7,379 words

ABSTRACT
In this work, ubiquitous and blended learning focused on biofuel characterization, through three virtual laboratories, named "Determination of biodiesel heating value by automatic calorimeter", "Determination of biodiesel density by densimeter" and "Determination of biodiesel kinematic viscosity by Canon-Fenske viscometer", all integrated in a virtual platform, has been proposed. The idea was to approach environmental issues and sustainability needs to engineering students through biomass valorization or biorefinery development, avoiding or supporting costly lab equipment. Besides, same platform contents have been developed as web application and included in a Facebook social network group, named "BiomasaGen", which can be directly, automatically and ubiquitously accessed. Finally, verification, validation and evaluation of results from the developed three virtual laboratories and web app based on social network have been carried out, assisted by Context, Input, Process and Products method. The idea was to evaluate the inclusion of social networks, comparing the effectiveness of combining social networks and virtual laboratories as a new teaching methodology. As a result of this study, it was found that students appreciated both, developed virtual labs and network web app. Their decision was based on the accessibility of information, feedback during process, useful virtual training experiments and video tutorials, as well as theoretical concepts explained during virtual learning process. Social networks are used for almost all students; for this reason, they represent a powerful tool to improve communication between teachers and students, in this virtual learning context. The social network-based web app helped students to easily access virtual laboratories from any location, which was also very useful when University servers were not accessible or unavailable. Moreover, it has been demonstrated that ubiquitous and blended learning combined with experimental laboratory increases the probability of successful scores in final exams of Master subject (p-value 0.0183). Finally, students prefer social networks as a channel for exchanging information rather than common channels, i.e. e-mails. It may be concluded that the proposed combination of methodologies may significantly promote integration of subjects related to new sources of bioenergy (biodiesel and biorefineries) in postgraduate education. This methodology strongly approaches environmental and sustainability issues to education institutions.

Keywords: Facebook, e-learning, biomass, biofuel property, Learning Virtual Environment

1. INTRODUCTION

Nowadays, higher educational system includes Information and Communication Technologies (ICT) in the learning process (Klimova et al., 2016; Torres et al., 2016; Vidaceck-Hains et al., 2016). This fact has led to the evolution of new research pathways applied to technological development, resulting in the production of a huge variety of interactive and didactic tools available from different electronic devices (computer, mobile phone, tablet, etc.) (Castillo-Manzano et al., 2017; Martinez Jimenez, P. et al., 2010; Olufadi, 2015). Developed technological applications and tools have been incorporated into different educational activities, among them, laboratory training stands out (Cambronero-López et al., 2017) aiming to improve both performance of educational process (Ramírez-Romero and Rivera-Rodríguez, 2017) and capacity of student self-learning (Roy et al., 2015). In this sense, it also facilitates student self-evaluation (Hulsman and van der Vloodt, 2015) besides evaluation of teaching-learning process of both teacher and student (Sapia et al., 2016).

Virtual Laboratories (VL) and Learning Virtual Environments (LVE), as integrated parts of blended learning (b-learning) Interactive Virtual Platforms (IVP), support face-to-face formation in virtual rooms, which is characterized by the flexibility and interactivity of the process (Olympiou and Zacharia, 2012). B-learning, also named hybrid and mixed-mode learning, is an educational approach that blends complementary manifold delivery media while promoting learning (Olelewe and Agomuo, 2016) in the field of sustainability (Rose et al., 2015). These ICT resources are focused on collaborative learning, as they are based on communicative and interactive tools, i.e. chat, e-mail, discussion forum, instantaneous messenger services and weblogs (Venville et al., 2017). Numerous studies corroborate the usefulness of VL as didactic tool (Daineko et al., 2017; Olympiou and Zacharia, 2012; Redel-Macías et al., 2015) or as instrument for research or industry decision making (Silva et al., 2016). These laboratories promote acquisition of skills when no access to experimental laboratories is granted (i.e. developing countries or mobility difficulties), besides the potential use as supporting tool to experimental laboratories.

In a previous research, a virtual laboratory focused on the production of biodiesel, which may be accessed through a website, was developed (Redel-Macías et al., 2016). This web application was tested with students of the Master of “Distributed renewable energies” (MECES 3 -EQF7) of the University of Cordoba, Spain, achieving very good results. However, the application was created with Flash Programming language, which only allows to be used as hosted web application on personal computers (with operating system Windows or MacOSX). Moreover, Flash is expected to disappear in the coming years, being replaced by languages like HTML5.

Besides, the increasing use of social networks (SN) sites, i.e. Facebook, Twitter, Instagram or WhatsApp, constitutes an undeniable reality. In fact, these networks are the most common way of sociocultural interaction for the youth (Watson et al., 2015). Moreover, audio-visual media, i.e. videos and photographs, show higher impact over users than written text, which means that they are preferred as propagation media of ideas in SN (Ghali et al., 2016; Pittman and Reich, 2016). Young people are main users, sometimes showing an addictive behavior, in many cases accessing daily SN sites and even with high daily frequency (Rodgers and Chabrol, 2009). As a result, SN have a great influence over youth habits and life style (Hayes et al., 2015).

Based on this influence, many authors have proposed new b- and ubiquitous learning (u-learning) educational methods based on SN sites (de Kraker et al., 2013; Dlouhá et al., 2013; Lorenzo-Romero and Buendía-Navarro, 2016) standing out the importance in education due to communication fluency between teachers and students (Celik et al., 2015). u-learning is usually associated to mobile learning (m-learning), as it allows accessing the platform independently of time and place. The easy accessibility to educational contents from ubiquitous devices (smart mobile phones, contactless smart cards, handheld terminals, sensor network nodes) allows individual learning activities embedded in daily life and enables anyone to learn, anyplace, anytime. Moreover, SN sites allow communication with experts in specific subjects and students from different places; besides, they ease accessibility of information to students to complete diary tasks in a self-didactic and efficient way, increasing educational community feeling (Arteaga Sánchez et al., 2014; Van Waes et al., 2016; Cincera et al., 2018). Previous works include the use of SN sites as learning tool for medical and chemistry subjects (Ainin et al., 2015; Al-Rahmi et al., 2018). In addition, these networks might incorporate multimedia tools, i.e. videos, web links, tutorials and animations, which

allow building private spaces for lecturing (Konstantinidis et al., 2013). As previously mentioned, these networks facilitate student self-learning, making possible to teachers to follow up the learning process, helping them to improve the weaknesses of the process.
However, the feasibility of SN as learning tool in the classroom needs some grade of control and responsibility practiced by both teachers and students. Undoubtedly, SN sites constitute a magnificent educational and learning tool, besides being a space where information and experience may be exchanged. As a result, SN used in addition to learning virtual platforms help to increase effectiveness of the teaching-learning process (So, 2016). In this sense, few studies have studied the influence of SN combined with VL as u-learning. Furthermore, in the field of biomass, only our previous work (Redel-Macías et al., 2016) provided a VL with the purpose of improving the learning process of postgraduate students.
For the previous reasons, the aim of this research is the development of three VL for biodiesel characterization, as a complementary tool to experimental laboratory, namely "Determination of biodiesel heating value by automatic calorimeter", "Determination of biodiesel density by densimeter" and "Determination of biodiesel kinematic viscosity by Canon-Fenske viscometer". All of them are integrated in a virtual platform, made by authors, focused on the study of biodiesel and that can be accessed through the following link: <http://www.uco.es/docencia/grupos/laboratoriovirtualceia3/es/laboratorios-virtuales>. Additionally, implications of a VL mobile version development are also analyzed.
Complementary to the previous objective, inclusion of SN sites in the learning platform, combined with VL as new teaching methodology, has also been studied. In this sense, to improve accessibility and information dissemination, a Facebook group about biomass called BiomasaGen, which may be accessed through the link <https://www.facebook.com/BiomasaGen-602859903242579/>, was created. In our previous work (Redel-Macías et al., 2016), inclusion of SN sites in the learning platform or use of mobile app were not considered. Moreover, as previously mentioned, use of Flash limits accessibility of students to the learning process. For this reason, the platform has been improved, allowing u-learning and including three VL.
Another objective of this work is to evaluate the three proposed VL through verification and validation, focusing on Context, Input, Process and Product (CIPP) method (Stufflebeam, 2003), including expert, user and student point of views, satisfaction degree and effectiveness of tools in the educational process. To the best of our knowledge, studies using CIPP method to evaluate VL and SN are needed. Moreover, there is a lack of published research about the implementation of LV based on biodiesel characterization in SN.
Satisfaction degree analyses, including software and net where it is located, besides the influence over teaching-learning process, will be carried out at the end of the process, with students of subject "Biomass for generation of energy", within the Master of "Distributed renewable energies" (University of Cordoba, Spain). To achieve these goals, the proposed study has been divided into four phases, namely development of three VL, development of SN site, evaluation of VL (using CIPP method) as teaching tool and combination of both SN and VL as new learning methodology.

2. EXPERIMENTAL DESCRIPTION, MATERIALS AND METHODS

2.1. Development of virtual laboratories for biodiesel characterization

Three VL, which reproduce faithfully determination of some biodiesel properties in a chemical laboratory, have been developed (Figure 1). These VL are named *"Determination of biodiesel heating value by automatic calorimeter", "Determination of* *biodiesel density by densimeter"* and *"Determination of biodiesel kinematic viscosity by viscometer Canon-Fenske"*.

Biodiesel is considered among the most important products derived from biomass, as it may be used to fuel diesel engines. Biodiesel quality control is essential to ease its acceptance by both consumers and vehicle manufacturers (Pinzi et al., 2009). Quality control consists in the analysis of the most relevant physico-chemical properties, which includes heating value, density and kinematic viscosity.

1. *Determination of biodiesel heating value by means of C2000 IKA automatic calorimeter*

By this training, higher heating value (HHV) and lower heating value (LHV) of biodiesel and fossil fuels are determined. These parameters indicate released energy when a fuel undergoes complete combustion (HHV) and includes water heat of vaporization, whereas it is excluded in LHV calculation. As an example of its implications, biodiesel depicts a lower value compared to that of diesel fuel, thus needing to increase fuel consumption to provide same engine power (Dorado et al, 2003).

It is followed by further analysis considering standards. To carry out this training, bomb calorimeters help to define the heat released during the complete combustion of the mass unity of biodiesel. A fuel sample, previously weighted, is placed inside a disintegration container in the calorimeter, with oxygen excess. Then, an explosion takes place, allowing to measure the increase of temperature.

2. *Determination of biodiesel density by means of a densimeter*

Proposed biodiesel training follows standard EN ISO 3675 and is prepared to be used with refined sunflower oil and diesel fuel by the procedure of densimeter; results are compared to those of standard. Density is an important fuel property, that directly affects engine performance characteristics, such as cetane number and heating value. Moreover, diesel fuel injection system estimates fuel volume. Consequently, variations in fuel density will affect engine output power due to variations of fuel mass injected (Alptekin and Canakci, 2008).

3. *Determination of biodiesel kinematic viscosity by means of a viscometer Cannon-Fenske*

This training is focused on the determination of kinematic viscosity of both biodiesel and recycled waste oil samples at different temperatures, to compare them with that of diesel fuel under same temperature values. Canon-Fenske viscometers will be used to follow standard ISO 3104. Kinematic viscosity is an important fuel property, as it directly influences injection process, liquid atomization and spray formation (Lee et al., 2005).

2.2. Design of BiomasaGen group as part of social network

The three VL about characterization of biodiesel are located in a website called "Virtual Biorefineries" implemented by authors (University of Cordoba, Spain) in collaboration with the University of Huelva and Cadiz (Spain), Birmingham and Manchester (UK) and Agricultural University of Athens (Greece). First version of this webpage, out of two, was implemented using the open-source database management system MySQL and Apache HTTP server (see Figure 1 and visit the web link: <http://www.uco.es/docencia/grupos/laboratoriovirtualceia3/es/>). Animations and simulations were designed using ActionScript programming language under Adobe Flash 8 environment, to bring better definition to 3D graphics. This version is accessible from any web browser. However, since nowadays Adobe Flash cannot run on other operating systems, such as Android or iOS, it prevents their use in tablets and mobile phones. Moreover, Flash is expected to disappear in 2018. To overcome the disadvantage about accessibility, while linking VL with highly visited SN, i.e. Facebook, design software Genial.ly was used. It is based on HTML5 programming language, thus providing a fresh and more accessible version (see Figure 2 and visit the weblink: <https://www.genial.ly/58f76b27ba1aa60a6437807e/biomasa>). We also built a working group about biomass in Facebook and linked VL to it (<https://www.facebook.com/BiomasaGen-602859903242579/>). Each virtual laboratory contains mentioned biodiesel characterization experiments, explained step by step, including animations, thus reproducing real process.

VL must include necessary functions to simulate real process, in the most realistic way. In proposed VL of biodiesel characterization, development of experiments is based on the use of 3D animations, either in Flash environment (Windows/MacOSX version) or Genial.ly (version for mobile devices and accessible through every operating system). Animations allow to illustrate in detail procedures, i.e. sample manipulation or safety protocols.

Each VL presents a menu located in the upper side of the screen, showing the following options: “Start”, “Move through training”, “Training tutorial”, “Help”, “Links” and “Contact”. Moreover, each of the previous items offers several submenus, for example:

- Option *Move through training* includes the complete description of the laboratory, showing every component, as well as self-evaluation questionnaires and surveys of satisfaction.
- Option *Training tutorial* displays the next submenu: *training guide*, that may be downloaded in pdf format, *video tutorials* about the procedure of the complete training, which is linked to youtube (i.e., <https://youtu.be/3YGrFd-gUxc>; <https://youtu.be/x7UAhoUB_64>; <*https://youtu.be/nYKMw7kB_fM*>), *flow chart of the experiment* (Figure 3) and *photo gallery*. Video tutorials facilitate students the comprehension of proposed processes. They have been videotaped in the laboratory of research group BIOSAHE TEP-169, Department of Physical Chemistry and Applied Thermodynamics of the University of Cordoba (Spain) and correspond to real training experiments of biodiesel. Subsequently, videos have been edited and produced with the help of *Pinnacle Video Spin* software.
- In option *Help*, there is a menu that includes the User Guide and Help Forum.

In the main page of the website, a tridimensional laboratory is introduced to the user by virtual assistant “Azahara”, who indicates by texts the actions to do, step by step. The process reproduces faithfully laboratory experimental work, thus allowing students to work virtually and advising them. Finally, students can self-evaluate achieved knowledge.

2.3. CIPP method to evaluate VL

To evaluate the three proposed VL using CIPP method, a survey has been carried out. To accomplish this task, several questionnaires based on a recent work have been used, following the methodology proposed by Stufflebeam (2003). According to CIPP method, evaluation should consider four issues, namely context, input, process and product. In this work, they have been grouped in three correlated features, which are context, design and evaluation of VL and implementation process of VL.

Evaluation of context is intended to identify the features of environment where the three VL are used, which in this case corresponds to the subject “Biomass for the generation of energy”. Results on ICT integration, in terms of possible limitations of resources (materials, schedules, training, etc.) and willingness of teachers to use these VL as pedagogical resource complementary to experimental laboratory training have been analyzed.

2.3.1. VL design, evaluation and process implementation

Evaluation of educational tool consists in verification of whether the designed application meets the predefined objectives from a technical and educational point of view. The design of three biodiesel VL was evaluated by a group of teaching experts, according to the questionnaire developed in a previous work (Peinazo-Morales, 2012). Once designed and previously to its implementation in the classroom, it was submitted to a second set of experts for a second evaluation. They offered their point of view regarding technical and pedagogical properties of both design and use of three VL.

An evaluation form composed by four sections has been used: first one corresponds to assessment of technical and functional aspects of the program; second section is focused on pedagogical aspects; third section collects expert observations and, finally, last section covers the request of overall evaluation of the program (low, medium, high or excellent).

Process evaluation has been carried out to know how designed VL performs in a real context, including individual opinions, formal and material elements that could influence the application of the program.

The evaluation of the process has been performed for the course where experimental training of the subject "Biomass for generation of energy" was programmed. Four sources of information were used:

1. Structured observation in the classroom, as a qualitative research technique, using a record sheet as the instrument of observation by the teacher of the subject. Aspects related to the context in which the application of VL has been developed (classroom conditions, success of working groups, length of each activity, etc.), including aspects related to student attitude to VL (autonomy, concentration, motivation, etc.) and aspects related to the role played by teacher in the development of the activity (explanations, interventions, attention to students, etc.) are taken into consideration.
2. Information provided by software.
3. Student evaluation is collected in a questionnaire (Table 1). It contains two types of issues: a) descriptive questions that are focused on how the experience has been carried out and b) other group of questions with the objective of understanding the opinion of students and their interest and motivation for this type of laboratory activities supported by VL.
4. Teacher evaluation is provided by an interview, following a qualitative research technique with open response.

2.4. Student assessment of the use of social networks

Among young people, SN sites have become an instrument to connect and spread news that can influence trends in their behavioral model. There are numerous studies stating the importance of SN as ICT tools in education (Celik et al., 2015; Lorenzo-Romero and Buendía-Navarro, 2016). For this reason, as this research is focused on the influence of ICT on education, mainly virtual environments, introduction and use of SN in the learning system have been promoted and studied.

To assess student opinion about the use of these networks in education, an anonymous questionnaire was first designed and later answered by students (Table 1), through a Moodle questionnaire. Most responses were in favor of the use of SN, both as instruments of news dissemination and as teaching tool. Final evaluation, after implementation of the Facebook group, has been made using an additional questionnaire.

2.5. Teaching experience and methodology

As previously mentioned, three virtual laboratories have been used as a didactic tool in the subject "Biomass for generation of energy" (6 ECTS credits, corresponding to 100 h; 40 h correspond to master and training classes and 60 h to personal autonomous work. Lectures are scheduled from Friday to Saturday, so each subject is worked with students during two consecutive weeks. Timetable aims to promote compatibility of studies and jobs.

Training experiments have been carried out every course, since the beginning of the Master in the course 2012-2013. In the current course, 2016-2017, opinion of students about the use of SN as a complementary didactic tool of information has been gathered and evaluated, supervising both training and complete subject.

Methodology is similar to that of other subjects where VL are used and evaluated (Jara et al., 2009). Four training sessions, of two hours each, followed theoretical classes, scheduled for consecutive weeks. In the first session, students start familiarizing with laboratory equipment. The objectives of this first session are: first, to gain knowledge about the laboratory instruments as well as methodology of work and, second, to be informed about safety protocols to be followed during experiments. The second session is focused on the production of biodiesel by transesterification and its subsequent characterization. In the third and the fourth sessions, students carry out the characterization of this product. The objective is to analyze different physico-chemical properties of biodiesel.

To carry out the training, students are divided into small working groups. Once the procedure is known with the help of VL, students carry out real laboratory training, supervised by teachers and with the aid of VL included in both the webpage of the University and those developed in SN (links already mentioned) (Figure 4). In the academic year 2015-2016, training classes were only performed virtually, even though students visited the experimental laboratory to identify instrumentation.

At the end of the training classes, students were given a questionnaire to evaluate their degree of satisfaction about the use of VL included in both the University webpages and those developed in SN. Survey items include five main topics: (I1) help resources, (I2) ease-of-use and interface environment assessment, (I3) motivation and encouragement, (I4) learning promotion and (I5) adaptation of theory content. The purpose of this questionnaire was to evaluate the usefulness of the developed software, since it is known that student satisfaction and motivation are key success factors (Verdú et al., 2012). It also helps to further improve the platform.

3. RESULTS AND DISCUSSION

3.1. Evaluation of comprehensive VL using CIPP method

Results have been analyzed for: 1) comprehensive evaluation of both the platform and the VL using CIPP method; 2) evaluation of students about the inclusion of SN as learning tool and 3) results of experimental teaching using different multimedia tools and their impact over the learning process.

To perform the evaluation of ICT by CIPP method, firstly, before these tools are used, context, design and implementation methods are analyzed by experts, and later by teachers involved in the experience.

Figure 5 shows the technical assessment of both VL and platform carried out by expert users. Results of mean scores achieved for each technical - functional item (I) and pedagogical item (P) are shown in Table 2. Moreover, standard deviation and variance for each value have been calculated. There are four possible responses: low (1), mean (2), high (3) and excellent (4), for each item described in Table 2, grouped in 11 technical – functional items and 8 pedagogical items.

As may be seen from Figure 5, global score is around 3.8 (out of 5) ± 0.2. The best evaluated items (3.8 or higher) are information to user (I2) with a score of 3.8 ± 0.2, quantity and quality of multimedia content (I4) with a score of 4 ± 0 (excellent) and interactivity (I5), 3.8 ± 0.2. On the contrary, the worst evaluated and dispersed items (2.5 or lower) are access to scores (I8) with a value of 2.4 ± 0.3, and access to other resources (I9) with a mean of 2.2 ± 1.2. Remaining items show scores between 2.8 and 3.5, being considered as good marks. As the worst evaluated items are not influencing methodology implementation, results may be considered positive.

Study of teacher assessment of context (Table 2) has been carried out by means of a questionnaire that includes availability of computer rooms, number of computers and software, teacher skills (including ICT), etc. Results show that 90% teachers believe there are enough ICT resources, including laboratories, software and computers with access to internet. It is important to emphasize that a regular teacher holds a teaching experience from 5 to 15 years and uses ICT weekly in undergraduate courses and, fortnightly, in postgraduate courses. Considering other questions, it may be inferred that regular teachers show high interest in procedural content, mainly basic and technical skills, being an advanced level user of ICT.

Another technical item studied is the teacher assessment about the implemented website and VL. This study has been carried out using same questionnaire that was used for experts (Table 3). Results are similar to those provided by experts. Some positive technical items are interface, clarity, similarity with experimental laboratory and interactivity. Website maintenance (where VL are hosted) and easiness of registration process in the website have been suggested.

As positive pedagogical items, quality of information, feedback, video tutorials, theoretical contents and completeness of instruction sheets could be highlighted. Main advantages of VL *vs* experimental laboratory are the possibility of repeating training as often as needed, saving costly resources, besides the possibility of working with large groups. However, the main advantage for teachers is the required low level of abstraction and the need of a low initial effort by students to understand the virtual platform. In this sense, a previous study based on VL for undergraduate students highlighted usability, content and effectiveness as key points for pedagogical methodologies (Manzorro et al., 2015). Additionally, the use of VL has been proposed as substitute of experimental laboratory when it is not accessible (Norin et al., 2018; Zhu et al., 2018). Although, combination of experimental and virtual laboratories are mostly recommended (Berre et al., 2018; Norin et al., 2018; Zhu et al., 2018).

Furthermore, process evaluation of VL implementation in the classroom has been carried out by means of a registration form (Table 4). The following items have been highlighted: 1) working condition of computers and internet connection; 2) working condition of VL and potential problems to register in the website; 3) accessibility of program contents and easiness to use by students with little teacher assistance and high concentration and motivation, and 4) good working environment and student attention. In this sense, Table 5 shows main results collected by teachers. As may be inferred, when VL are used, combined or not with experimental laboratory, no deficient scores were given by students. Highest score was achieved with the use of VL combined with experimental laboratory, while lowest score was achieved with the use of real laboratory. These results are statistically validated (section 3.3).

3.2. Initial assessment of students regarding the use of social networks as a learning tool

The starting study gathering student opinion about SN sites and the potential use as learning tool in master’s degree courses have been carried out by means of a questionnaire, as shown in Table 4. The questionnaire has been answered by 46

voluntary and anonymous students. Table 4 shows the frequency of each item responses.
Results show that 97.83% of students use SN as way of communication, being Facebook the most used (86.95%) followed by Twitter (45.65%) and Instagram (43.47%). These results disagree with previous works focused on younger population, to whom the most used SN is Instagram (Phua et al., 2017). WhatsApp is less used to share news and multimedia (2.17%), although other studies has shown that WhatsApp is mostly used as mobile instant messaging (>90%) (Church and de Oliveira, 2013). Contrary to other authors (Phua et al., 2017), remaining students (19.6%) preferred diverse and uncommonly used SN sites, i.e. Snapchat.
Most students use from one to three SN sites (30.44%, 21.73% and 34.79%, respectively). Only a small percentage do not use any SN (2.17%) and few students use more than three (10.87%). Also, results showed that 80.4% of students used daily SN, to be in contact with friends and family (30.4%) and to gather and share information with other people (43.5 %). On the contrary, only 19.6% of students use it to chat or show information, while very few use SN to publish photographs or comments from other users. These results are in agreement with those from Phua et al. (2017).
Moreover, in terms of importance of SN, answers follow a normal or Gaussian distribution. In addition, 71.7% students consider that SN sites influence relationships. About the possibility of increasing the number of friends, most results were found from 50 to 200 and 200 to 300, that is, most considered intervals show same results (around 21%) excepting when the number of friends exceeds 500, that is halved. Also, 82.6% population knows above 50% of their followers. About the frequency of connection, in case they are checking SN daily, 45.7% check it for more than two hours, while it is checked hourly by 26.1% and every two hours by 15.2 %.

Finally, regarding the potential use of SN in the teaching process, most students agree it may be helpful (47.8%) while 30.4% hesitate. 52.2% students find that the use of SN for teaching is a good idea, while 17.4% hesitate and 30.4% disagree. These results agree with previous works about potential benefits of SN (Sousa-Vieira et al., 2017; Wu et al., 2016). Though, some works have shown that student interest is focused on the development of a community (Al-Rahmi et al., 2018; Phua et al., 2017) and the active interaction of the faculty members of the university (Doğan et al., 2018). Additionally, Facebook was pointed out as preferred SN site to provide a sense of community and interactional relationship (Arteaga Sánchez et al., 2014; Norin et al., 2018; Phua et al., 2017), though Twitter and Whatsapp might also meet this purpose (Vézina, 2014).

Based on these results, the working group "BiomasaGen" in Facebook and a web app in this network called "BiomasaGen" have been developed. The network includes ICT tools for VL, multimedia, groups, news, thus promoting collaborative work, regardless distance and time. Lastly, it is important to remark that SN and working group in SN sites are excellent alternatives when connection to university servers cannot be accessed or fails for any reason (VPN stops working when out of the campus, server is down, etc.). This technology, undoubtedly, will help engineers to achieve skills in biomass valorization and biorefinery development, in terms of biodiesel characterization. These findings are collaborating towards education for sustainable development, thus helping society becoming more sustainable and environmentally friendly.

3.3. Statistical study about teaching experience

Data about student training results and final evaluation scores on the subject "Biomass for energy generation" have been collected for five years, as depicted in Table 5. Moreover, main score and standard deviation are shown. In this table, higher frequencies correspond to good and very good scores, with deficient level showing no hits. During these academic years, teachers carried out training experiments using different modes:

a) Combining theoretical lectures with laboratory training (academic year 2012-13).

b) Carrying out VL training before doing any training experiments in the laboratory.

c) In the academic course 2015-16, due to logistic problems, training experiments could only be done virtually.

d) In the course 2016-17, only virtual training combined with the use of SN sites as an assistant tool and e-learning have been used.

To analyze whether the use of VL has any impact on final evaluation results of master-degree students, an ANOVA study was carried out (Table 6). Correlation between final evaluation scores (FE) and the use of VL was significantly above 98% (P-value of 0.0183). It corroborates that the use of VL improves understanding and learning experience. This result is reliable with previous reports on VL efficiency, improving practical skills and keeping technique knowledge for longer periods of time (Redel-Macías et al., 2016; Norin et al., 2018; Phua et al., 2017).

Moreover, a lineal model of correlation between variables has been carried out. As depicted in Table 7, lineal correlation between range of scores achieved in the final evaluation and the use of VL, for every range of final evaluation score, show a significant correlation (more than 92% of confidence level). Considering the value of polynomial regression (Pr) of t-student test, it is possible to appreciate that this correlation highly improves for 5-5.99 and 8-8.99 scores. In case of scores in the range of 5-5.99 of final evaluation of the subject, the use of VL depicts a negative influence, at 99% confidence level; whereas for good or very good evaluation (scores between 8 and 8.99) the use of VL shows a positive effect, at a 99% of confidence level. These findings clearly validate results showed in Table 5, which means that the use of biodiesel characterization-based VL increases the possibility to achieve good or very good marks in final exams, while decreases the possibility to achieve acceptable or low final marks in the master subject. In this sense, previous studies established this positive influence in new engineering degrees for undergraduate students (Norin et al., 2018). Though, its impact has never been previously studied in master degree engineering students.

4. CONCLUSIONS

Three virtual laboratories (VL) focused on biodiesel characterization have been developed. They have been integrated in a previous virtual platform for the subject “Biomass for generation of energy” in the Master of "Distributed renewable energies”. Moreover, a VL web application integrated in a social network group, thus providing a blended and ubiquitous learning (b- and u-learning) has been developed. The importance of the development of these VL is based on the needs of postgraduate students to understand the basis of residual biomass valorization sector, thus helping society being more sustainable. Postgraduate students were supervised and trained within the proposed methodology with successful results. It is important to mention that only few universities have included similar learning techniques for postgraduate students, and almost none have combined VL and social network (SN) sites to improve learning process.

To check the impact over students, Context, Input, Process and Product (CIPP) method has been proposed. Students appreciated VL-based learning, as well as the working group in the SN site, for clarity of information, feedback given during process, completeness of virtual training and video tutorials, as well as theoretical concepts explained during virtual learning process. It has been proved that SN sites are used by almost all master students. For this reason, they represent a powerful tool during the educational process, to improve communication between teachers, students, teachers-students, besides providing a more attractive virtual b-learning and u-learning context. The working group hosted in SN site, besides the web application developed in this work, resulted very useful to students to both facilitate the contact (to solve problems and gather more information) and access to VL, also when students are elsewhere with no access to university server. It has been demonstrated that the use of VL combined with traditional experimental one increases the possibility to improve the final mark in the master subject.

The use of VL located in SN site may combine the efficiency of virtual practices with the ubiquity of social networks to improve both participation and effective learning of postgraduate students.

As a general conclusion, the proposed methodology may significantly promote the integration of subjects related to new sources of bioenergy (biodiesel and biorefineries) in education institutions. The most outstanding benefit of this methodology is that it can be used anywhere, anytime, helping to increase knowledge, collaborative environment and training of future engineers working on biomass valorization and biodiesel industries. This methodology strongly approaches environmental and sustainability issues to education institutions.

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References

Ainin, S., Naqshbandi, M.M., Moghavvemi, S., Jaafar, N.I., 2015. Facebook usage, socialization and academic performance. Computers & Education 83, 64–73. https://doi.org/10.1016/j.compedu.2014.12.018

Alptekin, E., Canakci, M., 2008. Determination of the density and the viscosities of biodiesel–diesel fuel blends. Renewable Energy 33, 2623–2630. https://doi.org/10.1016/j.renene.2008.02.020

Al-Rahmi, W.M., Alias, N., Othman, M.S., Marín, V.I., Tur, G., 2018. A model of factors affecting learning performance through the use of social media in Malaysian higher education. Computers & Education 121, 59–72. https://doi.org/10.1016/j.compedu.2018.02.010

Arteaga Sánchez, R., Cortijo, V., Javed, U., 2014. Students' perceptions of Facebook for academic purposes. Computers & Education 70, 138–149. https://doi.org/10.1016/j.compedu.2013.08.012

Berre, A.J., Huang, S., Murad, H., Alibakhsh, H., 2018. Teaching modelling for requirements engineering and model-driven software development courses. Computer Science Education 28, 42–64. https://doi.org/10.1080/08993408.2018.1479090

Burke, R.D., De Jonge, N., Avola, C., Forte, B., 2017. A virtual engine laboratory for teaching powertrain engineering. Computer Applications in Engineering Education 25, 948–960. https://doi.org/10.1002/cae.21847

Cambronero-López, F., Gómez-Varela, A.I., Bao-Varela, C., 2017. Designing an ultrafast laser virtual laboratory using MATLAB GUIDE. European Journal of Physics 38, 034006.

Castillo-Manzano, J.I., Castro-Nuño, M., López-Valpuesta, L., Sanz-Díaz, M.T., Yñiguez, R., 2017. To take or not to take the laptop or tablet to classes, that is the question. Computers in Human Behavior 68, 326–333. https://doi.org/10.1016/j.chb.2016.11.017

Celik, I., Yurt, E., Sahin, I., 2015. A Model for Understanding Educational Facebook Use. EURASIA Journal of Mathematics, Science & Technology Education 11, 899–907.

Church, K., de Oliveira, R., 2013. What's up with whatsapp?: comparing mobile instant messaging behaviors with traditional SMS, in: Proceedings of the 15th International Conference on Human-Computer Interaction with Mobile Devices and Services - MobileHCI '13. Presented at the the 15th international conference, ACM Press, Munich, Germany, p. 352. https://doi.org/10.1145/2493190.2493225

Cincera, J., Biberhofer, P., Binka, B., Boman, J., Mindt, L., Rieckmann, M., 2018. Designing a sustainability-driven entrepreneurship curriculum as a social learning process: A case study from an international knowledge alliance project. Journal of Cleaner Production 172, 4357–4366. https://doi.org/10.1016/j.jclepro.2017.05.051

Daineko, Y., Dmitriyev, V., Ipalakova, M., 2017. Using virtual laboratories in teaching natural sciences: An example of physics courses in university: USING VIRTUAL LABORATORIES IN TEACHING NATURAL SCIENCES. Computer Applications in Engineering Education 25, 39–47. https://doi.org/10.1002/cae.21777

de Kraker, J., Cörvers, R., Valkering, P., Hermans, M., Rikers, J., 2013. Learning for sustainable regional development: towards learning networks 2.0? Journal of Cleaner Production 49, 114–122. https://doi.org/10.1016/j.jclepro.2012.11.019

Dlouhá, J., Huisingh, D., Barton, A., 2013. Learning networks in higher education: universities in search of making effective regional impacts. Journal of Cleaner Production 49, 5–10. https://doi.org/10.1016/j.jclepro.2013.01.034

Doğan, B., Demir, Ö., Ülkü, E.E., 2018. Applying social networks to engineering

education. Computer Applications in Engineering Education 26, 1782–1791. https://doi.org/10.1002/cae.21975
Dorado, MP; Ballesteros, E; Arnal, JM; Gómez, J; López, FJ, 2003. Exhaust emissions from a Diesel engine fueled with transesterified waste olive oil. Fuel 82(11), 1311-1315
Ghali, M.R., Frayret, J.-M., Robert, J.-M., 2016. Green social networking: concept and potential applications to initiate industrial synergies. Journal of Cleaner Production 115, 23–35. https://doi.org/10.1016/j.jclepro.2015.12.028
Hayes, M., van Stolk-Cooke, K., Muench, F., 2015. Understanding Facebook use and the psychological affects of use across generations. Computers in Human Behavior 49, 507–511. https://doi.org/10.1016/j.chb.2015.03.040
Hulsman, R.L., van der Vloodt, J., 2015. Self-evaluation and peer-feedback of medical students' communication skills using a web-based video annotation system. Exploring content and specificity. Patient Educ Couns 98, 356–363. https://doi.org/10.1016/j.pec.2014.11.007
Jara, C.A., Candelas, F.A., Torres, F., Dormido, S., Esquembre, F., Reinoso, O., 2009. Real-time collaboration of virtual laboratories through the Internet. Computers & Education 52, 126–140. https://doi.org/10.1016/j.compedu.2008.07.007
Klimova, A., Rondeau, E., Andersson, K., Porras, J., Rybin, A., Zaslavsky, A., 2016. An international Master's program in green ICT as a contribution to sustainable development. Journal of Cleaner Production 135, 223–239.
Konstantinidis, S., Fernandez-Luque, L., Bamidis, P., Karlsen, R., 2013. The role of taxonomies in social media and the semantic web for health education. A study of SNOMED CT terms in YouTube health video tags. Methods Inf Med 52, 168–179. https://doi.org/10.3414/ME12-02-0005
Lee, C.S., Park, S.W., Kwon, S.I., 2005. An Experimental Study on the Atomization and Combustion Characteristics of Biodiesel-Blended Fuels. Energy & Fuels 19, 2201–2208. https://doi.org/10.1021/ef050026h
Lorenzo-Romero, C., Buendía-Navarro, M. del M., 2016. Using social web tools in intermediate education. Interciencia: Revista de ciencia y tecnología de América 41, 98–203.
Manzorro, R., Acosta-Rueda, L., Yeste Siguenza, M.P., Hernandez-Saz, J., Oliva, J.M., Rodriguez-Izquierdo, J.M., 2015. Evaluating and Rethinking the Laboratory Practices in Chemistry Degrees, in: GomezChova, L., LopezMartinez, A., CandelTorres, I. (Eds.), Edulearn15: 7th International Conference on Education and New Learning Technologies. Iated-Int Assoc Technology Education a& Development, Valencia, pp. 4392–4399.
Martinez Jimenez, P., Pedros Perez, G., Cubero Atienza, A., Redel Macias, D., Salas Morera, L., Garcia Hernandez, L., 2010. Telematic Training Via a Website of Technicians in Work-related Risk Prevention. Presented at the CSEDU 2010 - Proceedings of the Second International Conference on Computer Supported Education, Valencia.
Norin, V.A., Norina, N.V., Pukharenko, Y.V., 2018. Interactive methods of teaching at Russian engineering universities. Education and Information Technologies 23, 2801–2820. https://doi.org/10.1007/s10639-018-9742-2
Olelewe, C.J., Agomuo, E.E., 2016. Effects of B-learning and F2F learning environments on students' achievement in QBASIC programming. Computers & Education 103, 76–86. https://doi.org/10.1016/j.compedu.2016.09.012
Olufadi, Y., 2015. A configurational approach to the investigation of the multiple paths to success of students through mobile phone use behaviors. Computers & Education 86, 84–104. https://doi.org/10.1016/j.compedu.2015.03.005
Olympiou, G., Zacharia, Z.C., 2012. Blending physical and virtual manipulatives: An

effort to improve students' conceptual understanding through science laboratory experimentation. Science Education 96, 21–47.
Peinazo-Morales, M., 2012. Laboratorio virtual de caracterización de biocombustibles, Trabajos Fin de Master. Universidad de Córdoba 210.
Phua, J., Jin, S.V., Kim, J. (Jay), 2017. Uses and gratifications of social networking sites for bridging and bonding social capital: A comparison of Facebook, Twitter, Instagram, and Snapchat. Computers in Human Behavior 72, 115–122. https://doi.org/10.1016/j.chb.2017.02.041
Pinzi, S., Garcia, I.L., Lopez-Gimenez, F.J., Luque de Castro, M.D., Dorado, G., Dorado, M.P., 2009. The Ideal Vegetable Oil-based Biodiesel Composition: A Review of Social, Economical and Technical Implications. Energy Fuels 23, 2325–2341. https://doi.org/10.1021/ef801098a
Pittman, M., Reich, B., 2016. Social media and loneliness: Why an Instagram picture may be worth more than a thousand Twitter words. Computers in Human Behavior 62, 155–167. https://doi.org/10.1016/j.chb.2016.03.084
Ramírez-Romero, J.M., Rivera-Rodríguez, S.R., 2017. Aplicación del ciclo de vida y el análisis estructurado en el desarrollo de un laboratorio virtual de transformadores monofásicos. Revista Educación en Ingeniería 12, 43. https://doi.org/10.26507/rei.v12n23.732
Redel-Macías, M.D., Cubero-Atienza, A.J., Martínez-Valle, J.M., Pedrós-Pérez, G., Martínez-Jiménez, M. del P., 2015. Noise and Vibration Risk Prevention Virtual Web for Ubiquitous Training. IEEE Transactions on Education 58, 303–308. https://doi.org/10.1109/TE.2015.2415769
Redel-Macías, M.D., Pinzi, S., Martínez-Jiménez, M.P., Dorado, G., Dorado, M.P., 2016. Virtual laboratory on biomass for energy generation. Journal of Cleaner Production 112, 3842–3851. https://doi.org/10.1016/j.jclepro.2015.07.075
Rodgers, R., Chabrol, H., 2009. The impact of exposure to images of ideally thin models on body dissatisfaction in young French and Italian women. Encephale 35, 262–268. https://doi.org/10.1016/j.encep.2008.05.003
Rose, G., Ryan, K., Desha, C., 2015. Implementing a holistic process for embedding sustainability: a case study in first year engineering, Monash University, Australia. Journal of Cleaner Production 106, 229–238. https://doi.org/10.1016/j.jclepro.2015.02.066
Roy, G., Ghosh, D., Mandal, C., 2015. A virtual laboratory for computer organisation and logic design (COLDVL) and its utilisation for MOOCs, in: 2015 IEEE 3rd International Conference on MOOCs, Innovation and Technology in Education (MITE). Presented at the 2015 IEEE 3rd International Conference on MOOCs, Innovation and Technology in Education (MITE), pp. 284–289. https://doi.org/10.1109/MITE.2015.7375331
Sapia, H.M., Garcia, R.E., Olivete, C., Pereira, D.R., Trevisani, K.M., 2016. Teaching-learning firewall configuration using a visual modeling web based tool: The SP2Model and its application to Computer Science course, in: 2016 IEEE Frontiers in Education Conference (FIE). Presented at the 2016 IEEE Frontiers in Education Conference (FIE), pp. 1–8. https://doi.org/10.1109/FIE.2016.7757537
Silva, C.M., Ferreira, A.F., Dias, A.P., Costa, M., 2016. A comparison between microalgae virtual biorefinery arrangements for bio-oil production based on lab-scale results. Journal of Cleaner Production 130, 58–67. https://doi.org/10.1016/j.jclepro.2015.09.053
So, S., 2016. Mobile instant messaging support for teaching and learning in higher education. The Internet and Higher Education 31, 32–42.
Sousa-Vieira, M.E., López-Ardao, J.C., Fernández-Veiga, M., Rodríguez-Pérez, M.,

López-García, C., 2017. Mining relationships in learning-oriented social networks. Computer Applications in Engineering Education 25, 769–784. https://doi.org/10.1002/cae.21835

Stufflebeam, D.L., 2003. The CIPP Model for Evaluation, in: Kellaghan, T., Stufflebeam, D.L. (Eds.), International Handbook of Educational Evaluation, Kluwer International Handbooks of Education. Springer Netherlands, Dordrecht, pp. 31–62. https://doi.org/10.1007/978-94-010-0309-4_4

Torres, A.L., Mota, M.M., Ferreira, H.S., Ferreira, A.F., Darido, S.C., 2016. As Tecnologias da Informação e Comunicação e a Educação Física Escolar: a realidade de professores da rede pública municipal de Fortaleza. ETD - Educação Temática Digital 18, 198–214. https://doi.org/10.20396/etd.v18i1.8640601

Van Waes, S., Moolenaar, N.M., Daly, A.J., Heldens, H.H.P.F., Donche, V., Van Petegem, P., Van den Bossche, P., 2016. The networked instructor: The quality of networks in different stages of professional development. Teaching and Teacher Education 59, 295–308. https://doi.org/10.1016/j.tate.2016.05.022

Venville, A., Cleak, H., Bould, E., 2017. Exploring the Potential of a Collaborative Web-based E-portfolio in Social Work Field Education. Australian Social Work 70, 185–196. https://doi.org/10.1080/0312407X.2017.1278735

Verdú, E., Regueras, L.M., Verdú, M.J., Leal, J.P., de Castro, J.P., Queirós, R., 2012. A distributed system for learning programming on-line. Computers & Education 58, 1–10. https://doi.org/10.1016/j.compedu.2011.08.015

Vézina, A., 2014. The role of social media in education: How Twitter can be used in the intermediate classroom as a tool for collaborative learning, MsC project, department of Curriculum, Teaching and Learning, Ontario Institute for Studies in Education, University of Toronto, Canada.

Vidaceck-Hains, V., Kozina, M., Kirinic, V., 2016. A model of education for assistants of students with disabilities supported by information and comunication technology. Presented at the 12th International Scientific Conference on Economic and Social Development, Agcy E, Bangkok, pp. 126–135.

Watson, A., Lecki, N.K., Lebcir, M., 2015. Does size matter? An exploration of the role of body size on brand image perceptions. Jnl of Product & Brand Mgt 24, 252–262. https://doi.org/10.1108/JPBM-05-2014-0616

Wu, S., Wee, H.-M., Lee, S.-B., 2016. Technical innovation vs. sustainability – A case study from the Taiwanese automobile industry. Transportation Research Part D: Transport and Environment 48, 20–30. https://doi.org/10.1016/j.trd.2016.07.004

Zhu, H., Yang, Z., Xiong, Y., Wang, Y., Kang, L., 2018. Virtual emulation laboratories for teaching offshore oil and gas engineering. Computer Applications in Engineering Education 26, 1603–1613. https://doi.org/10.1002/cae.21977

List of tables

Table 1.

STUDENT ASSESSMENT	
I-Knowledge of the tool	Computer availability at home Particular frequency of use of the computer Frequency of use at the University
II-Development of the experience	Difficulty in managing VL Use of tutorials and video tutorials Repetition of activities and exploration of the program
III-Assessment program	Assessment of tutorials and video tutorials Assessment of the simulation environment Assessment of activities carried out Assessment of evaluation process Assessment of learning process
IV-Motivation	Degree of interest over the developed activities Arrangement and attitude

Table 2.

I	TECHNICAL-FUNCTIONAL OBJECTIVES	PEDAGOGICAL OBJECTIVES
I1	Information to the user (About how to use it and objectives)	**P1.** Relevance of contents
I2	Visual environment (content presentation)	**P2.** Efficiency of learning process
I3	Surfing the net (easiness of use, efficiency, speed)	**P3.** Adequacy of contents (to the cognitive level of the user)
I4	Multimedia items (quantity, quality)	**P4.** Ability to motivate
I5	Interactivity (possibility of manipulation, ease of data input, answers)	**P5.** Supervising (utility of help resources)
I6	Contents (clarity, organization)	**P6.** Autonomy (encouragement of decision making)
I7	Support services (availability, access)	**P7.** Cognitive effort (comprehension, comparison, exploration, metacognitive reflection)
I8	Registration of scores (access to information, utility)	**P8.** Evaluation (promoting feedback)
I9	Access to other resources (link)	
I10	Adaptation of design to educational level	
I11	Adequacy of contents to time (same class time)	

Table 3.

CONTEXT	ANNOTATIONS
Working teams	Correct
Internet connection	Good
Software operation	Initial problems to register in the website
STUDENTS	
Management of VL tool	Good
Needs for teacher supervision	Limited
Concentration	High
Motivation	Medium-high
Difficulties to achieve didactic objectives	None
TEACHERS	
Length of explanations	Short (15 min)
Working environment	Good
Students supervision	Good

Table 4.

PRELIMINARY STUDENT QUESTIONNAIRE		Frequency (%)
I. Do you use any social network?	Yes	97.83
	No	2.17
II-What social networks do you generally use?	Facebook	86.95
	Twitter	45.65
	Instagram	43.47
	WhatsApp	2.17
	Others (Snapchat, google+, LinkedIn, etc.)	19.56
III- -How many social networks do you use?	0	2.17
	1	30.44
	2	21.73
	3	34.79
	More than three	10.87
IV-How often do you use social networks?	Daily	80.4
	Three to four times a week	8.7
	Biweekly	2.2
	Once a week	8.7
V- For what purpose do you use social networks?	To chat or to show informal information to everyone	19.6
	To get information and share it	43.5
	To keep in touch with friends or family	30.4
	To publish photos and comments from others	6.5
VI- Rate from 1 to 5 how important social networks are to you, being 1 not important and 5 very important	1 Unimportant	8.7
	2 Little important	19.6
	3 Regular	39.1
	4 Important	21.7
	5 Very important	10.9
VII-Do you think using social networks affects person-to-person relationships?	Yes	71.7
	No	8.7
	Maybe	19.6

VIII- If you have Facebook, how many friends do you have?	Between 50-200 Between 200-300 Between 300-500 More than 500 Do not know/no answer	21.7 21.7 23.9 10.9 21.7
IX – Out of your social network, how many friends do you really have?	Less than 50% More than 50% All of them Do not know/no answer	15.2 39.1 43.5 2.2
X- How often do you review social networks per day?	Every 15 min Every 30 min Hourly Every two hours Above two hours	4.3 8.7 26.1 15.2 45.7
XI-Do you consider that social networks can be used in subjects as a means to provide information and communication between teachers and students?	Yes No Maybe	47.8 21.7 30.4
XII. Would you like teachers to use social networks as a means of communication?	Yes No Maybe	52.2 30.4 17.4

Table 5.

Academic Year	No. of student	Type of training	Not attending (%)	Deficient (%)	Acceptable (%)	Good (%)	Very good (%)	Main score	Standard deviation
2012-13	36	RL	0	2.8	16.67	52.75	27.78	7.06	1.65
2013-14	34	VL+RL	0	0	11.76	41.17	47.07	8.53	0.99
2014-15	14	VL+RL	7.14	0	14.28	28.58	50	8.02	1.98
2015-16	23	VL	4.3	0	26.08	30.43	39.19	7.82	2.05
2016-17	10	VL	0	0	12.30	43.55	44.15	8.10	1.87

Table 6.

ANOVA	Sum Sq	Df	F value	p-value
FE *vs* VL	65.16	14	2.2204	0.0183
Residuals	115.29	55		

Table 7.

	Estimate	Std. error	t value	Pr (>|t|)
(Intercept)	2016.13696	0.52357	3850.713	< 2e-16 ***
FE	-0.22195	0.05569	-3.985	< 0.001 ***
FE (Not attending)	-0.96544	0.24554	-3.932	< 0.001 ***
FE (score 4-4.9)	-1.22817	0.62275	-1.972	0.054
FE (score 5-5.9)	-1.19858	0.38616	-3.104	<0.01**
FE (score 6-6.9)	0.83841	0.45663	1.836	0.072
FE (score 7-7.9)	0.90500	0.45699	1.980	0.053
FE (score 8-8.9)	0.96604	0.34680	2.786	<0.01 **
FE (score 9-9.9)	0.71079	0.34655	2.051	<0.05 *

*Significance at 0.05 level; **Significance at 0.01 level; ***Significance at 0.001 level

Figure captions

Figure 1. Access to biodiesel characterization virtual laboratories web platform

Figure 2. BiomasaGen working group in Facebook (left) and access to VL via Genial.ly (right)

Figure 3. Flow chart of the experiment “determination of biodiesel density by means of a densimeter”

Figure 4. Coordination of virtual and experimental laboratories. a) Coordinated use between experimental and virtual laboratories, b) Virtual laboratory published in the social network Facebook

Figure 5. Technical evaluation carried out by the expert group (N = 6)

Figure1

Click here to download high resolution image

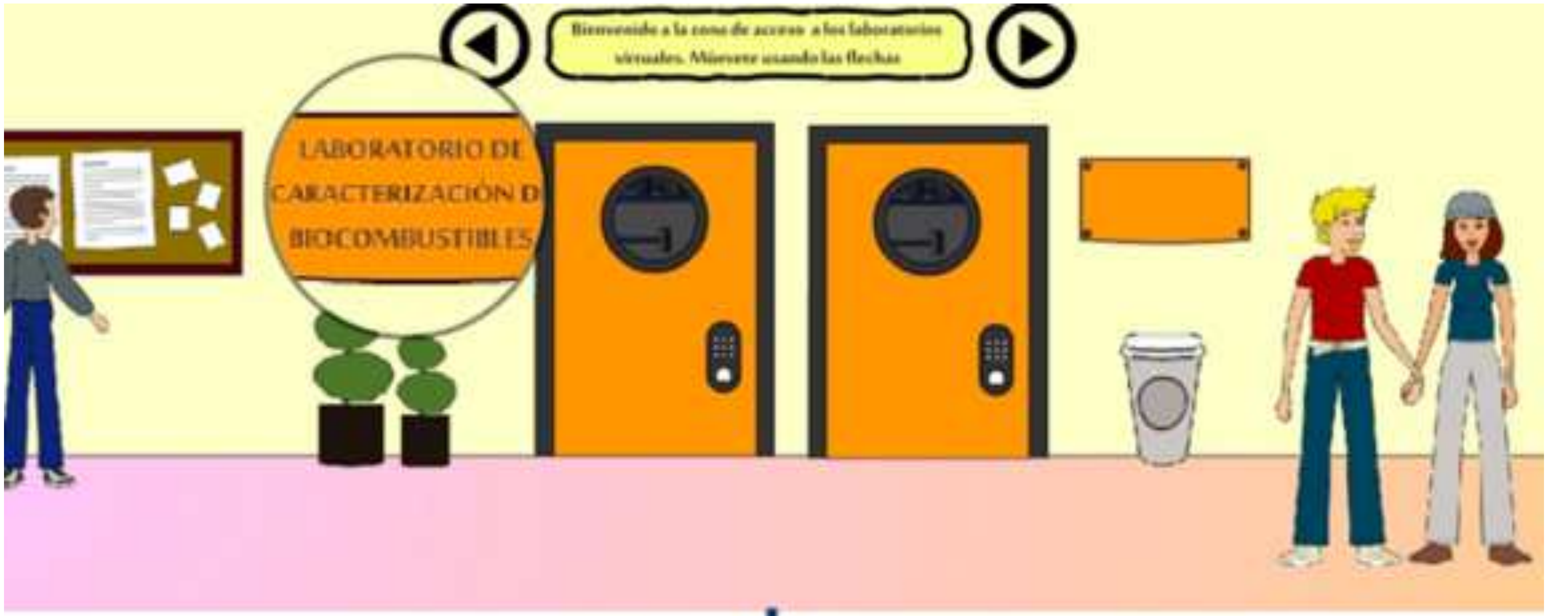

Figure2

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Figure3

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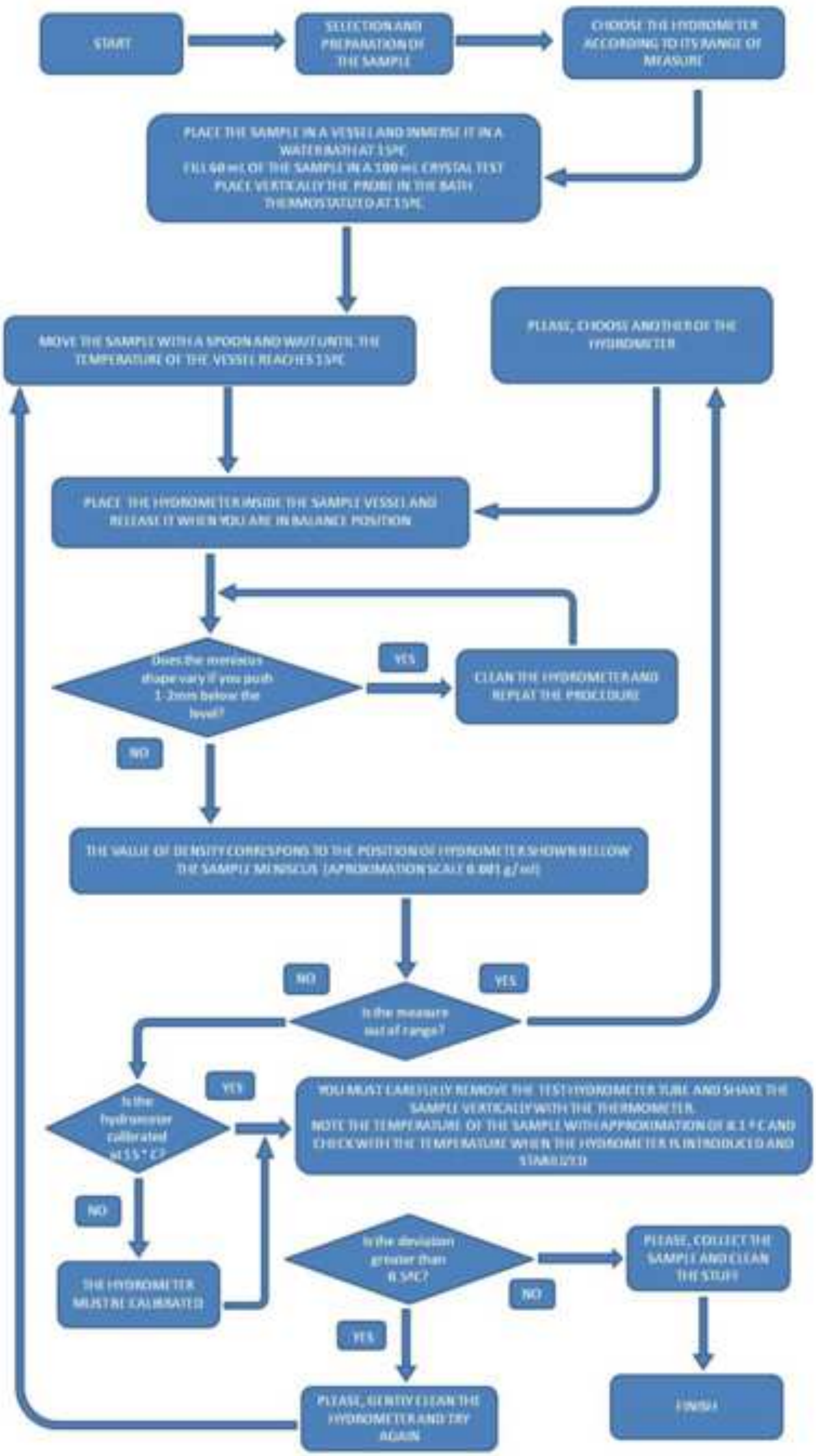

Figure4
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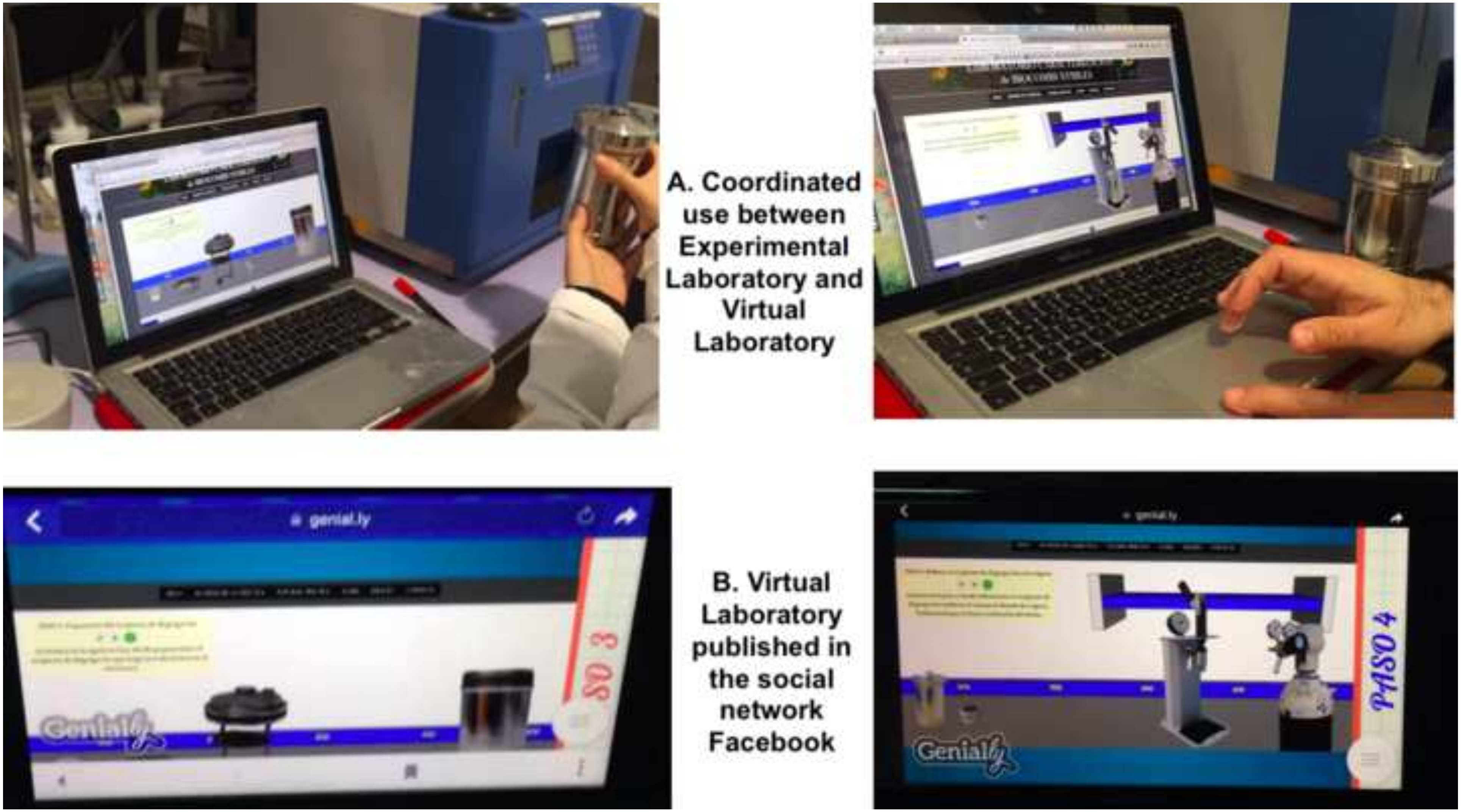

Figure5
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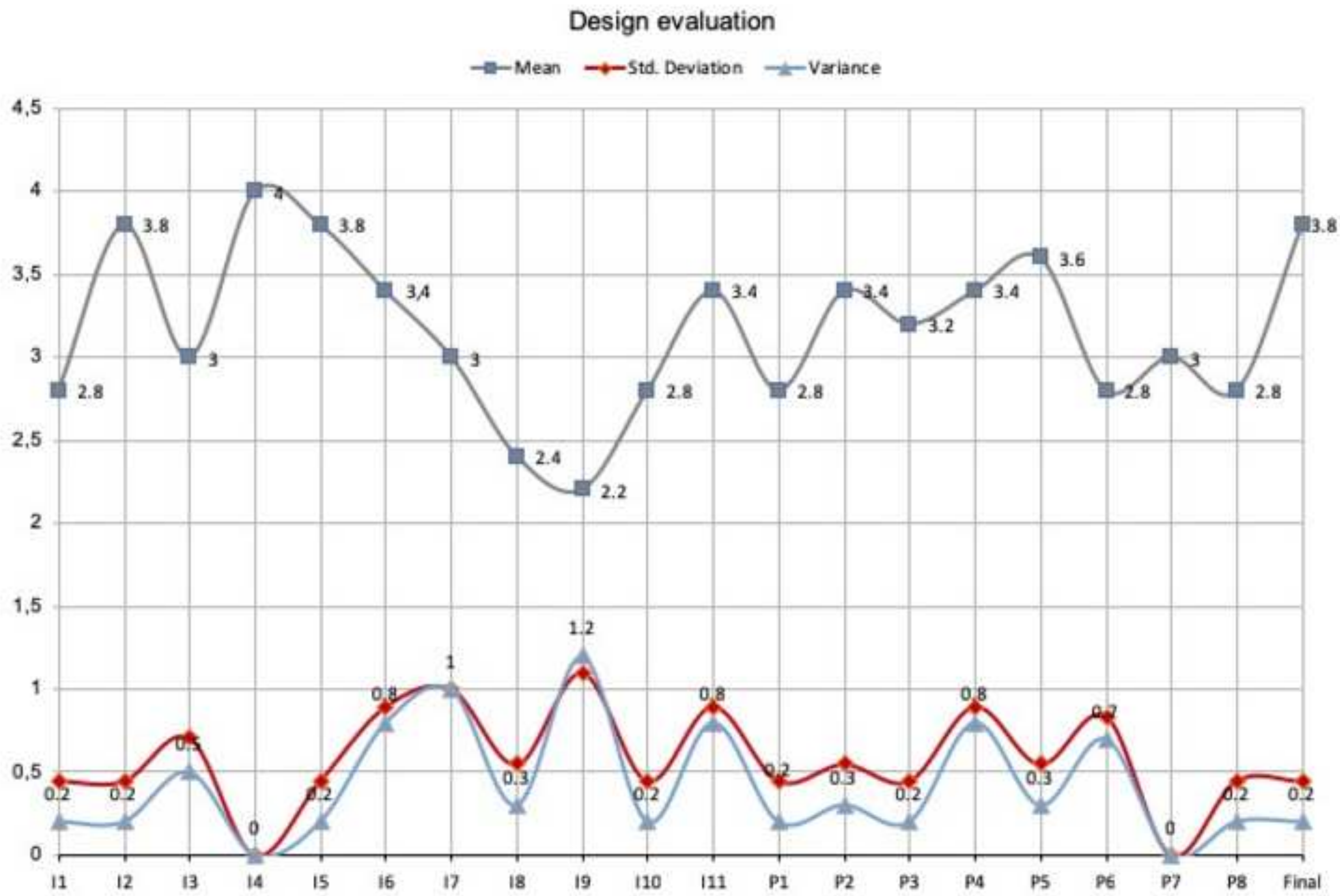

7,379 words

ABSTRACT

In this work, ubiquitous and blended learning focused on biofuel characterization, through three virtual laboratories, named “Determination of biodiesel heating value by automatic calorimeter”, “Determination of biodiesel density by densimeter” and “Determination of biodiesel kinematic viscosity by Canon-Fenske viscometer”, all integrated in a virtual platform, has been proposed. The idea was to approach environmental issues and sustainability needs to engineering students through biomass valorization or biorefinery development, avoiding or supporting costly lab equipment. Besides, same platform contents have been developed as web application and included in a Facebook social network group, named “BiomasaGen”, which can be directly, automatically and ubiquitously accessed. Finally, verification, validation and evaluation of results from the developed three virtual laboratories and web app based on social network have been carried out, assisted by Context, Input, Process and Products method. The idea was to evaluate the inclusion of social networks, comparing the effectiveness of combining social networks and virtual laboratories as a new teaching methodology. As a result of this study, it was found that students appreciated both, developed virtual labs and network web app. Their decision was based on the accessibility of information, feedback during process, useful virtual training experiments and video tutorials, as well as theoretical concepts explained during virtual learning process. Social networks are used for almost all students; for this reason, they represent a powerful tool to improve communication between teachers and students, in this virtual learning context. The social network-based web app helped students to easily access virtual laboratories from any location, which was also very useful when University servers were not accessible or unavailable. Moreover, it has been demonstrated that ubiquitous and blended learning combined with experimental laboratory increases the probability of successful scores in final exams of Master subject (p-value 0.0183). Finally, students prefer social networks as a channel for exchanging information rather than common channels, i.e. e-mails. It may be concluded that the proposed combination of methodologies may significantly promote integration of subjects related to new sources of bioenergy (biodiesel and biorefineries) in postgraduate education. This methodology strongly approaches environmental and sustainability issues to education institutions.

Keywords: Facebook, e-learning, biomass, biofuel property, Learning Virtual Environment

1. INTRODUCTION

Nowadays, higher educational system includes Information and Communication Technologies (ICT) in the learning process (Klimova et al., 2016; Torres et al., 2016; Vidaceck-Hains et al., 2016). This fact has led to the evolution of new research pathways applied to technological development, resulting in the production of a huge variety of interactive and didactic tools available from different electronic devices (computer, mobile phone, tablet, etc.) (Castillo-Manzano et al., 2017; Martinez Jimenez, P. et al., 2010; Olufadi, 2015). Developed technological applications and tools have been incorporated into different educational activities, among them, laboratory training stands out (Cambronero-López et al., 2017) aiming to improve both performance of educational process (Ramírez-Romero and Rivera-Rodríguez, 2017) and capacity of student self-learning (Roy et al., 2015). In this sense, it also facilitates student self-evaluation (Hulsman and van der Vloodt, 2015) besides evaluation of teaching-learning process of both teacher and student (Sapia et al., 2016).

Virtual Laboratories (VL) and Learning Virtual Environments (LVE), as integrated parts of blended learning (b-learning) Interactive Virtual Platforms (IVP), support face-to-face formation in virtual rooms, which is characterized by the flexibility and interactivity of the process (Olympiou and Zacharia, 2012). B-learning, also named hybrid and mixed-mode learning, is an educational approach that blends complementary manifold delivery media while promoting learning (Olelewe and Agomuo, 2016) in the field of sustainability (Rose et al., 2015). These ICT resources are focused on collaborative learning, as they are based on communicative and interactive tools, i.e. chat, e-mail, discussion forum, instantaneous messenger services and weblogs (Venville et al., 2017). Numerous studies corroborate the usefulness of VL as didactic tool (Daineko et al., 2017; Olympiou and Zacharia, 2012; Redel-Macías et al., 2015) or as instrument for research or industry decision making (Silva et al., 2016). These laboratories promote acquisition of skills when no access to experimental laboratories is granted (i.e. developing countries or mobility difficulties), besides the potential use as supporting tool to experimental laboratories.

In a previous research, a virtual laboratory focused on the production of biodiesel, which may be accessed through a website, was developed (Redel-Macías et al., 2016). This web application was tested with students of the Master of “Distributed renewable energies” (MECES 3 -EQF7) of the University of Cordoba, Spain, achieving very good results. However, the application was created with Flash Programming language, which only allows to be used as hosted web application on personal computers (with operating system Windows or MacOSX). Moreover, Flash is expected to disappear in the coming years, being replaced by languages like HTML5.

Besides, the increasing use of social networks (SN) sites, i.e. Facebook, Twitter, Instagram or WhatsApp, constitutes an undeniable reality. In fact, these networks are the most common way of sociocultural interaction for the youth (Watson et al., 2015). Moreover, audio-visual media, i.e. videos and photographs, show higher impact over users than written text, which means that they are preferred as propagation media of ideas in SN (Ghali et al., 2016; Pittman and Reich, 2016). Young people are main users, sometimes showing an addictive behavior, in many cases accessing daily SN sites and even with high daily frequency (Rodgers and Chabrol, 2009). As a result, SN have a great influence over youth habits and life style (Hayes et al., 2015).

Based on this influence, many authors have proposed new b- and ubiquitous learning (u-learning) educational methods based on SN sites (de Kraker et al., 2013; Dlouhá et al., 2013; Lorenzo-Romero and Buendía-Navarro, 2016) standing out the importance in education due to communication fluency between teachers and students (Celik et al., 2015). u-learning is usually associated to mobile learning (m-learning), as it allows accessing the platform independently of time and place. The easy accessibility to educational contents from ubiquitous devices (smart mobile phones, contactless smart cards, handheld terminals, sensor network nodes) allows individual learning activities embedded in daily life and enables anyone to learn, anyplace, anytime. Moreover, SN sites allow communication with experts in specific subjects and students from different places; besides, they ease accessibility of information to students to complete diary tasks in a self-didactic and efficient way, increasing educational community feeling (Arteaga Sánchez et al., 2014; Van Waes et al., 2016; Cincera et al., 2018). Previous works include the use of SN sites as learning tool for medical and chemistry subjects (Ainin et al., 2015; Al-Rahmi et al., 2018). In addition, these networks might incorporate multimedia tools, i.e. videos, web links, tutorials and animations, which allow building private spaces for lecturing (Konstantinidis et al., 2013). As previously mentioned, these networks facilitate student self-learning, making possible to teachers to follow up the learning process, helping them to improve the weaknesses of the process.

However, the feasibility of SN as learning tool in the classroom needs some grade of control and responsibility practiced by both teachers and students. Undoubtedly, SN sites constitute a magnificent educational and learning tool, besides being a space where information and experience may be exchanged. As a result, SN used in addition to learning virtual platforms help to increase effectiveness of the teaching-learning process (So, 2016). In this sense, few studies have studied the influence of SN combined with VL as u-learning. Furthermore, in the field of biomass, only our previous work (Redel-Macías et al., 2016) provided a VL with the purpose of improving the learning process of postgraduate students.

For the previous reasons, the aim of this research is the development of three VL for biodiesel characterization, as a complementary tool to experimental laboratory, namely “Determination of biodiesel heating value by automatic calorimeter”, “Determination of biodiesel density by densimeter” and “Determination of biodiesel kinematic viscosity by Canon-Fenske viscometer”. All of them are integrated in a virtual platform, made by authors, focused on the study of biodiesel and that can be accessed through the following link: <http://www.uco.es/docencia/grupos/laboratoriovirtualceia3/es/laboratorios-virtuales>. Additionally, implications of a VL mobile version development are also analyzed.

Complementary to the previous objective, inclusion of SN sites in the learning platform, combined with VL as new teaching methodology, has also been studied. In this sense, to improve accessibility and information dissemination, a Facebook group about biomass called BiomasaGen, which may be accessed through the link <https://www.facebook.com/BiomasaGen-602859903242579/>, was created. In our previous work (Redel-Macías et al., 2016), inclusion of SN sites in the learning platform or use of mobile app were not considered. Moreover, as previously mentioned, use of Flash limits accessibility of students to the learning process. For this reason, the platform has been improved, allowing u-learning and including three VL.

Another objective of this work is to evaluate the three proposed VL through verification and validation, focusing on Context, Input, Process and Product (CIPP) method (Stufflebeam, 2003), including expert, user and student point of views, satisfaction degree and effectiveness of tools in the educational process. To the best of our knowledge, studies using CIPP method to evaluate VL and SN are needed. Moreover, there is a lack of published research about the implementation of LV based on biodiesel characterization in SN.

Satisfaction degree analyses, including software and net where it is located, besides the influence over teaching-learning process, will be carried out at the end of the process, with students of subject “Biomass for generation of energy”, within the Master of "Distributed renewable energies” (University of Cordoba, Spain). To achieve these goals, the proposed study has been divided into four phases, namely development of three VL, development of SN site, evaluation of VL (using CIPP method) as teaching tool and combination of both SN and VL as new learning methodology.

2. EXPERIMENTAL DESCRIPTION, MATERIALS AND METHODS

2.1. Development of virtual laboratories for biodiesel characterization

Three VL, which reproduce faithfully determination of some biodiesel properties in a chemical laboratory, have been developed (Figure 1). These VL are named *"Determination of biodiesel heating value by automatic calorimeter", "Determination of* *biodiesel density by densimeter"* and *"Determination of biodiesel kinematic viscosity by viscometer Canon-Fenske"*.

Biodiesel is considered among the most important products derived from biomass, as it may be used to fuel diesel engines. Biodiesel quality control is essential to ease its acceptance by both consumers and vehicle manufacturers (Pinzi et al., 2009). Quality control consists in the analysis of the most relevant physico-chemical properties, which includes heating value, density and kinematic viscosity.

1. *Determination of biodiesel heating value by means of C2000 IKA automatic calorimeter*

By this training, higher heating value (HHV) and lower heating value (LHV) of biodiesel and fossil fuels are determined. These parameters indicate released energy when a fuel undergoes complete combustion (HHV) and includes water heat of vaporization, whereas it is excluded in LHV calculation. As an example of its implications, biodiesel depicts a lower value compared to that of diesel fuel, thus needing to increase fuel consumption to provide same engine power (Dorado et al, 2003).

It is followed by further analysis considering standards. To carry out this training, bomb calorimeters help to define the heat released during the complete combustion of the mass unity of biodiesel. A fuel sample, previously weighted, is placed inside a disintegration container in the calorimeter, with oxygen excess. Then, an explosion takes place, allowing to measure the increase of temperature.

2. *Determination of biodiesel density by means of a densimeter*

Proposed biodiesel training follows standard EN ISO 3675 and is prepared to be used with refined sunflower oil and diesel fuel by the procedure of densimeter; results are compared to those of standard. Density is an important fuel property, that directly affects engine performance characteristics, such as cetane number and heating value. Moreover, diesel fuel injection system estimates fuel volume. Consequently, variations in fuel density will affect engine output power due to variations of fuel mass injected (Alptekin and Canakci, 2008).

3. *Determination of biodiesel kinematic viscosity by means of a viscometer Cannon-Fenske*

This training is focused on the determination of kinematic viscosity of both biodiesel and recycled waste oil samples at different temperatures, to compare them with that of diesel fuel under same temperature values. Canon-Fenske viscometers will be used to follow standard ISO 3104. Kinematic viscosity is an important fuel property, as it directly influences injection process, liquid atomization and spray formation (Lee et al., 2005).

2.2. Design of BiomasaGen group as part of social network

The three VL about characterization of biodiesel are located in a website called "Virtual Biorefineries" implemented by authors (University of Cordoba, Spain) in collaboration with the University of Huelva and Cadiz (Spain), Birmingham and Manchester (UK) and Agricultural University of Athens (Greece). First version of this webpage, out of two, was implemented using the open-source database management system MySQL and Apache HTTP server (see Figure 1 and visit the web link: <http://www.uco.es/docencia/grupos/laboratoriovirtualceia3/es/>). Animations and simulations were designed using ActionScript programming language under Adobe Flash 8 environment, to bring better definition to 3D graphics. This version is accessible from any web browser. However, since nowadays Adobe Flash cannot run on other operating systems, such as Android or iOS, it prevents their use in tablets and mobile phones. Moreover, Flash is expected to disappear in 2018. To overcome the disadvantage about accessibility, while linking VL with highly visited SN, i.e. Facebook, design software Genial.ly was used. It is based on HTML5 programming language, thus providing a fresh and more accessible version (see Figure 2 and visit the weblink: <https://www.genial.ly/58f76b27ba1aa60a6437807e/biomasa>). We also built a working group about biomass in Facebook and linked VL to it (<https://www.facebook.com/BiomasaGen-602859903242579/>). Each virtual laboratory contains mentioned biodiesel characterization experiments, explained step by step, including animations, thus reproducing real process.

VL must include necessary functions to simulate real process, in the most realistic way. In proposed VL of biodiesel characterization, development of experiments is based on the use of 3D animations, either in Flash environment (Windows/MacOSX version) or Genial.ly (version for mobile devices and accessible through every operating system). Animations allow to illustrate in detail procedures, i.e. sample manipulation or safety protocols.

Each VL presents a menu located in the upper side of the screen, showing the following options: “Start”, “Move through training”, “Training tutorial”, “Help”, “Links” and “Contact”. Moreover, each of the previous items offers several submenus, for example:

- Option *Move through training* includes the complete description of the laboratory, showing every component, as well as self-evaluation questionnaires and surveys of satisfaction.
- Option *Training tutorial* displays the next submenu: *training guide*, that may be downloaded in pdf format, *video tutorials* about the procedure of the complete training, which is linked to youtube (i.e., <https://youtu.be/3YGrFd-gUxc>; <https://youtu.be/x7UAhoUB_64>; <*https://youtu.be/nYKMw7kB_fM*>), *flow chart of the experiment* (Figure 3) and *photo gallery*. Video tutorials facilitate students the comprehension of proposed processes. They have been videotaped in the laboratory of research group BIOSAHE TEP-169, Department of Physical Chemistry and Applied Thermodynamics of the University of Cordoba (Spain) and correspond to real training experiments of biodiesel. Subsequently, videos have been edited and produced with the help of *Pinnacle Video Spin* software.
- In option *Help*, there is a menu that includes the User Guide and Help Forum.

In the main page of the website, a tridimensional laboratory is introduced to the user by virtual assistant “Azahara”, who indicates by texts the actions to do, step by step. The process reproduces faithfully laboratory experimental work, thus allowing students to work virtually and advising them. Finally, students can self-evaluate achieved knowledge.

2.3. CIPP method to evaluate VL

To evaluate the three proposed VL using CIPP method, a survey has been carried out. To accomplish this task, several questionnaires based on a recent work have been used, following the methodology proposed by Stufflebeam (2003). According to CIPP method, evaluation should consider four issues, namely context, input, process and product. In this work, they have been grouped in three correlated features, which are context, design and evaluation of VL and implementation process of VL.

Evaluation of context is intended to identify the features of environment where the three VL are used, which in this case corresponds to the subject “Biomass for the generation of energy”. Results on ICT integration, in terms of possible limitations of resources (materials, schedules, training, etc.) and willingness of teachers to use these VL as pedagogical resource complementary to experimental laboratory training have been analyzed.

2.3.1. VL design, evaluation and process implementation

Evaluation of educational tool consists in verification of whether the designed application meets the predefined objectives from a technical and educational point of view. The design of three biodiesel VL was evaluated by a group of teaching experts, according to the questionnaire developed in a previous work (Peinazo-Morales, 2012). Once designed and previously to its implementation in the classroom, it was submitted to a second set of experts for a second evaluation. They offered their point of view regarding technical and pedagogical properties of both design and use of three VL.

An evaluation form composed by four sections has been used: first one corresponds to assessment of technical and functional aspects of the program; second section is focused on pedagogical aspects; third section collects expert observations and, finally, last section covers the request of overall evaluation of the program (low, medium, high or excellent).

Process evaluation has been carried out to know how designed VL performs in a real context, including individual opinions, formal and material elements that could influence the application of the program.

The evaluation of the process has been performed for the course where experimental training of the subject "Biomass for generation of energy" was programmed. Four sources of information were used:

1. Structured observation in the classroom, as a qualitative research technique, using a record sheet as the instrument of observation by the teacher of the subject. Aspects related to the context in which the application of VL has been developed (classroom conditions, success of working groups, length of each activity, etc.), including aspects related to student attitude to VL (autonomy, concentration, motivation, etc.) and aspects related to the role played by teacher in the development of the activity (explanations, interventions, attention to students, etc.) are taken into consideration.
2. Information provided by software.
3. Student evaluation is collected in a questionnaire (Table 1). It contains two types of issues: a) descriptive questions that are focused on how the experience has been carried out and b) other group of questions with the objective of understanding the opinion of students and their interest and motivation for this type of laboratory activities supported by VL.
4. Teacher evaluation is provided by an interview, following a qualitative research technique with open response.

2.4. Student assessment of the use of social networks

Among young people, SN sites have become an instrument to connect and spread news that can influence trends in their behavioral model. There are numerous studies stating the importance of SN as ICT tools in education (Celik et al., 2015; Lorenzo-Romero and Buendía-Navarro, 2016). For this reason, as this research is focused on the influence of ICT on education, mainly virtual environments, introduction and use of SN in the learning system have been promoted and studied.

To assess student opinion about the use of these networks in education, an anonymous questionnaire was first designed and later answered by students (Table 1), through a Moodle questionnaire. Most responses were in favor of the use of SN, both as instruments of news dissemination and as teaching tool. Final evaluation, after implementation of the Facebook group, has been made using an additional questionnaire.

2.5. Teaching experience and methodology

As previously mentioned, three virtual laboratories have been used as a didactic tool in the subject “Biomass for generation of energy” (6 ECTS credits, corresponding to 100 h; 40 h correspond to master and training classes and 60 h to personal autonomous work. Lectures are scheduled from Friday to Saturday, so each subject is worked with students during two consecutive weeks. Timetable aims to promote compatibility of studies and jobs.

Training experiments have been carried out every course, since the beginning of the Master in the course 2012-2013. In the current course, 2016-2017, opinion of students about the use of SN as a complementary didactic tool of information has been gathered and evaluated, supervising both training and complete subject.

Methodology is similar to that of other subjects where VL are used and evaluated (Jara et al., 2009). Four training sessions, of two hours each, followed theoretical classes, scheduled for consecutive weeks. In the first session, students start familiarizing with laboratory equipment. The objectives of this first session are: first, to gain knowledge about the laboratory instruments as well as methodology of work and, second, to be informed about safety protocols to be followed during experiments. The second session is focused on the production of biodiesel by transesterification and its subsequent characterization. In the third and the fourth sessions, students carry out the characterization of this product. The objective is to analyze different physico-chemical properties of biodiesel.

To carry out the training, students are divided into small working groups. Once the procedure is known with the help of VL, students carry out real laboratory training, supervised by teachers and with the aid of VL included in both the webpage of the University and those developed in SN (links already mentioned) (Figure 4). In the academic year 2015-2016, training classes were only performed virtually, even though students visited the experimental laboratory to identify instrumentation.

At the end of the training classes, students were given a questionnaire to evaluate their degree of satisfaction about the use of VL included in both the University webpages and those developed in SN. Survey items include five main topics: (I1) help resources, (I2) ease-of-use and interface environment assessment, (I3) motivation and encouragement, (I4) learning promotion and (I5) adaptation of theory content. The purpose of this questionnaire was to evaluate the usefulness of the developed software, since it is known that student satisfaction and motivation are key success factors (Verdú et al., 2012). It also helps to further improve the platform.

3. RESULTS AND DISCUSSION

3.1. Evaluation of comprehensive VL using CIPP method

Results have been analyzed for: 1) comprehensive evaluation of both the platform and the VL using CIPP method; 2) evaluation of students about the inclusion of SN as learning tool and 3) results of experimental teaching using different multimedia tools and their impact over the learning process.

To perform the evaluation of ICT by CIPP method, firstly, before these tools are used, context, design and implementation methods are analyzed by experts, and later by teachers involved in the experience.

Figure 5 shows the technical assessment of both VL and platform carried out by expert users. Results of mean scores achieved for each technical - functional item (I) and pedagogical item (P) are shown in Table 2. Moreover, standard deviation and variance for each value have been calculated. There are four possible responses: low (1), mean (2), high (3) and excellent (4), for each item described in Table 2, grouped in 11 technical – functional items and 8 pedagogical items.

As may be seen from Figure 5, global score is around 3.8 (out of 5) ± 0.2. The best evaluated items (3.8 or higher) are information to user (I2) with a score of 3.8 ± 0.2, quantity and quality of multimedia content (I4) with a score of 4 ± 0 (excellent) and interactivity (I5), 3.8 ± 0.2. On the contrary, the worst evaluated and dispersed items (2.5 or lower) are access to scores (I8) with a value of 2.4 ± 0.3, and access to other resources (I9) with a mean of 2.2 ± 1.2. Remaining items show scores between 2.8 and 3.5, being considered as good marks. As the worst evaluated items are not influencing methodology implementation, results may be considered positive.

Study of teacher assessment of context (Table 2) has been carried out by means of a questionnaire that includes availability of computer rooms, number of computers and software, teacher skills (including ICT), etc. Results show that 90% teachers believe there are enough ICT resources, including laboratories, software and computers with access to internet. It is important to emphasize that a regular teacher holds a teaching experience from 5 to 15 years and uses ICT weekly in undergraduate courses and, fortnightly, in postgraduate courses. Considering other questions, it may be inferred that regular teachers show high interest in procedural content, mainly basic and technical skills, being an advanced level user of ICT.

Another technical item studied is the teacher assessment about the implemented website and VL. This study has been carried out using same questionnaire that was used for experts (Table 3). Results are similar to those provided by experts. Some positive technical items are interface, clarity, similarity with experimental laboratory and interactivity. Website maintenance (where VL are hosted) and easiness of registration process in the website have been suggested.

As positive pedagogical items, quality of information, feedback, video tutorials, theoretical contents and completeness of instruction sheets could be highlighted. Main advantages of VL *vs* experimental laboratory are the possibility of repeating training as often as needed, saving costly resources, besides the possibility of working with large groups. However, the main advantage for teachers is the required low level of abstraction and the need of a low initial effort by students to understand the virtual platform. In this sense, a previous study based on VL for undergraduate students highlighted usability, content and effectiveness as key points for pedagogical methodologies (Manzorro et al., 2015). Additionally, the use of VL has been proposed as substitute of experimental laboratory when it is not accessible (Norin et al., 2018; Zhu et al., 2018). Although, combination of experimental and virtual laboratories are mostly recommended (Berre et al., 2018; Norin et al., 2018; Zhu et al., 2018).

Furthermore, process evaluation of VL implementation in the classroom has been carried out by means of a registration form (Table 4). The following items have been highlighted: 1) working condition of computers and internet connection; 2) working condition of VL and potential problems to register in the website; 3) accessibility of program contents and easiness to use by students with little teacher assistance and high concentration and motivation, and 4) good working environment and student attention. In this sense, Table 5 shows main results collected by teachers. As may be inferred, when VL are used, combined or not with experimental laboratory, no deficient scores were given by students. Highest score was achieved with the use of VL combined with experimental laboratory, while lowest score was achieved with the use of real laboratory. These results are statistically validated (section 3.3).

3.2. Initial assessment of students regarding the use of social networks as a learning tool

The starting study gathering student opinion about SN sites and the potential use as learning tool in master's degree courses have been carried out by means of a questionnaire, as shown in Table 4. The questionnaire has been answered by 46

voluntary and anonymous students. Table 4 shows the frequency of each item responses.
Results show that 97.83% of students use SN as way of communication, being Facebook the most used (86.95%) followed by Twitter (45.65%) and Instagram (43.47%). These results disagree with previous works focused on younger population, to whom the most used SN is Instagram (Phua et al., 2017). WhatsApp is less used to share news and multimedia (2.17%), although other studies has shown that WhatsApp is mostly used as mobile instant messaging (>90%) (Church and de Oliveira, 2013). Contrary to other authors (Phua et al., 2017), remaining students (19.6%) preferred diverse and uncommonly used SN sites, i.e. Snapchat.
Most students use from one to three SN sites (30.44%, 21.73% and 34.79%, respectively). Only a small percentage do not use any SN (2.17%) and few students use more than three (10.87%). Also, results showed that 80.4% of students used daily SN, to be in contact with friends and family (30.4%) and to gather and share information with other people (43.5 %). On the contrary, only 19.6% of students use it to chat or show information, while very few use SN to publish photographs or comments from other users. These results are in agreement with those from Phua et al. (2017).
Moreover, in terms of importance of SN, answers follow a normal or Gaussian distribution. In addition, 71.7% students consider that SN sites influence relationships. About the possibility of increasing the number of friends, most results were found from 50 to 200 and 200 to 300, that is, most considered intervals show same results (around 21%) excepting when the number of friends exceeds 500, that is halved. Also, 82.6% population knows above 50% of their followers. About the frequency of connection, in case they are checking SN daily, 45.7% check it for more than two hours, while it is checked hourly by 26.1% and every two hours by 15.2 %.

Finally, regarding the potential use of SN in the teaching process, most students agree it may be helpful (47.8%) while 30.4% hesitate. 52.2% students find that the use of SN for teaching is a good idea, while 17.4% hesitate and 30.4% disagree. These results agree with previous works about potential benefits of SN (Sousa-Vieira et al., 2017; Wu et al., 2016). Though, some works have shown that student interest is focused on the development of a community (Al-Rahmi et al., 2018; Phua et al., 2017) and the active interaction of the faculty members of the university (Doğan et al., 2018). Additionally, Facebook was pointed out as preferred SN site to provide a sense of community and interactional relationship (Arteaga Sánchez et al., 2014; Norin et al., 2018; Phua et al., 2017), though Twitter and Whatsapp might also meet this purpose (Vézina, 2014).

Based on these results, the working group "BiomasaGen" in Facebook and a web app in this network called "BiomasaGen" have been developed. The network includes ICT tools for VL, multimedia, groups, news, thus promoting collaborative work, regardless distance and time. Lastly, it is important to remark that SN and working group in SN sites are excellent alternatives when connection to university servers cannot be accessed or fails for any reason (VPN stops working when out of the campus, server is down, etc.). This technology, undoubtedly, will help engineers to achieve skills in biomass valorization and biorefinery development, in terms of biodiesel characterization. These findings are collaborating towards education for sustainable development, thus helping society becoming more sustainable and environmentally friendly.

3.3. Statistical study about teaching experience

Data about student training results and final evaluation scores on the subject "Biomass for energy generation" have been collected for five years, as depicted in Table 5. Moreover, main score and standard deviation are shown. In this table, higher frequencies correspond to good and very good scores, with deficient level showing no hits. During these academic years, teachers carried out training experiments using different modes:

a) Combining theoretical lectures with laboratory training (academic year 2012-13).

b) Carrying out VL training before doing any training experiments in the laboratory.

c) In the academic course 2015-16, due to logistic problems, training experiments could only be done virtually.

d) In the course 2016-17, only virtual training combined with the use of SN sites as an assistant tool and e-learning have been used.

To analyze whether the use of VL has any impact on final evaluation results of master-degree students, an ANOVA study was carried out (Table 6). Correlation between final evaluation scores (FE) and the use of VL was significantly above 98% (P-value of 0.0183). It corroborates that the use of VL improves understanding and learning experience. This result is reliable with previous reports on VL efficiency, improving practical skills and keeping technique knowledge for longer periods of time (Redel-Macías et al., 2016; Norin et al., 2018; Phua et al., 2017).

Moreover, a lineal model of correlation between variables has been carried out. As depicted in Table 7, lineal correlation between range of scores achieved in the final evaluation and the use of VL, for every range of final evaluation score, show a significant correlation (more than 92% of confidence level). Considering the value of polynomial regression (Pr) of t-student test, it is possible to appreciate that this correlation highly improves for 5-5.99 and 8-8.99 scores. In case of scores in the range of 5-5.99 of final evaluation of the subject, the use of VL depicts a negative influence, at 99% confidence level; whereas for good or very good evaluation (scores between 8 and 8.99) the use of VL shows a positive effect, at a 99% of confidence level. These findings clearly validate results showed in Table 5, which means that the use of biodiesel characterization-based VL increases the possibility to achieve good or very good marks in final exams, while decreases the possibility to achieve acceptable or low final marks in the master subject. In this sense, previous studies established this positive influence in new engineering degrees for undergraduate students (Norin et al., 2018). Though, its impact has never been previously studied in master degree engineering students.

4. CONCLUSIONS

Three virtual laboratories (VL) focused on biodiesel characterization have been developed. They have been integrated in a previous virtual platform for the subject “Biomass for generation of energy” in the Master of "Distributed renewable energies”. Moreover, a VL web application integrated in a social network group, thus providing a blended and ubiquitous learning (b- and u-learning) has been developed. The importance of the development of these VL is based on the needs of postgraduate students to understand the basis of residual biomass valorization sector, thus helping society being more sustainable. Postgraduate students were supervised and trained within the proposed methodology with successful results. It is important to mention that only few universities have included similar learning techniques for postgraduate students, and almost none have combined VL and social network (SN) sites to improve learning process.

To check the impact over students, Context, Input, Process and Product (CIPP) method has been proposed. Students appreciated VL-based learning, as well as the working group in the SN site, for clarity of information, feedback given during process, completeness of virtual training and video tutorials, as well as theoretical concepts explained during virtual learning process. It has been proved that SN sites are used by almost all master students. For this reason, they represent a powerful tool during the educational process, to improve communication between teachers, students, teachers-students, besides providing a more attractive virtual b-learning and u-learning context. The working group hosted in SN site, besides the web application developed in this work, resulted very useful to students to both facilitate the contact (to solve problems and gather more information) and access to VL, also when students are elsewhere with no access to university server. It has been demonstrated that the use of VL combined with traditional experimental one increases the possibility to improve the final mark in the master subject.

The use of VL located in SN site may combine the efficiency of virtual practices with the ubiquity of social networks to improve both participation and effective learning of postgraduate students.

As a general conclusion, the proposed methodology may significantly promote the integration of subjects related to new sources of bioenergy (biodiesel and biorefineries) in education institutions. The most outstanding benefit of this methodology is that it can be used anywhere, anytime, helping to increase knowledge, collaborative environment and training of future engineers working on biomass valorization and biodiesel industries. This methodology strongly approaches environmental and sustainability issues to education institutions.

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References

Ainin, S., Naqshbandi, M.M., Moghavvemi, S., Jaafar, N.I., 2015. Facebook usage, socialization and academic performance. Computers & Education 83, 64–73. https://doi.org/10.1016/j.compedu.2014.12.018

Alptekin, E., Canakci, M., 2008. Determination of the density and the viscosities of biodiesel–diesel fuel blends. Renewable Energy 33, 2623–2630. https://doi.org/10.1016/j.renene.2008.02.020

Al-Rahmi, W.M., Alias, N., Othman, M.S., Marín, V.I., Tur, G., 2018. A model of factors affecting learning performance through the use of social media in Malaysian higher education. Computers & Education 121, 59–72. https://doi.org/10.1016/j.compedu.2018.02.010

Arteaga Sánchez, R., Cortijo, V., Javed, U., 2014. Students' perceptions of Facebook for academic purposes. Computers & Education 70, 138–149. https://doi.org/10.1016/j.compedu.2013.08.012

Berre, A.J., Huang, S., Murad, H., Alibakhsh, H., 2018. Teaching modelling for requirements engineering and model-driven software development courses. Computer Science Education 28, 42–64. https://doi.org/10.1080/08993408.2018.1479090

Burke, R.D., De Jonge, N., Avola, C., Forte, B., 2017. A virtual engine laboratory for teaching powertrain engineering. Computer Applications in Engineering Education 25, 948–960. https://doi.org/10.1002/cae.21847

Cambronero-López, F., Gómez-Varela, A.I., Bao-Varela, C., 2017. Designing an ultrafast laser virtual laboratory using MATLAB GUIDE. European Journal of Physics 38, 034006.

Castillo-Manzano, J.I., Castro-Nuño, M., López-Valpuesta, L., Sanz-Díaz, M.T., Yñiguez, R., 2017. To take or not to take the laptop or tablet to classes, that is the question. Computers in Human Behavior 68, 326–333. https://doi.org/10.1016/j.chb.2016.11.017

Celik, I., Yurt, E., Sahin, I., 2015. A Model for Understanding Educational Facebook Use. EURASIA Journal of Mathematics, Science & Technology Education 11, 899–907.

Church, K., de Oliveira, R., 2013. What's up with whatsapp?: comparing mobile instant messaging behaviors with traditional SMS, in: Proceedings of the 15th International Conference on Human-Computer Interaction with Mobile Devices and Services - MobileHCI '13. Presented at the the 15th international conference, ACM Press, Munich, Germany, p. 352. https://doi.org/10.1145/2493190.2493225

Cincera, J., Biberhofer, P., Binka, B., Boman, J., Mindt, L., Rieckmann, M., 2018. Designing a sustainability-driven entrepreneurship curriculum as a social learning process: A case study from an international knowledge alliance project. Journal of Cleaner Production 172, 4357–4366. https://doi.org/10.1016/j.jclepro.2017.05.051

Daineko, Y., Dmitriyev, V., Ipalakova, M., 2017. Using virtual laboratories in teaching natural sciences: An example of physics courses in university: USING VIRTUAL LABORATORIES IN TEACHING NATURAL SCIENCES. Computer Applications in Engineering Education 25, 39–47. https://doi.org/10.1002/cae.21777

de Kraker, J., Cörvers, R., Valkering, P., Hermans, M., Rikers, J., 2013. Learning for sustainable regional development: towards learning networks 2.0? Journal of Cleaner Production 49, 114–122. https://doi.org/10.1016/j.jclepro.2012.11.019

Dlouhá, J., Huisingh, D., Barton, A., 2013. Learning networks in higher education: universities in search of making effective regional impacts. Journal of Cleaner Production 49, 5–10. https://doi.org/10.1016/j.jclepro.2013.01.034

Doğan, B., Demir, Ö., Ülkü, E.E., 2018. Applying social networks to engineering education. Computer Applications in Engineering Education 26, 1782–1791. https://doi.org/10.1002/cae.21975

Dorado, MP; Ballesteros, E; Arnal, JM; Gómez, J; López, FJ, 2003. Exhaust emissions from a Diesel engine fueled with transesterified waste olive oil. Fuel 82(11), 1311-1315

Ghali, M.R., Frayret, J.-M., Robert, J.-M., 2016. Green social networking: concept and potential applications to initiate industrial synergies. Journal of Cleaner Production 115, 23–35. https://doi.org/10.1016/j.jclepro.2015.12.028

Hayes, M., van Stolk-Cooke, K., Muench, F., 2015. Understanding Facebook use and the psychological affects of use across generations. Computers in Human Behavior 49, 507–511. https://doi.org/10.1016/j.chb.2015.03.040

Hulsman, R.L., van der Vloodt, J., 2015. Self-evaluation and peer-feedback of medical students' communication skills using a web-based video annotation system. Exploring content and specificity. Patient Educ Couns 98, 356–363. https://doi.org/10.1016/j.pec.2014.11.007

Jara, C.A., Candelas, F.A., Torres, F., Dormido, S., Esquembre, F., Reinoso, O., 2009. Real-time collaboration of virtual laboratories through the Internet. Computers & Education 52, 126–140. https://doi.org/10.1016/j.compedu.2008.07.007

Klimova, A., Rondeau, E., Andersson, K., Porras, J., Rybin, A., Zaslavsky, A., 2016. An international Master's program in green ICT as a contribution to sustainable development. Journal of Cleaner Production 135, 223–239.

Konstantinidis, S., Fernandez-Luque, L., Bamidis, P., Karlsen, R., 2013. The role of taxonomies in social media and the semantic web for health education. A study of SNOMED CT terms in YouTube health video tags. Methods Inf Med 52, 168–179. https://doi.org/10.3414/ME12-02-0005

Lee, C.S., Park, S.W., Kwon, S.I., 2005. An Experimental Study on the Atomization and Combustion Characteristics of Biodiesel-Blended Fuels. Energy & Fuels 19, 2201–2208. https://doi.org/10.1021/ef050026h

Lorenzo-Romero, C., Buendía-Navarro, M. del M., 2016. Using social web tools in intermediate education. Interciencia: Revista de ciencia y tecnología de América 41, 98–203.

Manzorro, R., Acosta-Rueda, L., Yeste Siguenza, M.P., Hernandez-Saz, J., Oliva, J.M., Rodriguez-Izquierdo, J.M., 2015. Evaluating and Rethinking the Laboratory Practices in Chemistry Degrees, in: GomezChova, L., LopezMartinez, A., CandelTorres, I. (Eds.), Edulearn15: 7th International Conference on Education and New Learning Technologies. Iated-Int Assoc Technology Education a& Development, Valencia, pp. 4392–4399.

Martinez Jimenez, P., Pedros Perez, G., Cubero Atienza, A., Redel Macias, D., Salas Morera, L., Garcia Hernandez, L., 2010. Telematic Training Via a Website of Technicians in Work-related Risk Prevention. Presented at the CSEDU 2010 - Proceedings of the Second International Conference on Computer Supported Education, Valencia.

Norin, V.A., Norina, N.V., Pukharenko, Y.V., 2018. Interactive methods of teaching at Russian engineering universities. Education and Information Technologies 23, 2801–2820. https://doi.org/10.1007/s10639-018-9742-2

Olelewe, C.J., Agomuo, E.E., 2016. Effects of B-learning and F2F learning environments on students' achievement in QBASIC programming. Computers & Education 103, 76–86. https://doi.org/10.1016/j.compedu.2016.09.012

Olufadi, Y., 2015. A configurational approach to the investigation of the multiple paths to success of students through mobile phone use behaviors. Computers & Education 86, 84–104. https://doi.org/10.1016/j.compedu.2015.03.005

Olympiou, G., Zacharia, Z.C., 2012. Blending physical and virtual manipulatives: An effort to improve students' conceptual understanding through science laboratory experimentation. Science Education 96, 21–47.

Peinazo-Morales, M., 2012. Laboratorio virtual de caracterización de biocombustibles, Trabajos Fin de Master. Universidad de Córdoba 210.

Phua, J., Jin, S.V., Kim, J. (Jay), 2017. Uses and gratifications of social networking sites for bridging and bonding social capital: A comparison of Facebook, Twitter, Instagram, and Snapchat. Computers in Human Behavior 72, 115–122. https://doi.org/10.1016/j.chb.2017.02.041

Pinzi, S., Garcia, I.L., Lopez-Gimenez, F.J., Luque de Castro, M.D., Dorado, G., Dorado, M.P., 2009. The Ideal Vegetable Oil-based Biodiesel Composition: A Review of Social, Economical and Technical Implications. Energy Fuels 23, 2325–2341. https://doi.org/10.1021/ef801098a

Pittman, M., Reich, B., 2016. Social media and loneliness: Why an Instagram picture may be worth more than a thousand Twitter words. Computers in Human Behavior 62, 155–167. https://doi.org/10.1016/j.chb.2016.03.084

Ramírez-Romero, J.M., Rivera-Rodríguez, S.R., 2017. Aplicación del ciclo de vida y el análisis estructurado en el desarrollo de un laboratorio virtual de transformadores monofásicos. Revista Educación en Ingeniería 12, 43. https://doi.org/10.26507/rei.v12n23.732

Redel-Macías, M.D., Cubero-Atienza, A.J., Martínez-Valle, J.M., Pedrós-Pérez, G., Martínez-Jiménez, M. del P., 2015. Noise and Vibration Risk Prevention Virtual Web for Ubiquitous Training. IEEE Transactions on Education 58, 303–308. https://doi.org/10.1109/TE.2015.2415769

Redel-Macías, M.D., Pinzi, S., Martínez-Jiménez, M.P., Dorado, G., Dorado, M.P., 2016. Virtual laboratory on biomass for energy generation. Journal of Cleaner Production 112, 3842–3851. https://doi.org/10.1016/j.jclepro.2015.07.075

Rodgers, R., Chabrol, H., 2009. The impact of exposure to images of ideally thin models on body dissatisfaction in young French and Italian women. Encephale 35, 262–268. https://doi.org/10.1016/j.encep.2008.05.003

Rose, G., Ryan, K., Desha, C., 2015. Implementing a holistic process for embedding sustainability: a case study in first year engineering, Monash University, Australia. Journal of Cleaner Production 106, 229–238. https://doi.org/10.1016/j.jclepro.2015.02.066

Roy, G., Ghosh, D., Mandal, C., 2015. A virtual laboratory for computer organisation and logic design (COLDVL) and its utilisation for MOOCs, in: 2015 IEEE 3rd International Conference on MOOCs, Innovation and Technology in Education (MITE). Presented at the 2015 IEEE 3rd International Conference on MOOCs, Innovation and Technology in Education (MITE), pp. 284–289. https://doi.org/10.1109/MITE.2015.7375331

Sapia, H.M., Garcia, R.E., Olivete, C., Pereira, D.R., Trevisani, K.M., 2016. Teaching-learning firewall configuration using a visual modeling web based tool: The SP2Model and its application to Computer Science course, in: 2016 IEEE Frontiers in Education Conference (FIE). Presented at the 2016 IEEE Frontiers in Education Conference (FIE), pp. 1–8. https://doi.org/10.1109/FIE.2016.7757537

Silva, C.M., Ferreira, A.F., Dias, A.P., Costa, M., 2016. A comparison between microalgae virtual biorefinery arrangements for bio-oil production based on lab-scale results. Journal of Cleaner Production 130, 58–67. https://doi.org/10.1016/j.jclepro.2015.09.053

So, S., 2016. Mobile instant messaging support for teaching and learning in higher education. The Internet and Higher Education 31, 32–42.

Sousa-Vieira, M.E., López-Ardao, J.C., Fernández-Veiga, M., Rodríguez-Pérez, M., López-García, C., 2017. Mining relationships in learning-oriented social networks. Computer Applications in Engineering Education 25, 769–784. https://doi.org/10.1002/cae.21835

Stufflebeam, D.L., 2003. The CIPP Model for Evaluation, in: Kellaghan, T., Stufflebeam, D.L. (Eds.), International Handbook of Educational Evaluation, Kluwer International Handbooks of Education. Springer Netherlands, Dordrecht, pp. 31–62. https://doi.org/10.1007/978-94-010-0309-4_4

Torres, A.L., Mota, M.M., Ferreira, H.S., Ferreira, A.F., Darido, S.C., 2016. As Tecnologias da Informação e Comunicação e a Educação Física Escolar: a realidade de professores da rede pública municipal de Fortaleza. ETD - Educação Temática Digital 18, 198–214. https://doi.org/10.20396/etd.v18i1.8640601

Van Waes, S., Moolenaar, N.M., Daly, A.J., Heldens, H.H.P.F., Donche, V., Van Petegem, P., Van den Bossche, P., 2016. The networked instructor: The quality of networks in different stages of professional development. Teaching and Teacher Education 59, 295–308. https://doi.org/10.1016/j.tate.2016.05.022

Venville, A., Cleak, H., Bould, E., 2017. Exploring the Potential of a Collaborative Web-based E-portfolio in Social Work Field Education. Australian Social Work 70, 185–196. https://doi.org/10.1080/0312407X.2017.1278735

Verdú, E., Regueras, L.M., Verdú, M.J., Leal, J.P., de Castro, J.P., Queirós, R., 2012. A distributed system for learning programming on-line. Computers & Education 58, 1–10. https://doi.org/10.1016/j.compedu.2011.08.015

Vézina, A., 2014. The role of social media in education: How Twitter can be used in the intermediate classroom as a tool for collaborative learning, MsC project, department of Curriculum, Teaching and Learning, Ontario Institute for Studies in Education, University of Toronto, Canada.

Vidaceck-Hains, V., Kozina, M., Kirinic, V., 2016. A model of education for assistants of students with disabilities supported by information and comunication technology. Presented at the 12th International Scientific Conference on Economic and Social Development, Agcy E, Bangkok, pp. 126–135.

Watson, A., Lecki, N.K., Lebcir, M., 2015. Does size matter? An exploration of the role of body size on brand image perceptions. Jnl of Product & Brand Mgt 24, 252–262. https://doi.org/10.1108/JPBM-05-2014-0616

Wu, S., Wee, H.-M., Lee, S.-B., 2016. Technical innovation vs. sustainability – A case study from the Taiwanese automobile industry. Transportation Research Part D: Transport and Environment 48, 20–30. https://doi.org/10.1016/j.trd.2016.07.004

Zhu, H., Yang, Z., Xiong, Y., Wang, Y., Kang, L., 2018. Virtual emulation laboratories for teaching offshore oil and gas engineering. Computer Applications in Engineering Education 26, 1603–1613. https://doi.org/10.1002/cae.21977

List of tables

Table 1.

STUDENT ASSESSMENT	
I-Knowledge of the tool	Computer availability at home Particular frequency of use of the computer Frequency of use at the University
II-Development of the experience	Difficulty in managing VL Use of tutorials and video tutorials Repetition of activities and exploration of the program
III-Assessment program	Assessment of tutorials and video tutorials Assessment of the simulation environment Assessment of activities carried out Assessment of evaluation process Assessment of learning process
IV-Motivation	Degree of interest over the developed activities Arrangement and attitude

Table 2.

I	**TECHNICAL-FUNCTIONAL OBJECTIVES**	**PEDAGOGICAL OBJECTIVES**
I1	Information to the user (About how to use it and objectives)	**P1.** Relevance of contents
I2	Visual environment (content presentation)	**P2.** Efficiency of learning process
I3	Surfing the net (easiness of use, efficiency, speed)	**P3.** Adequacy of contents (to the cognitive level of the user)
I4	Multimedia items (quantity, quality)	**P4.** Ability to motivate
I5	Interactivity (possibility of manipulation, ease of data input, answers)	**P5.** Supervising (utility of help resources)
I6	Contents (clarity, organization)	**P6.** Autonomy (encouragement of decision making)
I7	Support services (availability, access)	**P7.** Cognitive effort (comprehension, comparison, exploration, metacognitive reflection)
I8	Registration of scores (access to information, utility)	**P8.** Evaluation (promoting feedback)
I9	Access to other resources (link)	
I10	Adaptation of design to educational level	
I11	Adequacy of contents to time (same class time)	

Table 3.

CONTEXT	ANNOTATIONS
Working teams	Correct
Internet connection	Good
Software operation	Initial problems to register in the website
STUDENTS	
Management of VL tool	Good
Needs for teacher supervision	Limited
Concentration	High
Motivation	Medium-high
Difficulties to achieve didactic objectives	None
TEACHERS	
Length of explanations	Short (15 min)
Working environment	Good
Students supervision	Good

Table 4.

PRELIMINARY STUDENT QUESTIONNAIRE		Frequency (%)
I. Do you use any social network?	Yes	97.83
	No	2.17
II-What social networks do you generally use?	Facebook	86.95
	Twitter	45.65
	Instagram	43.47
	WhatsApp	2.17
	Others (Snapchat, google+, LinkedIn, etc.)	19.56
III- -How many social networks do you use?	0	2.17
	1	30.44
	2	21.73
	3	34.79
	More than three	10.87
IV-How often do you use social networks?	Daily	80.4
	Three to four times a week	8.7
	Biweekly	2.2
	Once a week	8.7
V- For what purpose do you use social networks?	To chat or to show informal information to everyone	19.6
	To get information and share it	43.5
	To keep in touch with friends or family	30.4
	To publish photos and comments from others	6.5
VI- Rate from 1 to 5 how important social networks are to you, being 1 not important and 5 very important	1 Unimportant	8.7
	2 Little important	19.6
	3 Regular	39.1
	4 Important	21.7
	5 Very important	10.9
VII-Do you think using social networks affects person-to-person relationships?	Yes	71.7
	No	8.7
	Maybe	19.6

VIII- If you have Facebook, how many friends do you have?	Between 50-200 Between 200-300 Between 300-500 More than 500 Do not know/no answer	21.7 21.7 23.9 10.9 21.7
IX – Out of your social network, how many friends do you really have?	Less than 50% More than 50% All of them Do not know/no answer	15.2 39.1 43.5 2.2
X- How often do you review social networks per day?	Every 15 min Every 30 min Hourly Every two hours Above two hours	4.3 8.7 26.1 15.2 45.7
XI-Do you consider that social networks can be used in subjects as a means to provide information and communication between teachers and students?	Yes No Maybe	47.8 21.7 30.4
XII. Would you like teachers to use social networks as a means of communication?	Yes No Maybe	52.2 30.4 17.4

Table 5.

Academic Year	No. of student	Type of training	Not attending (%)	Deficient (%)	Acceptable (%)	Good (%)	Very good (%)	Main score	Standard deviation
2012-13	36	RL	0	2.8	16.67	52.75	27.78	7.06	1.65
2013-14	34	VL+RL	0	0	11.76	41.17	47.07	8.53	0.99
2014-15	14	VL+RL	7.14	0	14.28	28.58	50	8.02	1.98
2015-16	23	VL	4.3	0	26.08	30.43	39.19	7.82	2.05
2016-17	10	VL	0	0	12.30	43.55	44.15	8.10	1.87

Table 6.

ANOVA				
	Sum Sq	Df	F value	p-value
FE *vs* VL	65.16	14	2.2204	0.0183
Residuals	115.29	55		

Table 7.

	Estimate	**Std. error**	**t value**	**Pr (>|t|)**
(Intercept)	2016.13696	0.52357	3850.713	< 2e-16 ***
FE	-0.22195	0.05569	-3.985	< 0.001 ***
FE (Not attending)	-0.96544	0.24554	-3.932	< 0.001 ***
FE (score 4-4.9)	-1.22817	0.62275	-1.972	0.054
FE (score 5-5.9)	-1.19858	0.38616	-3.104	<0.01**
FE (score 6-6.9)	0.83841	0.45663	1.836	0.072
FE (score 7-7.9)	0.90500	0.45699	1.980	0.053
FE (score 8-8.9)	0.96604	0.34680	2.786	<0.01 **
FE (score 9-9.9)	0.71079	0.34655	2.051	<0.05 *

*Significance at 0.05 level; **Significance at 0.01 level; ***Significance at 0.001 level

Figure captions

Figure 1. Access to biodiesel characterization virtual laboratories web platform

Figure 2. BiomasaGen working group in Facebook (left) and access to VL via Genial.ly (right)

Figure 3. Flow chart of the experiment "determination of biodiesel density by means of a densimeter"

Figure 4. Coordination of virtual and experimental laboratories. a) Coordinated use between experimental and virtual laboratories, b) Virtual laboratory published in the social network Facebook

Figure 5. Technical evaluation carried out by the expert group (N = 6)