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Klaassen, Renate; de Vries, Pieter; Ioannides, M.G.; Papazis, S.

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R. Klaassen
Program Coordinator 4TU-CEE
Delft University of Technology
Delft, Netherlands
E-mail: R.G.Klaassen@tudelft.nl

P. de Vries [1]
Research Scientist
Delft University of Technology
Delft, Netherlands
E-mail: pieter.devries@tudelft.nl

M. G. Ioannides
Professor
National Technical University of Athens
Athens, Greece
E-mail: mgioann@mail.ntua.gr

S. Papazis
Senior Researcher
National Technical University of Athens
Athens, Greece
E-mail: spapazis@otenet.gr

ABSTRACT

This paper is about an explorative research into the use of emerging technologies in higher engineering education. New technologies are poised to better prepare students for the labour market and therefore help to endow vital innovative and creative skills. It is not yet fully clear what these skills are, but technological innovations are a good indicator of what to expect. Emerging technologies are technologies not yet widely adopted like there are 3D printing, Virtual Reality and Internet of Things. The diversity and the complexity of these technologies require a better understanding to decide about the value of such technologies for education. The research aims at the development of an approach that will help teachers to investigate, test, and assess the usability of such a technology in their micro-environment of teaching and learning.
This explorative research comprises an examination of the current use and experiences in education and the industry, an indebt analysis of some of the technologies and some small-scale experiments concerning the use of such technologies in daily educational practice. The paper summarizes the research results

[1] Corresponding Author
P. de Vries, pieter.devries@tudelft.nl

so far. Notably education is challenged to acquire an active role in assessing the usability and maximizing the opportunities of these technologies.

Conference Key Areas: Open and Online Engineering Education, Engineering Education Research, Continuing Education and Lifelong Learning

Keywords: Emerging technologies, Education, Virtual reality, Internet of Things

INTRODUCTION

This paper deals with an explorative research into the use of emerging technologies to better understand the possibilities and limitations of these technologies for teaching and learning. Technology has changed society, but not yet fundamentally transformed education. It is expected that the next generation of technologies will affect education more profoundly, also because of the massive integration of these technologies in our society at large [1]. In line with this development is the changing demand on the labor market for skills that are significantly different from what it used to be. Engineering education has been rather reluctant in using new technologies to improve their performance. The one argument has been that we do not know yet what the skills of the future will be. With the latest findings education cannot continue to say that this is a world we do not know yet [1], [2], [3]. A proactive approach is needed to figure out if and how these emerging technologies can be applied to modernize curricula and, thus, to better prepare education for their tasks and students for the labor market [4].
Emerging technologies are recent developments not yet widely adopted, but expected to influence educational practices. They tend to be in a dynamic state of change and will most likely be further developed and refined, [2], [5]. Because of the complexity, it is crucial to have a certain level of understanding to judge if a technology might help or not. This judgement is very much related to the micro-environment of the teacher who should be able to investigate, test, and assess the usability of a technology.
The first part of the paper zooms in on current knowledge and experiences derived by desk research and interviews. The following part is about a more indebt analysis of two emerging technologies: Virtual Reality (VR) and the Internet of Things (IoT), which are expected to have a profound impact on education in the years to come.

1 RESEARCH CONTEXT

1.1 Problem statement

Engineering education needs to explore the potential relevance of emerging technologies and emerging practices for teaching and learning, because these have an important role in making education more innovative and productive [2]. Therefor a better understanding is needed of what these technologies can do for education. This is a rather difficult question, because the decision on the usability of a technology or tool is being hampered by the increasing number of different emerging technologies, the speed of development, the multitude of educational settings and the time it takes to research all this, [6]. This is why teachers, educators and institutions have a hard time to develop a strategy to select and apply technologies [2].

1.2 Research focus

The purpose of this explorative research is to take a closer look at this problem, capture experiences in higher education and the industry, identify the added value for the learning process and identify what strategy might be of use. This exploration very much

looks at the micro-environment in which students and teachers are confronted with the question about the usability of these technologies. This is an ongoing research with findings from desk research and interviews and some small-scale hands-on experiments, which are half way through at the time of writing.
With emerging technologies, teachers are confronted with an unpredictable lifecycle of an application, implications for course redesign and the need to acquire new skills. This may eventually trigger a further reframing of the role of the teacher when these technologies proof to be of value [3].

2 LITERATURE REVIEW

2.1 Emerging technologies and education

Emerging technologies are technologies not yet widely adopted, but expected to influence educational practices in the years to come. These technologies like 3D printing, the Internet of Things, Virtual Reality, Makerspace, Learning Analytics, etc., are in a dynamic state of change, continuously refined and developed, but also can become obsolete with regard to new developments. In short, their state is rather unpredictable which makes it difficult to grasp the value for education [3], [5]. In addition, the diversity of educational contexts and settings and the different methodologies make it difficult to identify clear and specific implications for educational practices. Reference [5] claims that we do not have the tools yet to understand the implications of these technologies on educational practices, teaching, learning, and institutions, because it has not been researched yet.
Technology use in daily practice and in education show a multitude of technologies and applications with the overly linked patterns of usage making it difficult to decide about the specific contribution for education. The literacies needed to understand the rationale and limitations, makes appropriate and timely usage and research in this area rather complicated. In addition, the concepts and instruments used in most current educational research are not necessarily the appropriate instruments to assess the value of new technologies in new and different teaching and learning practices, [8]. Research obviously is struggling with this new complexity.
In the next two sections, we zoom in on the findings of two promising emerging technologies being virtual reality (VR) and the internet of Things (IoT). The goal is to bring the discussion closer to the interest of the main stakeholders, being the triangle student - teacher – organization and discover what these technologies have to offer.

2.2 Virtual Reality

Virtual reality (VR) simulates reality using a PC or smartphone in order to immerse the user in a sensory experience. With a VR headset on, one plunges into a 3D environment where you can look around, you can walk around and even use controllers to interact with objects and influence the virtual world you are in. In other words, users can experience and influence this world in various ways. The promises for education are that the learner is in control of the immersive environment, can move around, try things out, take tests multiple times, and explores different solutions. The one thing VR evokes is physical motion in a simulated real world and feels emotions. Obviously, VR engages and stimulates, but what do educational scientists say about the benefits?
Affordances of a 3-D Virtual Learning Environment (VLE) corresponds with spatial knowledge representation, experiential learning, engagement, contextual learning and collaborative learning [8]. More research is needed though to relate these affordances to learning benefits. One of the issues is that most studies retain the existing pedagogy

while using new technology, which makes it hard to capture what can be beneficial for very different VR supported teaching and learning practices [7], [8].
VR is seen as very helpful in subjects as engineering and architecture to design and manipulate virtual structures. VR has also shown to be effective in medical training, the military, air and space, warehouse training, coaching, onboarding, and we see more positive results, [5]. So evidence is building up which is a good basis for the verification of the perceived value and helps to guide research in the right direction. Also the technology is improving and with the investments the promise is that access and the use base will improve significantly in the years to come.
Can students learn as well with VR as in a traditional setting and what are the design features for the virtual environment to make it work [5]? The need to find out is urgent since these technologies will be dominantly present in our daily lives, in private, at work and at school. In Table 1, a summary of findings categorized in line with the educational triangle. This certainly is not complete, but is an indication of what VR is capable of and for what purpose.

Table 1. Virtual Reality: summary findings

1. Relevance for teaching and learning	· Virtual reality can mimic our sensory experience of the world. · It helps to construct an authentic learning environment · Learning with strong spatial, physical and interactive focus · An asset for inquiry-based learning · Potential for the training of practical skills · Contextual settings that mirror real world situations
2. Students	· The VR world can be experienced with others · Provide a contextual learning experience · Enables students to construct broader understandings based on interactions and virtual objects · Deeper levels of cognition and new perspectives · Exposure to real world companies and technologies
3. Teachers	· Positive impacts on the classroom, including enhanced group dynamics and peer-to-peer learning · Placing the course in a rich contextual setting · Mirror the real world in which new knowledge can be applied. · Avoid tricky laboratory settings and offer 24/7 opportunities to test, analyse and report
4. Organisation	· Incorporating VR learning environments into education programs · Serve the geographically diverse students with on-campus experiences · Facilitate group projects, discussions, networking · Renewal of staff development aiming to equip teachers with the skills and means to select, test and decide about technology use.

2.3 Internet of Things

The second technology we want to look at is the Internet of Things (IoT). The IoT is a network of smart physical objects, which are interlinked into a functional aggregation in which the whole is more than the parts. It is known as machine-to-machine communication (M2M) and some rather talk about the internet of everything (IoE) that comprises all objects, people and data smartly interacting together. IoT is inter-networking physical devices like vehicles, smart devices, buildings and other items, embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data. IoT is used by the Media for Environmental monitoring, Infrastructure management, Manufacturing, Energy management, Medical and healthcare, and others.

IoT envisions a situation in which the objects of everyday life will be equipped with microcontrollers, transceivers for digital communication, and suitable protocols that will make them able to communicate with one another and with the users, becoming an integral part of the Internet [9], [10], [11]. The IoT concept, by enabling easy access and interaction with a wide variety of devices such as, home appliances, surveillance cameras, monitoring sensors, actuators, displays, vehicles, will foster the development of a number of applications that make use of the potentially enormous amount and variety of data generated by such objects to provide new services to citizens, companies, and public administrations. This concept finds application in many different domains, such as industrial automation, medical aids, mobile healthcare, elderly assistance, intelligent energy management and smart grids, automotive, traffic management and others.
A general architecture for the IoT is a very complex task, mainly because of the extremely large variety of devices, link layer technologies, and services that may be involved in such a system, [12]. In Table 2 an overview of findings concerning the relevance of IoT use in education.

Table 2. Internet of Things: summary findings

1. Relevance for teaching and learning	· Skills shortage recommends that institutions increase diversity in STEM · Have the potential to enhance aspects of campus life · Has a great potential when it comes to learning analytics · Nice instruments for data collection · Stimulate learning experiences in a physical space
2. Students	· Students gain access to emerging technologies to transform ideas into realities · Aggregation of data will help students to understand their learning trajectories · Expected improved learning, feedback and support new experiences. · Will consolidate the involvement and knowledge of classical theory and modern technology.
3. Teachers	· Teachers need support to use IoT in strengthening pedagogical capabilities · The need of rubrics to understand the educational impacts · The self-made dashboard as a tool for coaching students at the point of time and need.
4. Organisation	· Modernization of curricula · Investment in new equipment for academic and research laboratories · Institutions partnering with industry to equip students with the latest skills · Connecting devices generate data on learning and campus activity. · Implications for privacy and security of data.

3 METHODS

The exploration started with an inventory of emerging technologies and tools that potentially give way to innovation and are used or about to be used in technical universities. The inventory was based on both a literature review and a review of reports and web resources like blogs and others and included a series of interviews with stakeholders in engineering education and at representative industries.

The exploration was extended with small-scale experiments on VR and IoT to better grasp the possibilities and limitations in the day-today learning environment. The outcome of the research so far is based on the exploration and the experiments, although not all are finished yet at the time of writing.

4 RESULTS AND OUTCOME

4.1. Emerging technologies and education

The technologies discussed are in a dynamic state of change and are continuously developed and refined, or becoming obsolete. The assumption was that these technologies can help to improve education, but we are still in a phase that we do not have the tools yet to fully understand the implications of these technologies on educational practices [5]. Research evidence over the last 40 years consistently identifies positive benefits, but also clarifies that the results very much depend on how well the technologies are being used [6]. Evidently, the skills to handle these technologies are in high demand and therefore education is urged to act. The industry worries about the willingness and capability of education to bridge the skills' gap.

Most experiences with these technologies, and in particular with VR and IoT, are in the industry. Consequently, education should use their relationships to extend their view on how these technologies work in business practice. The role of the teacher in this is crucial, but in their micro-environment they are not yet equipped to select, test and ultimately decide about these technologies.

4.2. Case study Virtual Reality

Two VR experiments are being executed which are half way through at the time of writing, so this is a state of affairs. One experiment is at the Centre for Language and Academic Skills of the Delft University of Technology (DUT) that offers a mandatory course on Presentations Skills for minors (VR-1). The second experiment is at the Department of Water Treatment at DUT, about a virtual tour in Waste Water a Plant (VR-2).

VR-1 dealt with the lack of opportunities to practice presentation skills in an authentic environment. The goal of the course is to improve presentation skills. The current program consisted of lectures, reading materials, check lists and opportunities to prepare and present short pitches and five to ten minutes presentations in groups or individually. Since the groups were large, like 60–150 students, the teachers and students felt that there was not enough time and opportunity for real time practice.

The experiment started with testing several apps for presentation skills. With the preference to self-develop an app a first design was made to clarify the demands and the requirements. Administrative issues comprised financial policy, privacy concerning the student use of an app for learning purposes and institutional ICT policies. These time consuming elements led to the decision to use an existing app with a restricted set of options. Clearly improving the possibilities to practice presentation skills requires an indebt understanding of the new technology to be able to reframe the course in the existing context. The VR-1 research focus is on the experiences of an A and B group of students and the teachers' experiences. For the analysis user data are collected, with survey outcomes and interviews to summarize the first experiences.

VR-2 is about developing a virtual tour in a waste water treatment plant. The teacher considered this tour essential for the understanding of the students, but was troubled by the fact that such tours were time consuming, difficult to plan and review and an increasing number of online students never had the opportunity to visit such a plant. Virtual tours are known tools in the tourist industry, factories, museums, the gaming

industry, etc. So nothing new, but developing a sound educational product requires a sustainable design showing installations and processes in an integrated manner.
The main question was how to develop such a tour that would fit the course design? It was decided to involve student assistants and students directly in developing the tour. They prepared a script framed by the initial course design and their experiences. They attended two introductory workshops to become familiar with VR systems and were trained to produce the VR-product under the guidance of a VR expert. VR-2 is being produced and receives lots of attention and requests from other faculties, which are faced with similar problems. Apparently, this effort evokes interest, as it is clear for what purpose the technology is being used.

4.3 Case study Internet of Things

This case study is about the design and implementation of educational experiments in an electric drives laboratory with Internet of Things (IoT) technology. The objectives were to upgrade and reengineer the existing laboratory equipment and to provide students with practical experience on up-to-date control of electric drives, and improve their understanding of the theory learned.

Along with other *smart* automation systems, electric machines have entered the realm of IoT. The induction motor control system when connected with IoT is able to circumvent a wire-bound sensor solution for drive over the web and enter the Internet-connected world. A host of embedded sensors is required in order to generate big data for cloud-based monitoring of induction motors drives and controllers.

The reengineering of existing educational laboratory includes:

- Device connectivity directly or indirectly via a gateway: electric motors, power electronics, microcontrollers, sensors, measurement instrumentation, internet.
- Data analysis, processing, decision, control, visualization and presentation, storage.
- Devices to facilitate bidirectional communication with the backend system to provide device registration and discovery, data collection and analysis, logic design and visualizations. The concept includes visualizing output data in real-time, sending data to the monitoring system and data security.

The students operate the system in both modes: with local control and with IoT control. Upgrading the educational laboratory equipment with IoT connected sensors, devices, and intelligent operations enables new educational opportunities for students, professors and curricula. It increases the benefits of the applied experience in the real physical on-site laboratory. From the professors' point of view, as human capital, there is an important investment in research and development of new innovative educational modules, with real practical application of new technological systems, involving design, test, pilot study and validation.For the educational laboratory, is expected that the IoT will result to a modernization of curriculum, plus improved operational efficiency and reliability. Our initiative improved students' experience and benefits organizations, which hired them. Although the apparent task of IoT is to connect the unconnected systems, its benefits and added-value results after data analysis and engineering and managerial decisions. The path from sensors to control and decisions involves microcomputer hardware and software, data acquisition, analysis and process, data quality and privacy and data management and builds an excellent knowledge of all involved fields of teaching, learning and apprenticeship.
So far the results in using this adapted laboratory show that there are multiple added values: new educational modules for existent curricula; well informed instructors in new

technologies; better prepared and trained graduates; industries opening new jobs for better trained candidates in modern technologies.

5. CONCLUSION

Emerging technologies will continue to influence our society and are expected to affect education more profoundly than before. To decide about the value for education we must develop an understanding of these technologies, which will allow students, teachers and institutions to judge if and how such technologies can help to improve teaching and learning. Due to the complexity, the diversity, the speed of development and the decay, education is challenged to develop an approach that can make these technologies work. For education to fully profit from the opportunities it is eminent to develop a pro-active strategy to develop a sustainable approach. The contribution of this exploration so far is that is helps to better frame the question.

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