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Mobile Technology in Academic Laboratories in Engineering*

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This article presents a proposal for applying mobile technology in teaching laboratory and the threefold purpose of creating a safer environment for students, enhancing their culture of safety, and training engineers sensitized to safety, which eventually will allow them to make responsible decisions in their professional practice.

Keywords: mobile technology; augmented reality; safety in educational lab; engineering education

1. Introduction

Chickering and Gamson [1] (also qtd. in [2]) have outlined seven principles for good practice in undergraduate education to improve teaching and learning, which can be summarized as follows:

1. Good practice encourages contacts between students and faculty. This helps students motivate and get involved.
2. Good practice develops reciprocity and cooperation among students. This promotes team work rather than competitiveness, stimulates the learning and exchange of ideas and how to react to the ideas of others. The capacity of students to retain what they have learned also increases.
3. Good practice makes use of active learning techniques. Learning is facilitated by talking about what has been learned, by writing about it, or also by relating it with what had been learned before.
4. Good practice gives prompt feedback so that students may be aware of what they know and of what they do not.
5. Good practice emphasizes time on task. To be able to organize time in a realistic way will have an influence on the effectiveness of their learning.
6. Good practice communicates high expectations. The trust that we show, that we want to achieve and for which we work, makes students to work harder.
7. Good practice respects diverse talents and ways of learning. All learning paths are valid, we must respect them. As time goes by, students will learn other more sophisticated methods.

Even though each of the above actions has independent value, if we succeed in combining them, their effect will multiply, as they imply six basic actions for education, namely activity, expectations, cooperation, interaction, diversity and responsibility [1]. Consequently, to achieve success in the teaching-learning process will only be possible with the commitment and dedication of both students and university academic staff.

Mobile technology is becoming increasingly present in university student life, and its use is fully integrated in their daily routines. In general terms, they are able to communicate, locate information, play, make different contents public, share information, or socialise. However, the next step, i.e. to apply their technological abilities for their learning process or for knowledge building, is hard for them to take [3–7].

The potential benefits of these ICTs for education (more active learning, greater motivation for students, sharing of knowledge, better team work, and so on [8–10]), should make university teachers provide students with more opportunities for widening the range of technological tools to use (which too often only have a distracting effect) and also enhance students' learning, when incorporated into the educational process. This view is in accordance with the European Commission when they posit that teachers should teach in a different way so that their learners may learn in a better way [11, 12].

In addition, and as Escudero contends [13], high-quality university education must be effective in achieving its goals as well as efficient in the use and management of its resources. It also must seek to succeed in their students achieving both academic and professional targets and competencies which are well defined, and with a leading role in the

regulation of their own learning. In this process, the role of the teacher will not only be that of information provider, but also of coordinator, supporter, mentor and facilitator [14].

Engineering is a practical profession, a profession where the key is making things. Accordingly, the training of engineers requires academic laboratories, where future professionals can acquire the competencies, abilities, and skills that will be practical for their profession [15–17]. We consider it necessary that the learning process of engineering students should include concepts from the culture of prevention [18], in order to increase people's awareness about safety, which will allow them to make responsible decisions in their professional practice [19].

2. Presentation

The proposal presented here seeks to increase safety in the academic laboratory by means of Augmented Reality techniques for smartphones or tablets, which are considered technological devices available to most students nowadays. The aim is to provide students with tools that allow them to incorporate a preventing protocol into their working routines which minimises the risks associated to work in laboratories and which integrates safety regulations; all this in order to achieve the acquisition and development of how to become competent in risk assessment, which we consider crucial for their future professional practice.

This work has been developed and carried out in the instructional laboratories of the High Polytechnic School of Zamora (University of Salamanca, Spain), implementing different levels of Augmented Reality.

Level 0. Using the QR codes

The first stage will help our students to understand the meaning of labelling the containers of reagents. In addition, they will be provided with information on how to react in critical situations with those reagents. To do so, we will implement a level 0 of Augmented Reality, so that students might quickly access to simple information on the reagents which they will employ using QR codes and their Smartphones or the tablets which are available in the laboratory (Fig. 1).

Students might have, in just a few seconds, detailed information on reagents which are used in everyday practice. This information will include data on risks associated with the individual products and the interactions between different products used each day.

By presenting this information in an appealing way, students will find this task more entertaining,

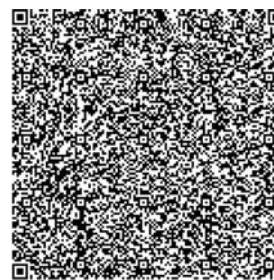


Fig. 1. QR code for Iron III Chloride.

so that they might add it to their daily routine as a preventive protocol which minimizes the risks associated with the work in the laboratory.

On the other hand, obtaining the information does not involve handling the container. Students will only need to bring their mobile device close to the container, which will make it possible to carry out a risk analysis prior to handling the material and reagents. The teacher might add an introduction on the risks of the practice of that day before students get ready for the work (taking gloves, glasses, etc.).

This information will remain in the device and it will be rapidly accessible in case the student has any doubt at a given time while working.

Level 1. Using the markers

The second stage will focus on the handling of the portable devices of the laboratory (such as a pH meter, refractometer or glassware intended to specific measurements). With the use of markers, AR environments will be created to assist them in their operation and safe use. With this technique, the teacher will not need to explain the use of the equipment every single time. Instead, the work groups can access all the required information when they need it, according to their own working rhythm.

Level 2. Markerless AR

The third stage will be similar to the second one, but it will focus on the fixed machines of the laboratory, for which an AR layer with geolocation will be created. Food Technology Laboratories are equipped with large machines. This semi-industrial equipment requires specific operating instructions and presents certain handling risks. At the same time, these devices are integrated into production lines that involve a sequential use of several of these machines. AR would make it possible for the students to establish the characteristics and peculiarities of the different machines and to locate them in their physical position so that they can establish their working sequence during the day and to decide the working protocols that lead to the highest performances while minimizing time and effort.

This would mean that the students would be more independent and they would extend their discovery learning to other fields inside the laboratory itself.

3. Discussion

3.1 Educational laboratories in Engineering

Instructional laboratories involve a number of risks related to the equipment and the chemical products employed. In such places there is a wide range and variety of hazardous products which might cause intoxication or accidents when handling [20].

The safe working practices established at each laboratory include the recommendation of an appropriate labelling for chemical products, including the verification of the label of each product received, and also the elaboration of complete and adequate labels for the solutions that are prepared.

Devastating incidents in academic laboratories and observations, by many, that university and college graduates do not have strong safety skills, have elevated concerns about the safety culture in academia. Calls for changes in the academic safety educational process and in the academic safety culture are becoming increasingly vocal both within and outside of the academic community [21].

Before performing any experiment it is necessary to foresee every possible consequence derived from the risks of handling the product, either for its nature, its state or its temperature, so that the appropriated safety measures may be adopted.

Every chemical product, whether a substance or a preparation is to be accompanied by both a Material Safety Data Sheet (MSDS) and a label.

The MSDS is provided together with the product at the time of the purchase, and does not accompany the individual packaging. It contains information on the properties of the substances and the risks to health and the environment, as well as the derived risks of their physical and chemical properties, and exposure, handling, storage and disposal controls. The safety data sheets are not conceived so much for a general and sporadic customer, but for the risks at work, since there are lots of products which are daily used by professionals. These sheets may be obtained on the web page of every trading house in case they have not been provided.

The label must be attached to the container, in a visible place which allows the user to quickly see the basic information on the inherent risks of the product, so that it may be handled taking the necessary precautions. The label of the chemical products must contain identifications, through pictographs and hazard pictograms, according to the level of risk of the product. These risk levels are stipulated and defined by law [22, 23], and they are based on their physicochemical and toxicological

properties, as well as on the specific effects of these substances on human health and the environment. Chemical reagents must contain on their labels:

1. Standardized hazard symbols and statements which stress the main risks
2. R-phrases which allow to identify risks, and
3. S-phrases which give tips on safety and establish preventive measures for handling and using the substance.

R- and S-phrases are identified with numbers from R1 to R68 and different combinations of this series, and from S1 to S64 and different combinations of them.

Within the area of labour risk prevention, Spanish universities have established general regulations in relation to work in laboratories. In this line, the working group on occupational risks prevention of the CRUE¹ has compiled and given visibility to different university initiatives focused on the prevention of occupational risks. There are many works collected on their web¹ which address safety at work. A reading of these works reveals that most of the measures adopted by the Spanish universities are aimed at the establishment of preventive measures which affect the academic staff as well as the administrative and support staff. It is a fact that these two groups present a higher contact with chemical products, and are responsible for their management and their main handling. However, we should not forget that, in many university degrees, students spend a considerable part of their contact hours in laboratories handling both chemical products and prepared solutions. In most cases, students have a huge lack of knowledge regarding the hazard characteristics of the substances handled, which might lead them to carry out dangerous working practices for both themselves and the rest of classmates who work in the laboratory.

Even though the laboratories of Food Technology of the High Polytechnic School of Zamora (University of Salamanca) meet all the safety regulations established by the University, what has been observed is that the corresponding information available for students during their laboratory practice is supplied from different sources, thus leading to students' confusion and lack of the required attention:

- In order to know the risks of the product that will be used it is necessary to know which phrases are

¹ Group on occupational risks prevention of the Conference of Rectors of Spanish Universities – Committee on Environmental Quality, Sustainable Development and Hazard Prevention. <http://apliweb.uned.es/crue2/documentacion/Higiene/norm-higiene-lab.asp>

associated with the R and S codes which are found in the containers, with all the explanations about the risk phrases.

- The label of the products might contain several R and S phrases for each reagent.

This amount of information is multiplied by an average of three or four containers used in each practice, which makes the reading of the whole information impossible to process, especially when we add the risks derived from the interaction of different reagents which will be used at the same time, and which will not be always brought in their containers.

Even in the case in which all the reagents and mixtures prepared are perfectly labeled with the necessary information, (which is not always true, especially when mixtures prepared from original reagents are concerned) it would be necessary for the student to use a lot of working time in the laboratory every day in order to establish the risks of the products that will be used in the practices and the risks derived from the incompatibility of the reagents that will be used. The student must be aware of the importance of knowing this information to prevent the risks associated with the work that will be carried out.

These are the reasons leading us to develop the experience presented here. With this, we seek our students to be in a safer environment by means of the use of tools meant to make them more familiar with the potential dangers, and which allow them to become more aware of the consequences of applying protocols incorrectly.

To do this, before starting the practical laboratory teaching sessions the teacher will hold an initial informative session. In it she will explain the safety rules, the safety data cards, the labelling, and the symbols indicating the precautions to be taken with the chemical reagents to the students.

Moreover, at the beginning of each practice session the need to be familiar with the risks associated with the handling of the reagents used in each session will be stressed. All the reagents necessary for the session will be placed together in a physical space apart from the students' work tables and will be identified with their QR labels and codes. The students should consult the information about the reagents before using them and the teacher will consult each group as to how they should handle each reagent before they take it to their work station. Indeed during the first laboratory sessions, the reports that students must complete each day at the end of the session will include questions that force them to consult the labels elaborated. However, this issue will disappear as the practical sessions advance. The teacher will use

an observation checklist where it will be reflected whether the students are adhering to the reviews of safety labelling in their work protocols.

3.2 Mobile technology

Mobile phones are becoming the cardinal feature in users' digital lives [24, 25]. Mobile users are constantly connected to the Internet and the mobile phone has become a source for accessing every kind of information [26], even in relation to the use of other devices (*Internet of Things*, IoT).

IoT is considered the next step in the evolution of intelligent objects [27–29]. The objective is to create objects that can access the Internet in any point of time and space, which transforms them into data sources with the mere use of small integrated sensors (similar, sometimes, to a sticker). The sensors use a unique identification code and allow the object to store a small amount of data that can be accessed from an external device that can transmit them.

One way of interacting with objects is the use of techniques of Augmented Reality (AR), which let the users add information to the physical world by increasing the perception of their surrounding environment. That is, it allows the users to combine the scenes that they see with computer-generated information.

As has been noted by Killer and Rampolla [28], this term appeared for the first time as a reference to the overlapping of digital information and real images in 1992 [30], although the first credited system of augmented reality was presented by Ivan Sutherland in 1968 [31]. In 1997, Ronald Azuma [32] provided a definition of Augmented Reality: “*To avoid limiting AR to specific technologies, this survey defines AR as identified by these three characteristics: 1. It combines real and virtual; 2. It is interactive in real time; 3. It is registered in 3D.*” [32, p.2].

There are multiple fields in which AR is applied today, as has been noted in [28, 33]: Advertising, Task Support, Navigation, Home and Industrial, Art, Sightseeing, Entertainment and Games, Social Networking, Translation, Education.

Also, different criteria can be applied in the classification of the types of AR: It can be fixed or mobile, depending on whether it allows the users to move [28]; depending on the type of device that represents the information, we can classify them into: head-mounted display, mobile display, computer display or spatial [28]; according to the type of main information that the mobile sensors collect (camera, GPS, accelerometer, compass), we can have vision-based AR (markers, markerless trackers, QR codes) or location-based AR (geolocation) [34]; and the level of immersion into the real world defines four different levels [35]:

Table 1. Some downloadable apps for AR

	App	Web reference
AR browsers	Junaio	www.junaio.com
	Layar	www.layar.com
	Wikitude	www.wikitude.com
	LibreGeoSocial	www.libregeosocial.org
QR code readers	QuickMark	www.quickmark.com.tw
	1QR	1qr.es
	i-nigma	www.i-nigma.com
	QR Droid	qrdroid.com
	Qr Barcode Scanner	...

Table 2. Some applications to implement AR

Applications	Web reference
ARToolKit	http://www.hitl.washington.edu/artoolkit/
Atomic Authoring Tool	http://www.sologicolibre.org/projects/atomic/en/
Atomic Web Authoring Tool	http://www.sologicolibre.org/projects/atomicweb/en/
Google Sketchup	http://sketchup.google.es/index.html
Hoppala	http://www.hoppala-agency.com/
Chrome extension	https://chrome.google.com/webstore
QR Stuff	http://www.qrstuff.com/
QR Code	http://www.qrcode.es
Aumentaty Author	http://www.aumentaty.com/
D'Fusion Studio	http://www.t-immersion.com/products/dfusion-suite/dfusion-studio
Junaio	http://www.junaio.com/develop/
Wikitude SDK	http://www.wikitude.com/products/wikitude-sdk/download-sdk/

- Level 0, Physical World Hyper Linking. Quick Response (QR) codes activate information associated to an object (hyperlinks, text, SMS, VCards, phone numbers).
- Level 1, Marker based AR. Markers are generally simple forms (squares, usually), over which three-dimensional geometric shapes can be inserted.
- Level 2, Markerless AR. No markers are used, and the information transfer is produced when the device recognizes images, objects or people, or via geolocated AR.
- Level 3, Augmented Vision. AR is projected straight on the users' eyes (via glasses or lenses) [36, cited in 37]. This model can be seen in the "Smart Glasses" project announced by Google in 2012, available to consumers in 2014.

As we have seen, there is a variety of available devices specifically designed for AR (the most ambitious project being Google Glass). However, their use is not strictly necessary when working with AR environments. AR can be managed with devices that are already being used by most students (their mobile phones) via free or low-cost downloadable apps, through Android Market, App Store, App World, and others, depending on phone/tablet, as shown in Table 1.

In order to implement AR features, first it is necessary to obtain information via the sensors or the input devices (mobile, tablet, glasses, etc.). Second, to process the information that was supplied by the sensors (with a connection to the

Internet, access to a database, object recognition, etc.), and, finally, to represent the virtual elements that are superimposed on the real image depending on the type of AR used in the output device (which is generally the same one that has the sensors). To carry out this process, we can use Web applications or free software applications (Table 2).

3.3 AR and education

AR allows us to mix real and virtual worlds by overlapping layers. Through the screen of our device, we can see the physical (real) elements together with the virtual ones, which appear as if they were really part of the same environment. This is what gives the use of AR a great potential for the teaching-learning process [38].

As it was pointed out by EDUCAUSE[®] [37] in 2005, by combining technology familiar to students with locations that students see as their own, augmented reality has the potential to move learning out of the classrooms and into the spaces where students feel comfortable. Although it may seem like this approach encourages an informal learning that is easily accessible, engaging students in learning spaces that form connections between places and contents actually promotes formal learning and, therefore, the acquisition of new skills and abilities. In this teaching approach that has been

² EDUCAUSE[®] is a nonprofit association and the foremost community of IT leaders and professionals committed to advancing higher education.

Table 3. European Projects. AR applications in Education

PROJECTS	Description
CREATE9	2002–2005 http://www.cs.ucl.ac.uk/research/vr/Projects/Create Mixed-reality framework applied to cultural heritage content in an educational context, and to the design and review of architectural/urban planning settings.
CONNECT10	2005–2006 http://www.ea.gr/ep/connect Learning environment combining science teaching in schools with science learning in science centers or museums with the aid of emerging technologies.
ARISE11	2006–2008 http://www.arise-project.org AR teaching platform integrating the everyday environment of teachers and students by the development of tools necessary for the easy production of content by non-AR-experts at a moderate effort.
SCeTGo12	2010–2012 http://www.sctg.eu/about.asp SCeTGo brings similar comprehensive learning experiences out of the SC into a school's classroom and/or everyone's home operating with ordinary hardware and thus enabling learners to experiment whenever and wherever they please.
Venturi13	2011–2014 https://venturi.fbk.eu/ VENTURI has created a user appropriate and contextually aware AR system, fully integrating core technologies and applications on a state-of-the-art mobile platform.
AR.KEY	2014–2015 https://sites.google.com/site/arkeyproject/home This project develops a training-module system based on AR for non-qualified workers from construction industry, in order to improve their mathematical competence and basic competences in science and technology, key to their professional career.

referred to as “situated learning” by [39], the location and place are an essential element, because we believe, as has been noted by [40], that learning is a context-dependent activity. Our mind naturally looks for meaning in the environment in which we are situated, and it seeks relations that make sense and seem useful.

A good compilation of experiences, research and references on the applications of AR on education can be found in [38, 41], where the authors suggest that AR reinforces the learning process and increases the students' motivation on it, and they also list a group of education projects that have been implemented in Europe and which focus on the applications of AR on Education (Table 3).

The projects described in Table 3 above are aimed at developing learning based on experience by allowing students to interact with virtual objects in an AR environment.

Along a similar line, but this time with the focus on distance education at tertiary level, we also find the virtual laboratory SARLAB jointly developed by the University of Huelva, the University of Cadiz and the National University of Distance Education (UNED). SARLAB provides a free software system for online experimental practice in education [42]. By means of AR techniques, SARLAB allows students to experience sensations and to explore with learning experiences which sometimes can be qualitatively superior to traditional lab sessions. In

[43] it is shown that its use enhances students' results, as the potential of AR to prepare different experiments with the same physical configuration is practically unlimited.

4. Conclusions

The different AR experiences assessed show that the use of this technique is not only extremely useful but also that it has a great potential for educative purposes. However, although many of these experiences are inscribed within the educational laboratory, none of them has focussed so far on enhancing the safety of students when they are carrying out their practice activities in the laboratory. In this sense, the work we present here seeks to mitigate what in our view is a lack of an appropriate treatment of safety in professional training.

In our view AR has an unparallel potential to create a preventive culture as well as to train future professionals appropriately sensitized with safety, which ultimately will allow them to make responsible decisions in their professional practice. This is our overall aim for developing the work presented here and which was implemented during 2013–2014 academic year.

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