International Journal of Engineering Education Vol. 33, No. 5, pp. 1664–1671, 2017
Printed in Great Britain
0949-149X/91 $3.00+0.00

Sustainability and Distance Learning: Technical Universities Sharing High Cost Resources*

N. EFKOLIDIS
Dept. of Design and Manufacturing Engineering of the University of Zaragoza, Spain. E-mail: efkolidi@unizar.es

C. GARCÍA-HERNÁNDEZ**
Dept. of Design and Manufacturing Engineering of the University of Zaragoza, Spain. E-mail: garcia-hernandez.cesar@unizar.es

J. L. HUERTAS-TALÓN
Dept. of Design and Manufacturing Engineering of the University of Zaragoza, Spain. E-mail: jhuertas@unizar.es

P. KYRATSIS
Dept. of Mechanical Engineering & Industrial Design of the Western Macedonia University of Applied Sciences, Greece.
E-mail: pkyratsis@teiwm.gr

Current research based on positive results and obtained experience of a previous publication has developed a training course of metrology based on sustainable characteristics such as remote control freeware applications, share of valuable resources, distance learning methodology and active participation of the students. This is based on a remote control operation using special software, with a real CMM. Although the CMM was placed at the University of Zaragoza (Spain), ten students from Greece, with the valuable help of a remote control freeware application, participated in real time measuring process from their own computers under the supervision of two instructors. The results of the remote operation of the CMM were very successful. A feeling of responsibility for using a remote piece of equipment and the extra care that the students should prove created a more stimulating learning environment. Moreover, according to the students' opinion, the process as a whole was impressive and provided a unique experience. More effort has to be made in order to increase the number of the participants and the number of the used pieces of equipment.

Keywords: sustainability; distance learning; remote control; educational-resources optimization; active methodologies

1. Introduction

This study starts from the previously published results of the use of freeware applications in order to increase the laboratory capacity in gear measurement practical sessions [1], without needing additional equipment. The main requirement for that experience was the use of the Internet to send the data, although the CMM and the students, using laptops to control it, were in the same area, as a preceding experience. A logical evolution of that research was the application of the developed methodology with students separated from the equipment. The students in this study were in Kozani (Greece) and they were controlling a CMM placed in Zaragoza (Spain).

Distance learning has emerged in response to the growing demand for educational opportunities, without the spatial restrictions of the traditional learning environments and has become an important tool in higher education. Basically, time and geographical constraints make distance learning an appropriate and attractive option for many students.

Furthermore, the straightforward need for companies to requalifying their workforce engaged in a lifetime professional development is something which should be considered as important for the future of the distance learning method. Numerous studies have investigated the differences in outcomes between distance learning and traditional learning methods.

1.1 Distance learning

At the early 90s, a novel program was developed, in which the researchers included the use of computer-integrated multimedia classrooms at both the home and remote sites, in order to achieve two-way transmission of video, audio and data [2]. The research suggested a feasible televised interactive multimedia distance education program for engineering courses. Based on that, a series of technical courses that were taught in Japanese engineering students offered to professionals at corporations and government laboratories around the United States via audiographic teleconferencing and interactive satellite broadcasts [3]. The results of this study supported the assertion that students at remote sites in a well-planned distance education program can achieve a performance comparable to that of students who receive on-site instruction.

** Corresponding author.

* Accepted 28 April 2017.

After that a computer-based and interactive laboratory system was designed and implemented for the undergraduate electrical machines and drives teaching laboratory. The changing status of the experimenting in engineering education analyzed, and the problems identified in the conventional method of delivering the experiments studied together with the proposed solutions. It was shown that the alternative and cost-effective solution can overcome most of the problems that academic institutions are facing in the area of experimental work, and prepare the academic institutions to the new era of computer-based teaching and learning [4].

The continuing education of engineering professionals has been an important objective [5]. This fact led to a relevant graduate-level program, accessible to a population of engineering professionals, separated from traditional university communities, working at remote sites while using emerging telecommunication technologies. It was later that a new approach was introduced to deliver a senior-level laboratory course at a distance in real-time [6]. The enabling technology was the combination of an interactive TV system and the Internet access. The two years assessment and analysis of student learning and achievement of learning objectives of each laboratory showed that the e-Lab created an effective learning environment.

Furthermore, a video-teleconferenced course entitled 'Principles of Biomedical Engineering I and II' introduced, for graduate students [7]. They managed to provide evidence that upon implementation of interactive distance learning methods, the on-and-off-campus students received similar final grades. Until then, during traditional distance learning lectures, on-campus students consistently received statistically significant higher final course grades than off-campus students.

The effect of a distance course format on the knowledge acquisition (cognitive learning) and satisfaction (affective learning) of students were determined, by investigating student learning responses and social presence during a graduate level engineering course taught via traditional (i.e., professor present in the classroom) and synchronous distance-learning formats [8]. The results of the research were that:

- Cognitive learning is not strongly affected by the social presence.
- Implementing strategies to enhance social presence may improve the overall learning experience.
- Distance learning experience is more enjoyable for students.

Recent advances in technology have introduced new tools to enhance learning, especially in higher education. Among these, computer simulations have been used in a wide range of contexts. Setting up virtual laboratories via interactive 3-D simulations is one way of augmenting the learning and training processes with substantial benefits. An instructional module was developed for a middle school engineering class and was intended to introduce students to the practice of engineering, using an original web-based multimedia learning environment as well as off-line, hands-on building activities [9]. A different research depicted a comparison of educational outcomes between in-person and remotely operated laboratories in the mechanical engineering curriculum [10]. That study was performed using a remotely operated and an in-person jet thrust laboratory. The laboratories illustrate the fundamentals of compressible fluid mechanics as part of an undergraduate mechanical engineering curriculum. Students develop problem solving skills by deducing the reasons for discrepancies between theoretical and actual outcomes. The results from a study (on a jet thrust laboratory) indicated no significant difference between the instructional outcomes associated with the students who carried out the experiments remotely and those who performed the experimentation in-person.

Based on the same philosophy, a number of distance courses offered a completely hands-on experience, where the student remotely controls equipment over the Internet [11]. So, the distance laboratory course was introduced, combining multi-media computer experiments, portable hands-on exercises, and place-bound laboratory experiments. Class communication was accomplished through e-mail, online discussion groups and telephone conversations. The result was that the distance laboratory was successful in introducing engineering concepts, developing hands-on skills, and motivating students to become independent learners.

The change of the classical classroom lecture model towards the more active participation of the students is something necessary [12]. It is considered that the key issue is the courses to be taught in their genuine context rather than the current more theory oriented model. This can be done by supporting the classroom theoretical lectures with real applications, closing the distance through remote operation of the lab rig during the lecture and enriching the number of utilized rigs through sharing among institutes.

One of the suitable pedagogical models for engineering education is Kolb's experiential learning framework. Kolb's experiential learning cycle is particularly suitable for engineering education which is an experiential field of science [13, 14]. A model described for laboratory education was based on Kolb's experiential learning theory [15]. The method is implemented using modern teaching technologies and a combination of remote, virtual and hands-on laboratory sessions at a Chemical Engineering Department. The results demonstrate that designing engineering laboratory education based on well-developed pedagogical theory can lead to excellent learning outcomes.

Simulation-based Learning (SBL) was used in Machining Technology at a second year engineering students [16]. The aim of this study was to investigate the effect of SBL on learners' motivation and performance. The research suggested that the students perceived their psychological needs to be satisfied and had high levels of self-determined motivation. This means that SBL can potentially enhance self-determined motivation as well as improve learning in general. Researchers described the development, implementation and preliminary operation assessment of Multiuser Network Architecture in order to integrate a number of Remote Academic Laboratories for educational purposes on automatic control [17]. Through the Internet, real processes or physical experiments, conducted at the control engineering laboratories of four universities, were remotely operated. On engineering curricula about electrical circuits, students often face problems dealing with conceptual understanding [18]. With an aim to facilitate the acquisition of conceptual understanding: a) the traditional condition was supplemented with computer-based practice and b) the virtual lab condition was supplemented with inquiry learning in a virtual lab. The result was that students in the virtual lab condition acquired better conceptual understanding and also developed better procedural skills, then students in the traditional condition.

By permitting designers to realistically, accurately and quantitatively prototype and test multiple intermediate models within virtual environment, Virtual Prototyping (VP), also known as Simulation-Based Design (SBD), has rapidly gained popularity and become a crucial part of most engineering design processes [19]. The luck of classes fixed for training of this methodology had as result the development of a rationale and its various stages for a series of web-based and self-paced VP tutorial case studies targeted at students on a course in machine and mechanism design. Interactively exploration of the process of creating engineering analysis models in a VP environment, developed skills for interactive SBD of models and development of engineering judgment by interactive exploration of a spectrum of examples, were some of the basic outcome of the research.

A network infrastructure was made for education and control of modular production system (a.k.a. a mechatronics system) and it was analyzed [20]. The structure was applied to mechatronics laboratory. In this way, an educator provided the education of trainees, from any location with internet access.

Efforts to introduce training at a national level led to the European project EUKOM, which developed a user-centered training course, using new learning methods to meet the demands of coordinate measuring machine (CMM) operators [21]. Today, this association offers manufacturer-independent courses in coordinate metrology and it is continually improving its learning methods and learning contents. The courses combine face-to-face teaching, workshops and online learning in a blended learning environment. Within EUKOM, training for coordinate metrology is being developed, aiming at synchronizing and harmonizing the training activities in Europe, while applying new learning arrangements for vocational training in a user-centered approach. Additionally, EUKOM introduces the training concept for coordinate metrology and invests on the internet as a medium for delivering learning contents and establishing learning groups [22].

Coordinate metrology is a subject that has evolved, driven by two important factors: hardware and software development. An innovative learning tool was developed and can complement existing models for CMM based training [23]. This tool simulates a complete measuring environment encompassing: the CMM, the human operator, a robot or automated system for manipulating the parts. An additional project was established and allows the implementation of an interactive teaching model, focused on the student. It combines master classes and virtual applications, in an environment known as DE–learning (driven e-learning) [24]. In particular, this project simulates the function, the calibration and the measurement implementation using a horizontal coordinate measuring machine (HCMM).

1.2 Sustainability

Nowadays sustainability concepts meet with general acceptance worldwide and are developed and implemented for a wide range of industries, research and development and manufacturing products. In a globalized, rapidly developing world, training and education sustainability is considered an important issue. In the future, only those regions and companies that develop modern training concepts with an emphasis on sustainability will continue to be competitive. Sustainability has received increasing attention in education over the last decade. The terms Education for Sustainability and Education for Sustainable Development increased their use internationally. It is in this context, that new educational programs, research institutions and scientific publications, all with an emphasis on sustainability in higher education, have emerged.

There are different pedagogic methods that have been used in order to educate engineering students about sustainability [25]. These methods were supported with data, indicating whether they achieved their learning targets. Lectures, in-class-active-learning, readings and appropriately targeted homework assignments can achieve basic sustainability knowledge and comprehension. This becomes reality by requiring students to define, identify and explain aspects of sustainability. Another way for educating sustainability can be considered the development of case studies and the application of software tools with an aim to achieve application and analysis competencies. Project-based learning (PBL) and project-based service-learning (PBSL) design projects can reach the synthesis level and may also develop affective outcomes related to sustainability.

Attempts are being made to distinguish different types of sustainability in Higher Education projects [26, 27]. The can be categorized into:

- greening the campus initiatives/campaigns, with a focus on operational improvements (eco-efficiency),
- revision of learning outcomes and curriculum reformulation and
- institutional research and development projects.

However, despite the progress achieved, sustainability has not become yet an integral part of the university system and further research is needed to tackle the complex challenges and demands within a transition to sustainable universities [28].

Current research is developed based on characteristics of the three pillars of sustainability (social-economic-environmental). From the economic point of view, the expensive CMM equipment (hardware and software license) could be virtually shared to other laboratories all over the world. The only resources needed are the remote control software and the commonly available personal computers. The rest of the financial costs are low while apart from the CMM, the used equipment (or similar) is commonly available in the universities or training centers worldwide. Moreover, many travel costs are avoided, thus making this method more attractive and appropriate for the Universities and companies cooperation. At this point should be mentioned that the total cost of a CMM machine is superior to 50.000 euro, while in the case of in-person educating method, the travel, accommodation and the rest of operational costs for the ten students who participated to this process are estimated to approximately 10.000 euros, plus the additional required time. In this way, there are many possibilities for creating revenue, especially for the Universities. From the environmental point of view, the distance learning courses prevent people from traveling, which has a great effect on the environmental protection. Furthermore, the need of fewer pieces of equipment makes possible to decrease the energy and material consumption. Last but not least, from the social point of view, this study promotes the cooperation between universities and training centers in all over the world. This kind of co-operation is considered as promising for the future. The participants have to collaborate with people from different countries, with different culture and beliefs. It is an experience for the students to be taught from foreigner tutors and operate equipment in a different country just by sitting in their laboratory.

2. Case study: training students via the web

In all aspects of engineering, metrology plays a significant role in acquiring precise and reliable measurements and thus results. For this reason, CMMs are used more and more often due to their universality and flexibility. It plays a vital role in the mechanization of the inspection process. Some of them can even be used as layout machines before machining and for checking feature locations after machining. Measurement and analysis involve gathering quantitative data about products, processes and projects. A number of actions and plans are influencing on the results from analyzing these data. Operators of CMM machine should be highly trained in order to minimize technicians' influence, they need to be provided with the necessary knowledge to carry out such tasks.

In this study, a group of 10 students, with ages of 20 to 24 years old, during the spring semester of course 2014–2015, participated in this pilot study. They were Greek students of the Dept. of Mechanical Engineering and Industrial Design, Western Macedonia University of Applied Sciences, Kozani, Greece.

Each student had a laptop, which was a property of the CAD/CAM/CAE laboratory, Dept. of Mechanical Engineering and Industrial Design. The operating system was WindowsTM XP. A basic step before the starting of the process was the installation of the AnyDeskTM software. Each laptop used the available campus's wi-fi for their connection to the web, in order to link the local computers with the computer that controlled the CMM. Two projectors (SONY VPL-VW1100ES) were connected to a set of two cameras used at the laboratory in Spain.

The connected computer to the CMM was placed

Fig. 1. CMM (from the room camera) used in the Spanish laboratory to measure a gear.

at the Centre of Professional Training "Corona de Aragon" at Zaragoza, Spain. It was a PC with Intel Core 2 6400, 2.13 GHz and 1 GB RAM and 128 GB hard drive. The operating system was WindowsTM XP. The AnyDeskTM software was installed on this computer too and the Ethernet protocol was used for the web connection. The main software for controlling the CMM was MCOSMOSTM 1 v3.0.

Two conventional video cameras were used. The first one was providing real-time images from the CMM probe when performing the measurement process on the workpiece used (Fig. 1). The second was used to show a panoramic view of the CMM lab environment and the Spanish Tutor at the same time. The CMM model was a Mitutoyo EURO-C544 and the sample workpiece measured was recommended by the equipment manufacturer for training purposes. The lecturers on both laboratories used whiteboards, that were useful for the required explanations of the measuring process, supporting conventional explanations and presenting interesting graphical materials.

A day prior to the implementation of the web-based training, an additional course was organized for the students participating. The aim was to offer a presentation of the next day's session and explain the aims and the steps to be followed.

In addition, a specially prepared material about the operation of the CMM and the measurement process was delivered in order to provide a better understanding of the next day's experiment.

At the beginning of the class, the Tutor from Spain explained how to use the CMM in order to measure dimensions using a series of generic workpieces. He connected his laptop to the CMM computer using AnyDeskTM and performed a workpiece partial measurement. At the same time with the tutor, the students had their laptops connected to the Tutor's laptop via AnyDeskTM and watch the CMM control software. Simultaneously with the use of two projectors, they were following up both the:

- measurement process via the camera placed next to the CMM probe, and
- presentation of the tutor from the CMM room camera.

After the initial measurements performed by the tutor, each student was connecting with its laptop to the computer controlling the CMM and was taking a series of measurements of the workpiece geome-

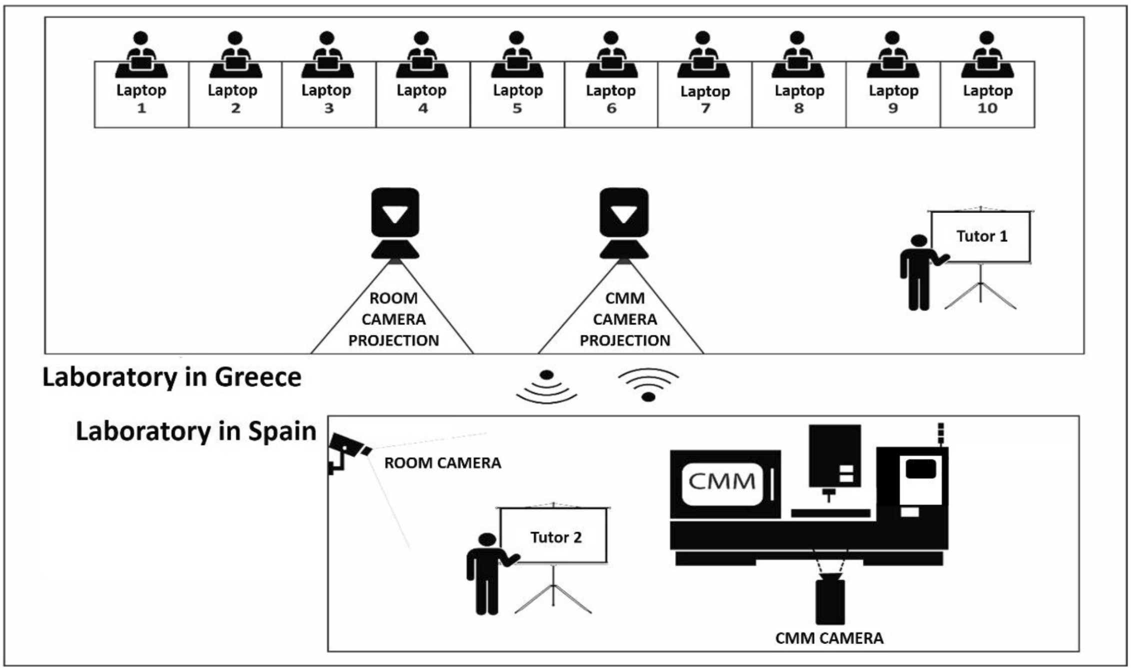

Fig. 2. Measuring process developed using the CMM placed in Spain, being controlled from students in Greece.

try. They were performing the measurements in real time, while everybody else was watching all the measurement activities. It was then that each student participated as a user of the CMM, although he/she was in a different country.

3. Results

In order to evaluate the success of the presented new teaching method, it was crucial that the students had no previous knowledge related to CMM. Students were, prior to the measurement training class, evaluated with an initial test, named pre-training test. Questions used in this test were directly linked to required mathematical concepts and aspects related to numeric control, computer aided manufacturing and machining technology. After the training class, students were reevaluated, using the same questionnaire (post-training test) in order to evaluate the acquired knowledge.

Figure 3 depicts the number of the total right answers from both the tests (pre and post training) for each of the participating students. The difference between the number of correct answers delivered by the students is clear. Only two students answered correctly in the same way on both tests.

The rest of the students greatly increased the number of correct answers given in the post-training test.

A second questionnaire used a five-level Likert scale, in order to access the feeling of the participating students about the proposed methodology (Table 1). A series of outcomes were concluded after the students experience in using the distance learning methodology:

- The workpiece model used for the study gave the students the opportunity to experience the remote control of the CMM from their own laptops via a web connection. Both the students and the web-based tutor collaborated very effectively.
- To a great extent, students strongly believe that

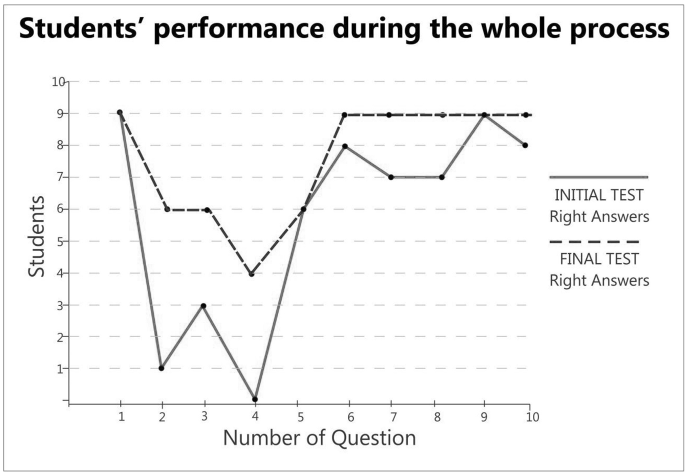

Fig. 3. Right answers for each participating student for pre and post training tests.

Table 1. Results of the students' satisfaction assessment

Item (Five-level Likert: 0 = "Totally disagree" ; 5 = "Totally agree") Total number of students: 10		**Average value**	**Standard deviation**
1	Learning to use the CMM with is method is better than just watching the teacher using the machine.	4.8	0.42
2	I feel I can measure the manufacturing quality of a gear after this class.	3	0.47
3	With this method, I can take a more active part in class.	4.1	0.56
4	I think I will apply these tools (teleconferencing and remote desktop) in future works, either as a student or as a professional.	3.8	0.78
5	I think that this is a friendly learning method.	4.6	0.51
6	I have been paying attention and I have understood what has been taught in class.	4.1	0.56
7	I think that with this method I can learn more details about how to use a CMM than just by watching somebody else measuring a gear.	4.1	0.73
8	I think this is a good method to learn how to use this type of machinery.	4.1	0.56
9	This method has improved my learning process.	3.7	0.82
10	The class has been pleasant.	4.5	0.70

learning to use the CMM with the proposed methodology is better than watching the teacher using the equipment.

- A high proportion (60%) of the students mentioned that, after their experience, they feel comfortable that they can measure real workpieces in an industrial manufacturing environment.
- The majority of them reported that with this methodology they felt the satisfaction of actively participating in the class.
- Because of their exposure to the new use of the aforementioned communication tools, they consider both teleconferencing and remote desktop utilities extremely useful for the future. They would even prefer to use them either as students or as professionals.
- They found the methodology proposed extremely friendly and very interesting for themselves. The responsibility of using a costly piece of equipment led the students to be focused on the tutor's guidelines.
- To a great extent they felt that the proposed methodology is successful for learning how to use this type of machinery and their experience was very positive and improved their learning process.

The development of the user-friendly piece of software helped the whole process to be implemented with a minimum amount of resources and thus promote the low cost and sustainable use of the available CMM.

The use of both measuring and data analysis offered a complete learning experience to the students. They have the opportunity to get involved in the measurements and then obtain valuable results from the analysis of the data acquired.

After the practical session, all students were able to access their own educational material (i.e. tutor's notes, measurement files) for further study. They were able to share results among themselves and generate valuable feedback for their final report. The role of the tutors was also extremely important. All tutors on both sides of the web had to assess continuously the process on both laboratories, making corrections or improvements in the design and implementation of the class.

4. Conclusions

Further development of this kind of resource-sharing projects would help to the creation of an educational network is absolutely necessary to increase the number of benefited students or professionals that will be able to practice with real life equipment.

The majority of similar approaches are based on remote laboratories and simulations. The current project is based on the use of professional tools, which are useful for the students, who are learning now the real machines and their control software. The visualization of the path of the measuring probe on a CMM, which is projected in real time, made possible to understand all the software commands and their effects. It is very important that the time required to adapt classes to use this method and prepare tutors to put it into practice was not excessive, especially if it is compared with the helpful results. The results can be considered only as positive. According to student opinion about the whole process, this study should be continued, while managed to improve factors such participation, interest, friendliness and even professional applicability of the introduced tools. The obtained experience made both the university laboratories to decide to keep on using this teaching methodology, at least in the metrology sector, in which the required equipment has been already installed. The most promising aspect is that those laboratories would also be able to share other machines conversely following the same process. The future plans have as target this methodology to be cultivated to the CNC machines sector. In a sustainable society, where people take more responsibility for the consequences of their actions and play a more active role as citizens and workers, they must have access to quality education throughout their lives. This process can facilitate the development of collaborative projects with participants from different centers, not necessarily in the same country. This kind of actions is conventional with the rules of the globally free market promoting simultaneously the value of the three pillars of sustainability.

Acknowledgements—This research was co-funded by Gobierno de Aragón, European Regional Development Funds, Universidad de Zaragoza and Western Macedonia University of Applied Sciences. The authors would like to thank the Direction Team of the Centre of Professional Training "Corona de Aragón", for its valuable help, making available human and technical resources.

References

1. R. M. Gella-Marín, C. García-Hernández, J. L. Huertas-Talón and P. Kyratsis, Increasing Laboratory Capacity of a Gear Measurement Practical Session using Freeware Applications, *International Journal of Engineering Education*, **32**(1), 2016, pp. 246–251.
2. B. Daily and M. Daily, Effectiveness of a Multimedia Televised Distance Education Program for Engineering Majors, *Journal of Engineering Education*, **83**(4), 1994, pp. 383–388.
3. J. L. Davis, Computer-Assisted Distance Learning, Part II: Examination Performance of Students On and Off-Campus, *Journal of Engineering Education*, **85**, 1996, pp. 77–82
4. N. Ertugrul, New era in engineering experiments: an integrated and interactive teaching/learning approach, and real-time visualizations, *International Journal of Engineering Education*, **14**(5), 1998. pp. 344–355
5. G. Rafe and J. H. Manley, Assessing quality issues in interactive video teleconferencing-based graduate level engi-

neering courses, *Journal of Engineering Education*, **88**(1), 1999, pp. 119–128.
6. H. Gurocak, e-Lab: An Electronic Classroom for Real-Time Distance Delivery of a Laboratory Course, *Journal of Engineering Education*, **90**(4), 2001, pp. 695–705.
7. T. J. Webster and K. M. Haberstroh, An Interactive, Video-teleconferenced Graduate Course in Biomedical Engineering, *Journal of Engineering Education*, **91**(2), 2002, pp. 159–166.
8. K. Mackey and D. Freyberg, The Effect of Social Presence on Affective and Cognitive Learning in an International Engineering Course Taught via Distance Learning, *Journal of Engineering Education*, **99**, 2010, pp. 23–34.
9. A. McKenna and A. Agogino, A Web-Based Instructional Module for Teaching Middle School Students Engineering Design with Simple Machines, *Journal of Engineering Education*, **87**(4), 1998, pp. 437–444.
10. M. Ogot, G. Elliott and N. Glumac, An assessment of in-person and remotely operated laboratories, *Journal of Engineering Education*, **92**(1), 2003, pp 57–64.
11. D. G. Alexander and R. E. Smelser, Delivering an Engineering Laboratory Course Using the Internet, the Post Office, and a Campus Visit, *Journal of Engineering Education*, **92**(1), 2003, pp 79–84.
12. M. Abdulwahed, Z. K. Nagy, R. Blanchard, Beyond the classroom walls: remote labs, authentic experimentation with theory lectures, *Proceedings of 19th Annual Conference of the Australasian Association For Engineering Education*, Yeppoon, Australia, 7–10 December, 2008, pp W1A8.
13. B. Bender, Concepts for purposive and motivational teaching and learning in engineering design courses, *International Journal of Engineering Education*, **17**(4–5), 2001, pp 336–41.
14. R. Felder, D. Woods, J. Stice and A. Rugarcia, The future of engineering education: II. Teaching methods that work. *Chemical Engineering Education*, **34**(1), 2000, pp 26–39.
15. M. Abdulwahed and Z. K. Nagy, Applying Kolb's experiential learning cycle for laboratory education, *Journal of Engineering Education*, **98**(3), 2009, pp. 283–294.
16. C. Koh, H. S. Tan, K. C. Tan, L. Fang, F. M. Fong, D. Kan, S. L. Lye and M. L. Wee, Investigating the Effect of 3D Simulation-Based Learning on the Motivation and Performance of Engineering Students, *Journal of Engineering Education*, **99**(3), 2010, pp. 237–251.
17. A. Barrios, S. Panche, M. Duque, H. V Grisales, F. Prieto, J. L Villa, P. Chevrel and M. Canu. A multi-user remote academic laboratory system, *Computers & Education*, **62**, 2012, pp 111–122.
18. B. Kolloffel and T. Jong, Conceptual Understanding of Electrical Circuits in Secondary Vocational Engineering Education: Combining Traditional Instruction with Inquiry Learning in a Virtual Lab, *Journal of Engineering Education*, **102**(3), 2013, pp. 375–393.
19. R. Bhatt, C. P. Tang, L. F. Lee and V. Krovi. A case for scaffolded virtual prototyping tutorial case-studies in engineering education, *International Journal of Engineering Education*, **25**(1), 2009, pp. 84–92.
20. A. Gullu, O. Aki and H. Kuscu, Remote Access for Education and Control of Mechatronics Systems, *Procedia—Social and Behavioral Sciences,* **176**, 2015, pp. 1050–1055.
21. R. Kuster, M. Marxer, E. Savio, S. Carmignato and L. Rocha, Training in Coordinate Metrology—Experiences with a dazzling Learning Approach, *Proceedings of International Symposium on Measurement and Quality Control (ISMQC)*, Krakow, Poland, 11–13 September, 2013.
22. A. Weckenmann and S. Beetz, Training in Coordinate Metrology EUKOM: Made in Europe—Open to the World. *Proceedings of XVIII IMEKO World Congress Metrology for a Sustainable Development*, Rio de Janeiro, Brazil, 17–22 September, 2006, p. 7
23. C. Neamţu, D. Hurgoiu, S. Popescu, M. Dragomir and H. Osanna, Training in coordinate measurement using 3D virtual instruments, *Measurement*, **45**(10), 2012, pp. 2346–2358.
24. P. Maresca, E. Gómez, J. Caja and C. Barajas, Virtual environment for the simulation of a horizontal coordinate measuring machine in the teaching of dimensional metrology, *Procedia Engineering*, **63**, 2013, pp. 234–242.
25. A. R. Bielefeldt, Pedagogies to Achieve Sustainability Learning Outcomes in Civil and Environmental Engineering Students, *Sustainability*, **5**(10), 2013, pp. 4479–4501.
26. A. Disterheft, S. Caeiro, W. Filho and U. Azeiteiro (2016). The INDICARE-model—measuring and caring about participation in higher education's sustainability assessment, *Ecological Indicators*, **63**, 2016, pp. 172–186.
27. A. Beringer and M. Adomssent, Sustainable university research and development: inspecting sustainability in higher education research, *Environmental Education Research*, **14**(6), 2008, pp. 607–623.
28. R. Lozano, R. Lukman, F. Lozano, D. Huisingh and W. Lambrechts, Declarations for sustainability in higher education: becoming better leaders through addressing the university system, *Journal of Cleaner Production*, **48**, 2013, pp. 10–19.

Nikolaos Efkolidis is a PhD Student at the Department of Design and Manufacturing Engineering at the University of Zaragoza.

César García-Hernández is a lecturer and researcher in the Department of Design and Manufacturing Engineering of the University of Zaragoza. He coordinates mobility programmes with European and American Universities.

José-Luis Huertas-Talón is a lecturer and researcher in the Department of Design and Manufacturing Engineering of the University of Zaragoza. He coordinates the Innovation and Knowledge Transference Department in the Centre of Vocational Training "Corona de Aragon".

Panagiotis Kyratsis is a lecturer and researcher in the Department of Mechanical Engineering & Industrial Design of the Technological Educational Institution of Western Macedonia. He coordinates mobility programmes with European and American Universities.