL LABORATORY WITH INTEGRATED COLABORATIVE LEARNING ARCHITECTURE

The innovation of the CORELA RVL platform architecture rises from the idea that globally distributed systems could be interconnected to function concurrently. Such systems are intended to be controlled by international teams of teachers and pupils, also distributed worldwide. The VET students collaborate and communicate through the platform to achieve the required objectives. Remote virtual laboratories, which started their development about two decades ago, are currently seen as the beginning for future advanced global educational systems. They offer a unique opportunity to develop a teaching and learning platform for the development of skills required for efficient collaboration and communication on a local and global scale. Currently there are several RVLs reported worldwide, yet only a few are constructed in such way to allow involved participants to collaborative and operate in real-time. However, a number of other institutions have recognized the advantages of collaborative RVLs and are in the process of redeveloping their RVLs into collaborative learning environment. On the other hand, very little research has been done on the evaluation of collaborative learning in RVLs, especially in secondary education. Among others, this is because a large majority of RVLs are designed as single user laboratories where pupil's collaboration is not possible. This contradicts vocational secondary education practice where pupils normally perform laboratory experiments collaboratively in larger groups. Such approach will not only enhance the employability and career prospects of the VET students by providing them access to sector-specific skills, but at the same time will support their creative potential and increase the innovative capacity of the VET education centers.

The CORELA remote virtual laboratory with integrated collaborative learning consists of two integral parts: a moodle-based platform, and Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) laboratory environment. The general CORELA architecture is given in Figure 1.

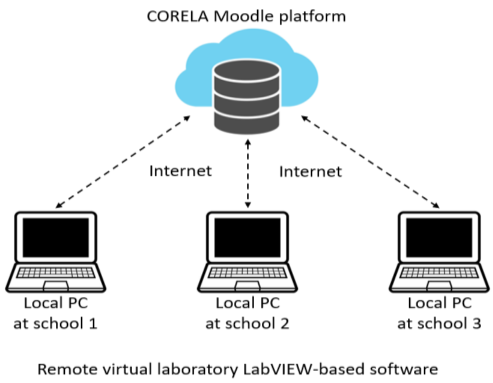

Fig.1. CORELA remote virtual platform with integrated collaborative learning architecture

The moodle platform contains centralized database hosted on a web-server located in SETUGS Mihajlo Pupin. This platform serves as a data sharing and communication tool between the VET schools. By using the platform, VET teachers can easily distribute educational materials, organize students in groups and deliver assignments. Afterwards the students can realize experiments, work in a collaborative environment and submit reports. However, regarding the CORELA project, two most important aspects of the moodle platform implementation should be highlighted: extended database for communication with the RVL, and tools for application of the new teaching methodology for optimal application of collaborative learning in VET. The available tools for collaborative learning in VET have been defined in accordance with the survey [9] provided in the CORELA project. The survey results showed that students are eager to work in international groups, they prefer real-time chat instead of video or audio communication, and overcome the cultural and language barriers.

The moodle platform database has been extended with additional features in order to couple with the LabVIEW-based RVL platform. It contains additional information regarding the users (login credentials, dedicated user identification, laboratory experiment identification, etc.), as well as specialized data channels for exploitation with the RVL.

There are ten easily upgradeable input/output channels in the database associated to the RVL. These channels are polymorphic, meaning that the users can exploit them by using different data types and structures (scalars, arrays, signals, etc.). Once the user is logged-in to the RVL, they can perform continual two-way communication by using the JavaScript Object Notation (JSON) data interchange format that uses human-readable text to store and transmit data objects consisting of attribute–value pairs and arrays. The detailed implementation of the LabVIEW-based RVL is given in the following chapter in this paper.

CORELA LABVIEW-BASED REMOTE VIRTUAL LABORATORY

The CORELA remote virtual laboratory is a stand-alone personal computer (PC) software implemented in LabVIEW environment. The program is intended to be installed on each computer at VET institutions and provide direct communication with the CORELA database integrated into the moodle platform. The virtual instrument consists of two main parts: front panel given in Figure 2, and block diagram given in Figure 3.

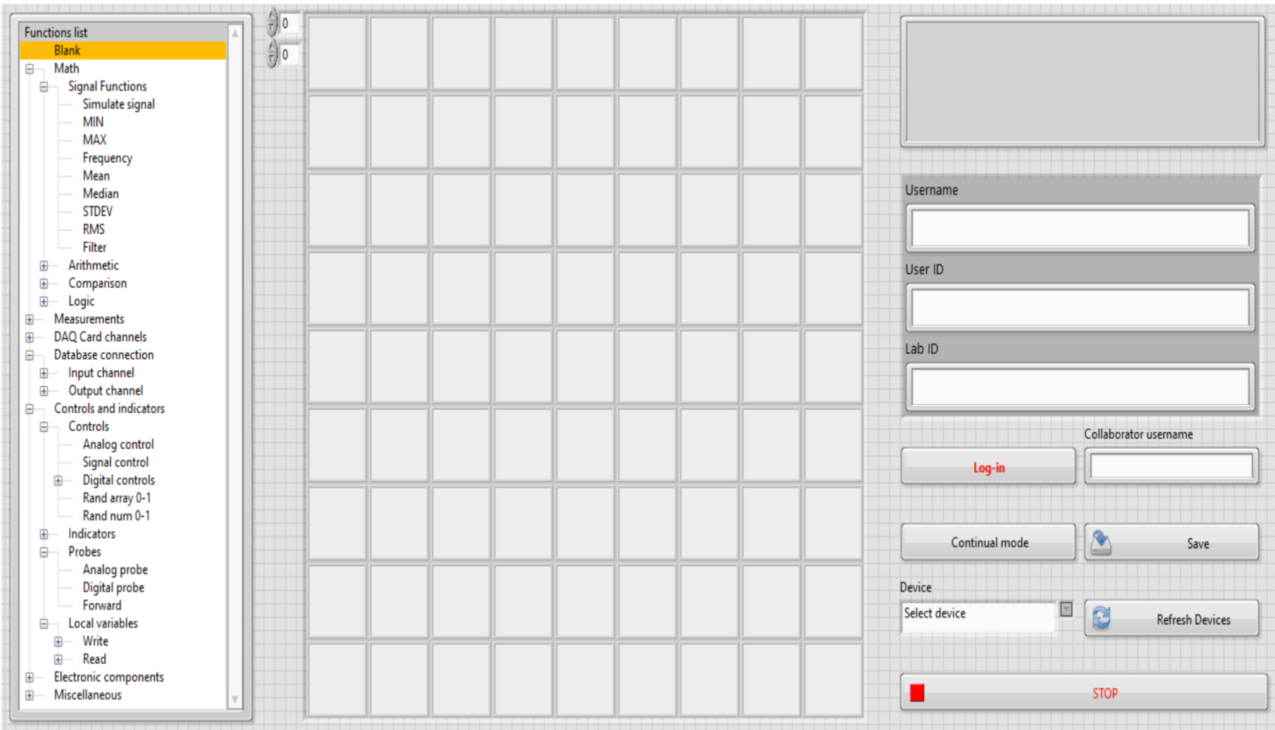

Fig. 2. Front panel of the LabVIEW-based CORELA remote virtual laboratory

The front panel is the graphical user interface which provide all functionalities of the remote virtual laboratory. It is divided into three main sections: function list (left part in Figure 2), experiment development space (central part in Figure 2), and configuration and log-in user space (right part in Figure 3). Initially, the user must log-in with a valid username and user identification (ID), as well as to provide the laboratory exercise ID. Once the user logs-in, they can start developing the laboratory experiment by using the functions given in the function list. There are a lot of predefined functions in the function list, generic ones (mathematics, controls, indicators, probes, etc.), and specialized functions (database connection, signal functions, data acquisition cards, variables, electrical engineering functions, etc.) The experiment is realized by selection of particular function from the function list and then placing it in a given square of the experiment development space. There are specific rules for inputs (left side) and outputs (right side) for each function from the functions list that can be analyzed with the implemented help tools. Once the experiment diagram is finished, the user can then execute the program in one of the two regimes: single-stepping, and continual mode.

In the single-stepping mode, a function is executed as soon as it is placed in the experiment development space. However, if particular input of that function changes later on, than the output of the function will remain unchanged. Such regime is suitable for development of simple calculation tasks, reading single measurements from the data acquisition card, etc. On the other hand, in the continual mode all functions are continually updated with frequency of approximately 2 Hz. It is obvious that such behavior of the program is suitable real-time applications.

The programming code (block diagram) of the LabVIEW-based CORELA remote virtual laboratory is given in Figure 3. The program is based on a producer-consumer with integrated event-driven state machine programming architecture. In general, there are two while loops running in parallel: a producer loop (upper part in Figure 3) and consumer loop (lower part in Figure 3). The producer loop is used for registering events, such as clicking on a control button or placing a function on the experiment development space. Once an event is been registered it is automatically processed, and particular message is submitted to the consumer loop by using queues. The program architecture is developed in such a way that it guaranties lossless information.

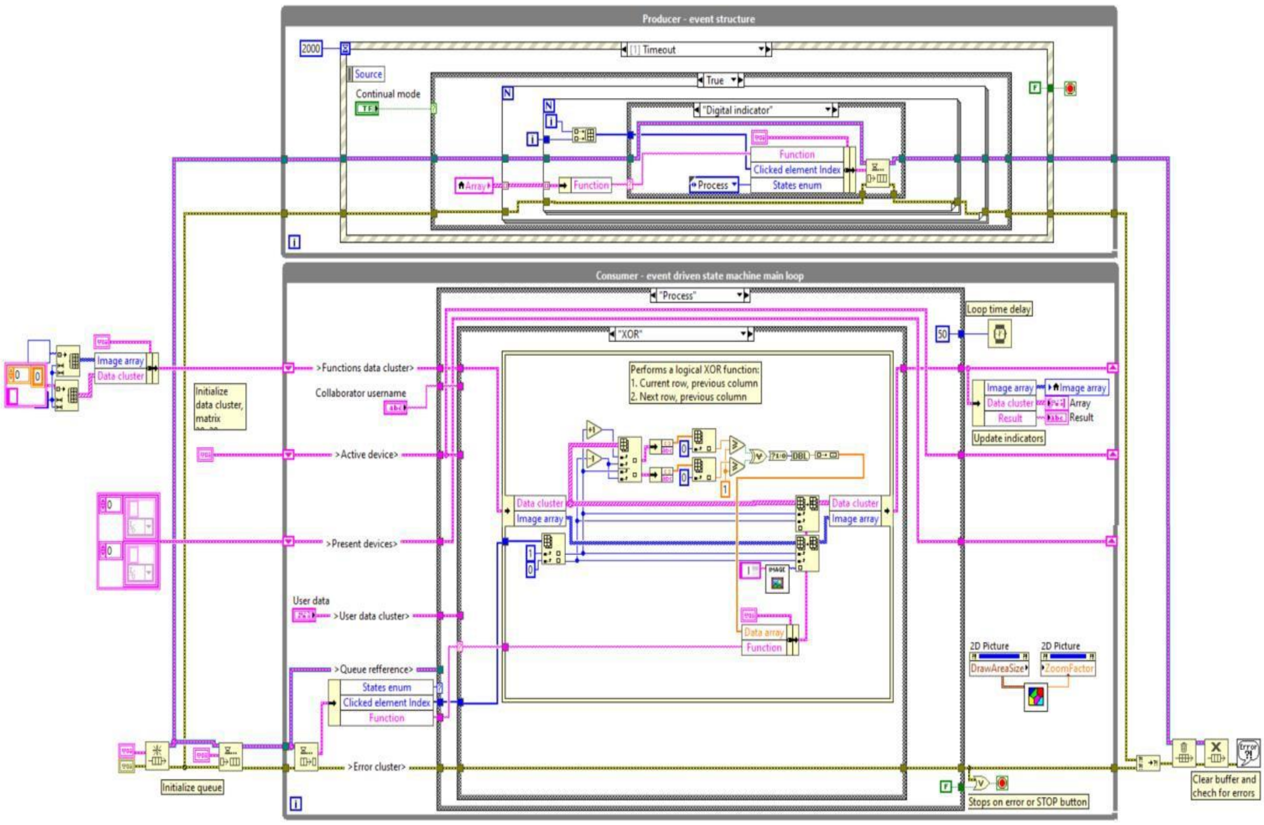

Fig. 3. Block diagram of the LabVIEW-based CORELA remote virtual laboratory

That means that if more than one event occurs in a short period of time, the program will buffer all of them in the queue so no information will be lost. The consumer loop processes the messages from the queue one by one by using the first-in-first-out (FIFO) principle. Each message contains information about the nature of the event and define the state-transition diagram for the state-machine. Later, the state machine executes the programming sequence determined by the message from the producer loop and updates the experiment development space and/or the front panel controls and indicators. Example of a simple exercise in the experiment development space of the RVL platform is given in Figure 4.

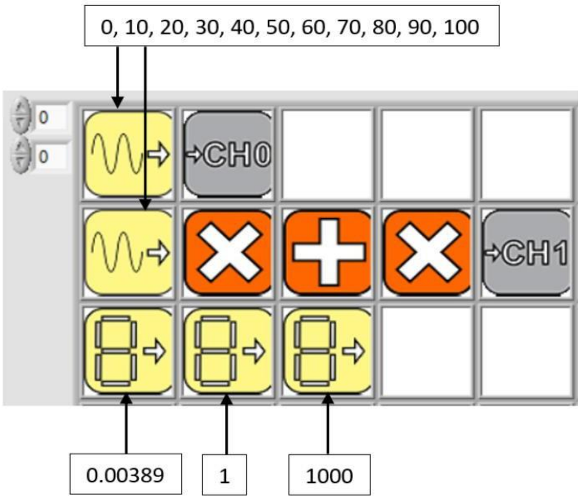

Fig. 4. Realized experiment in the RVL platform, an examination of the transfer function of resistive temperature detector (RTD)

The task of the experiment given in Figure 4 is to simulate the RTD transfer function by using the CORELA RVL platform and compare them with the theoretical transfer function. The coefficients for particular RTD sensor are taken from the manufacturer datasheets. These coefficients are implemented as a platform constants defined by the user as soon as he/she clicks on particular field of the development space. Later the user defines the RTD transfer function by implementation of a given mathematical approximation function, as shown in Figure 4. Finally the obtained data points are recorded into particular database channel from the CORELA RVL platform. According to the developed block diagram in Figure 4, the Channel 0 contains the input temperature covering entire measurement range from 0 °C to 100 °C with a step of 10 °C, whereas the Channel 1 of CORELA database contains the resistance of the RTD for the predefined temperature set points. The transfer function can be further graphically presented by using the “graph” functions from the function list.

Besides using the development user-space, it is possible to develop a dedicated custom-made laboratory experiments by using the CORELA RVL platform. One such experiment related to the verification of the First Kirchhoff law is given in Figure 5. The exercise consists of a simple electrical circuits including a voltage source and three resistors. The resistors are wired in such a way that they form a single junction “J”. The current flowing through each resistor is measured with ampere meter. The task is to simulate, and then practically verify, the First Kirchhoff low for the junction J.

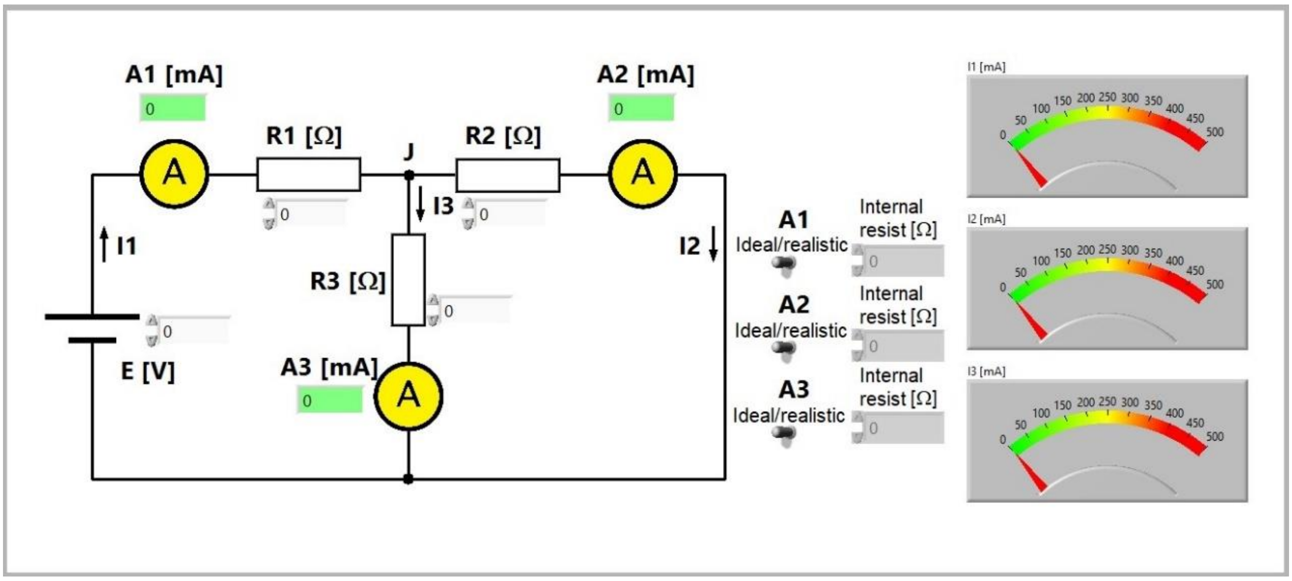

Fig. 5. Experiment related to the First Kirchhoff law

The simulation of the circuit is realized by defining all electrical circuit parameters: the voltage of the voltage source, resistor resistances, as well as the internal resistance of the ampere meters. Note that, if an ideal ampere meter is used, then the simulation assumes zero internal resistance. Afterwards the user can directly read the measured electrical current through each resistor and confirm the results obtained by theoretical calculation. Nevertheless, the obtained theoretical and simulation results can be also confirmed by a realistic measurements. Namely, assuming that the electrical circuit given in Figure 5 is physically realized, the electrical current through each resistor can be measured by a NI-DAQ hardware supported by the CORELA platform. Each current can be measured simply by wiring the DAQ board in series with particular resistor and clicking on the appropriate ampere meter symbol of the virtual instrument front panel.

4. EVALUATION OF CORELA PLATFORM

The quality control of the CORELA remote virtual laboratory with collaborative learning was performed by forming international groups of students from the VET participating institutions in the project (SETU of GS Mihajlo Pupin – North Macedonia, TU Rugjer Boškovič – Croatia, and SC Kranj-Slovenia). A total of 33 students from modules for electrical technicians took part in the realization of laboratory exercises by using the RVL platform. Afterwards, the students answered a questionnaire for evaluation of their user experience. The purpose of the questionnaire is to evaluate the students experience in terms of several criteria: collaborative learning, exploitation of the CORELA RVL platform, and evaluation of student satisfaction in conducting remote laboratory experiments.

In total eight questions were related to the concept of collaborative learning in a form of multiple-choice answers, but also keeping the possibility to add additional explanation. The distribution of used languages in the process of collaborative learning is given in Figure 6.

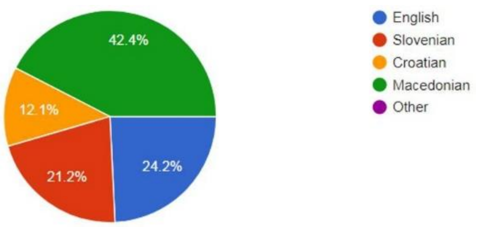

Fig. 6. Used languages in performing collaborative learning by using the CORELA RVL platform

From the results given in Figure 6 it can be seen that all native languages from the VET participating institution and international English language were used for communication between the students. One of the most important conclusions regarding this aspect of the survey is that students are eager to perform collaborative learning in international groups.

More than 94% of students didn't experience any language, religious, cultural, social or any other barriers while working with students from another countries. Moreover, more than 90% of the students think that collaborative learning makes learning easier, and that it makes students who work together achieve more than when they work alone. Such an opinion is of a very high importance because it unites the technical content with the collaborative international experience, which is one of the main goals of the CORELA RVL platform. Regarding the mental process of thinking, students think that collaborative learning increase their motivation to learn and make them express their opinions, argue, debate, negotiate, and increase their knowledge.

Most of the students (74%) found CORELA platform good or very good, whereas the other 26% of them have a satisfactory opinion. Such evaluation suggests that the CORELA platform fulfills the criteria from the user's point of view, but also needs certain improvements. This can also be confirmed by the quantitative evaluation where the CORELA RVL platform got 4.06 out of 5 score points. During the laboratory experiments, nearly 50% of the students have used a dedicated hardware (NI MyDAQ or Arduino, supported by the platform). These students didn't report any hardware-related problems, but however they suggest that it can be improved to be more intuitive. The overall evaluation of the areas where the CORELA RVL platform could be improved is given in Figure 7.

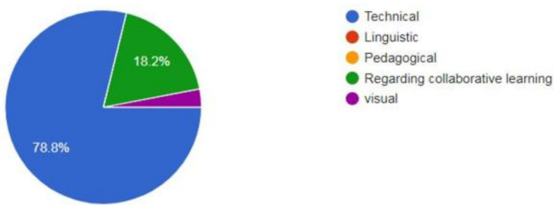

Fig. 7. Areas of improvement for the CORELA RVL platform

From the results given in Figure 7 it is clear that the CORELA RVL platform can, and should, be improved. According to the performed survey, the most improvements should be focused to the technical content, the visual aspect of the program, and the process of building circuit diagrams. Moreover, students suggest that the CORELA moodle platform should also consider using additional tools and techniques for collaborative learning.

5. CONCLUSION

CORELA remote virtual laboratory with integrated collaborative learning introduces innovative, integrated remote virtual laboratory designed to be used by the vocational education centers. The platform proposed in this paper is a step towards diversification and modernization of the teaching methodology in VET.

The paper summarizes the CORELA RVL platform architecture and gives an overview of the process of virtual instrument design. It has been shown that the applied virtual instrument architecture is suitable for implementation of the RVL platform and guaranties lossless information.

The evaluation of the CORELA RVL platform was performed by the VET education centers by forming an international group of students. The conducted survey showed that the students are strongly supporting the collaborative learning aspects implemented in the platform, and find them very inspiring and useful. The user experience of using the RVL platform is well evaluated but possible areas of improvements have also been identified. It has been suggested that the virtual platform can be improved regarding the technical content, application interaction, and incorporation of more diverse tools for collaborative learning.

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