4TU.Centre for Engineering Education

Emerging Technologies in Engineering Education:

Do we need them and can we make them work?

TU Delft Delft University of Technology

TU/e Eindhoven University of Technology

University of Twente.

Wageningen University & Research

4TU.

Authors

Pieter de Vries

Renate Klaassen

Danielle Ceulemans

Maria Ionnides

4TU. CENTRE FOR ENGINEERING EDUCATION

MANAGEMENT SUMMARY

One of the issues high on the agenda in Europe has been digital and technological skill shortages in the engineering field. Figures from the European Commission show that there could be 756.000 unfilled jobs in the European ICT sector alone by 2020 (Kiss, 2017). On average, by 2020, more than a third of the desired core skill sets of most occupations will be comprised of skills that are not yet considered crucial to the job today, according to the world economic forum. The engineering labour market change will equally be affected by the digital change. Universities play an important role, preparing students for a labour market that is undeniably moving towards the use of new emerging technologies. These technologies though are recognized only to a very limited extend in tertiary education as essential and helpful to improve the connection with the demands on the labour market. Therefore the 4TU.Centre for Engineering Education, initiated an explorative research into emerging technologies in 2015-2017.

The main aim of this research was to explore the current state of affairs of emerging technologies and develop insight into the perceived values of emerging technologies for higher engineering education.

This explorative research comprised an examination of the current use and experiences in education and industry, an in-depth analysis of several technologies and some small-scale experiments concerning the use of such technologies in daily educational practice. With emerging technologies, teachers are confronted with a plethora of tools and applications (hardware and software) which are also rapidly improving in terms of quality and applicability. The implications for course (re)design and the need to acquire new digital skills, design skills for tooling and for instructional design for teachers are demanding. It is difficult for teachers, educators and institutions to develop a strategy to select and apply emerging technologies. These technologies in itself may eventually trigger a further reframing of the role of the teacher when these technologies prove to be of value.

The literature review and the small scale experiments with emerging technologies deliver an indication of the needs in terms of creating preconditions for effective use of emerging technologies, such as appropriate tooling and training of staff and supportive expertise for teachers as well as clear insights into "How to embed emerging technologies in the instructional context" to make it supportive of learning, let alone realising labour market readiness skills.

The main conclusions of this explorative research:

- Emerging technologies will increasingly influence all parts of our society.
  They are expected to affect education more profoundly than anything 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 benefit from the opportunities it is eminent to develop a pro-active, sustainable strategy as part of an inter-institutional approach to deal with these challenges from an educational perspective.
- The contribution of this exploration for further research is that it helps to better frame the questions.

Our recommendation is to keep stimulating the use of emerging technologies in higher engineering education by demonstrating the relevance. This can be reinforced by e-leadership at macro level, open research at meso level and e-hubs on emerging technologies with process guidelines for "easy" implementation of emerging technology ideas of teachers.

From this research the next question is how to proceed? The urgency is evident and acknowledged by institutions and industries in varying degrees. The one thing that becomes clear is that to be able to deal with the challenges and to enhance the opportunities, education needs to develop a pro-active role and show leadership. Higher Engineering Education (HEE) is bound to better illuminate her role and her competences in this digital timeframe. At this moment, new educational developments predominately take place outside the educational arena initiated by commercial parties. HEE needs to claim ownership and show involvement when it comes to educational innovation. This means that digitisation must be on top of the list. This explorative research needs to be framed as part of this mission.

CONTENTS

INTRODUCTION

This explorative research into the use of emerging technologies in higher engineering education (HEE), has taken place in 2015-2017 as an initiative of the 4TU.Centre for Engineering Education which is part of the 4TU.Federation, an alliance of the four technical universities in the Netherlands. The mission of the 4TU.Centre for Engineering Education is jointly inspiring, stimulating, supporting and disseminating effective and high quality Engineering Education practices through research and application of evidence-based innovations. This research took place under the umbrella of the Virtual Lab Work Package of the 4TU.Centre for Engineering Education research programme following a rolling wave approach. Each year, starting in 2015, TU Delft chooses another theme in engineering education for study and development, with the intention to further improve the effectiveness of engineering education. A promising candidate was a comparison between virtual simulations, remote labs and virtual labs (2D and 3D) for use in blended learning applications in bachelor and master programmes. The original purpose in 2015 was to enhance flexibility of the study programmes and to help relieve the intensive use of the experimental facilities, by using these virtual simulations or remote labs.

In the initial exploration phase, however, it very quickly surfaced that traditional lab situations changed rapidly under the influence of new technologies, such as Virtual Reality (VR) using a variety of headsets e.g. Google Cardboard, Samsung Gear VR and Oculus Rift and other new practices to make things work according to today's standards (Jansen, 2015). So, contemporary virtual and remote labs necessarily contain many more technologies that in general belong to the technologies which can be qualified as emerging technologies with a potential value for education, but are not yet used extensively. Therefore very early in the phase of research design, it was decided to extend the field and put the focus on the broader field of emerging technologies.

Emerging technologies are poised to better prepare students for the labour market and help to endow innovative and creative skills (Kamp, 2016; World Economic Forum, 2015 & 2016, Dassault, Xavier Fourget, 2017). It is not yet fully clear though what these skills are, but technological innovations are an indicator of what to expect with respect to emerging technologies. Universities should equip students with digital engineering skills to solve future problems and to work in industry 4.0. According to companies such as Microsoft, Dassault systems, OCE and Netcompany this is not done sufficiently (SEFI 2018, panel discussion). The increasing shortage on labour markets for technologically trained students becomes more urgent towards 2020 as vacant positions impact our economy at large (Kiss, 2017; European Commission, 2016; European Commission, 2018). The 4TU have and feel a responsibility to deliver sufficient qualified students to the market to limit economic havoc. Yet are equally searching for answers to realise evidence based improvements on technological developments in education.

The classification of the so called emerging technologies is that these are not yet widely adopted technologies, but some like 3D printing, VR and the Internet of Things have spread substantially in the business environment and increasingly appear in professional education. The diversity and the complexity of these technologies require a better understanding to decide on the value of such technologies for education. They evoke the use of different teaching and learning practices. It requires a certain level of understanding to be able to judge if a technology can be of value in HEE teaching and learning practices. Therefore education is challenged to acquire an active role in assessing the usability and maximizing the opportunities of these technologies. As such the intention was to look into an approach that will help teachers to investigate, test, and assess the usability of such technologies in their micro-environment of teaching and learning and develop a better judgement of the value and what it takes to make these technologies work.

In this study we have explored emerging learning technologies and emerging practices and their the potential relevance for teaching and learning.

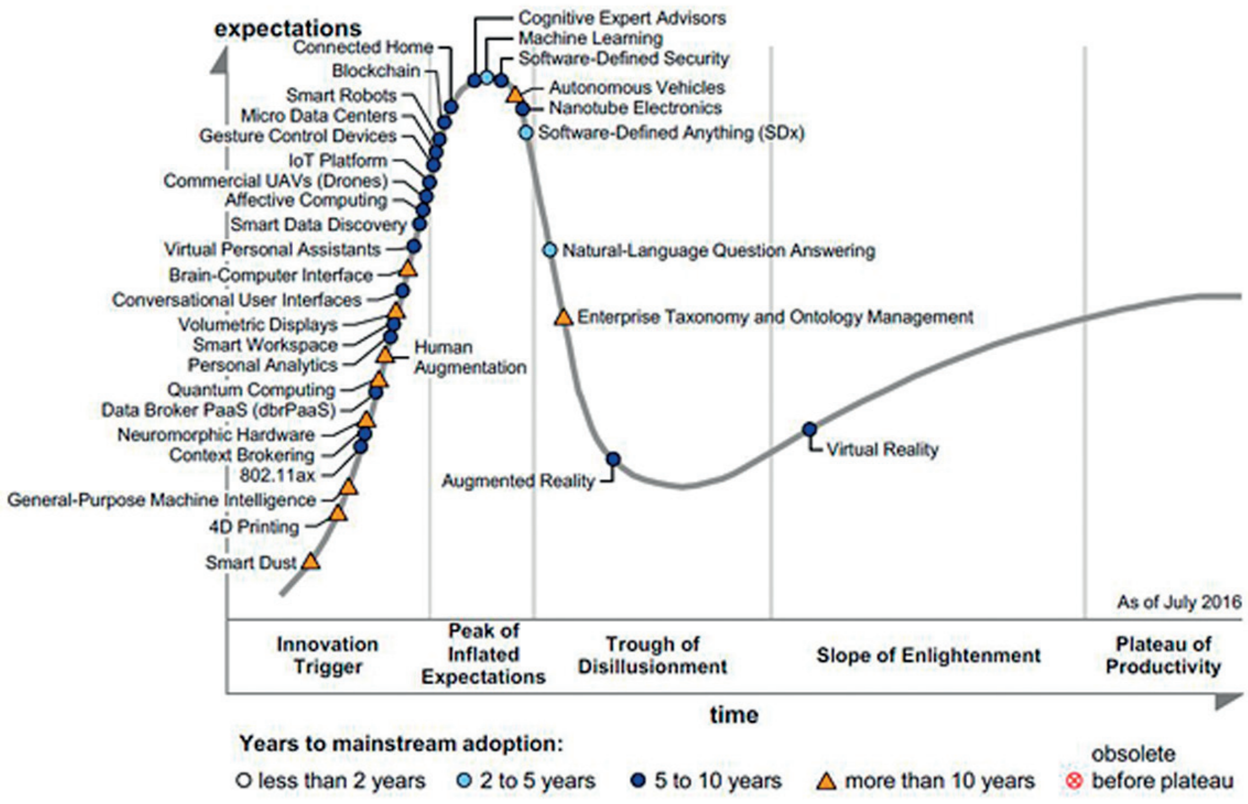
Research focus

The purpose of this exploration is to find ways of how to deal with these technologies from an educational point of view. In this stage of the exploratory study we have considered questions such as what kind of technologies fit the perception of what emerging technologies are, which technologies are already used, what is the relevance for HEE with a focus on the added value for students, for teachers and the consequences for the organisation, and which activities do teachers need to do to make things work? The first part of the report deals with the general review including a selection of emerging technologies. The exploration is limited to technologies that are considered relevant and usable within a certain period of time (Gartner, 2016; King & South, 2017; Johnson, Adams Becker, Cummins, Estrada, et al, 2016; Adams Becker, Cummins, Davis, Freeman et al. 2017). These technologies are: Virtual and remote laboratories/experiments, Virtual Reality (VR), Internet of Things (IoT), Makerspaces and Bring Your Own Device (BYOD).

In the second part the focus is on the two technologies that are considered the most promising for the years to come, which are VR and IoT. As can be seen in the Gartner hype cycle (figure 1), VR is poised to enter the market rather soon and IoT is located in the innovation trigger category. The hype cycle report on emerging technologies provides a cross-industry perspective on technologies one should consider in developing emerging-technology portfolios (Gartner, 2016).

Figure 1: The Gartner Hype Cycle (2016)

The Gartner analysis is an estimation about the timeline for technologies to reach maturity



Source: Gartner (July 2016)

An important educational reference is the Horizon report with a focus on the five-year horizon for higher education institutions in relation to trends and technology developments which will drive educational change (Adams Becker, Cummins, Davis, Freeman et al. 2017). The yearly report focuses on the critical challenges and the way to strategize solutions. VR and IoT are considered important technologies with a role in key trends such as blended learning designs, advancing cultures of innovation and redesign of learning spaces. The financial analysis by Goldmann Sachs (2016) on the emerging investments in VR seems to support this estimation and this is equally true for IoT. Therefore VR and IoT have been selected to be used as an illustration of the kind of technologies and functionalities that are likely to affect education in the short run in a way different than technologies have done so far (Carlton, 2017; Kirkwood, Price, 2013; Mesquita, Peres, 2016, World Economic Forum, 2016).

The rationale for the research

An important stimulus for this explorative research into the use of emerging technologies for teaching and learning is the digital engineering skills gap, or as some call it 'the mismatch of supply and demand of skills needed by today's employing industries' (Kiss, 2017). Looking at the progress made, it seems an issue that requires permanent attention as it is firmly related to the ongoing changes in society. In general shortage emerges where the skills required are unavailable in the workforce and the opportunities for change insufficient. It might be that people are over- or under skilled, whatever their qualification level, but apparently their skills do not match the job (Cedefop, 2015). One of the actions taken to deal with the mismatch is to forge stronger links between institutions and industry with structured partnerships as 'knowledge alliances' to adapt curriculum to demands of society (European Commission, 2016).

The rapid changing demand puts a lot of pressure on education and the promise is that emerging technologies might help to solve the problem. The new industrial revolution of the creative knowledge economy necessitates that people of all ages embrace technology and virtual connectivity, pursue more flexible occupations, utilising creative and social intelligence to drive innovation (Bakhshi et al. 2015; Frey and Osborne, 2013).

The growing expectations also contain the believe that the use of technologies will help HEE to become more innovative and productive (Klopfer, 2016). However, technological adaptation does not necessarily mean better performance. Some believe that technology is the way to go (Johnson et al. 2017), others believe that the effect of technology on teaching and learning has been limited and expect that it will not fundamentally change education (Bruyckere et al. 2015). It is evident that our society at large, including education, has been infiltrated over the last decade with technologies and tools that have affected our way of life in a rather profound way (World Economic Forum, 2016). This is also true for the educational community. The smartphone is a prominent example and can be considered an important reference to judge the prospect of technology use on a day-to-day basis. As such, education shows the same pattern of technology use as society as a whole. These also include tools that become obsolete, stop to exist, are withdrawn or merge with other developments (Johnson et al, 2016, Adams Becker et al, 2017; Veletsianos, 2016a, 2016b). In most cases, it is difficult to understand the value or the implications of these technologies for education. The promise of these technologies also relies on factors hard to influence like politics and economics. So, it is crucial to have a certain level of understanding to be able to judge whether a technology might help or not. The multitude of options and heterogeneity of teaching and learning settings, requires a decision-making process that can be handled to a large extend by the prime users, as became apparent in many of our informal conversations with experts in the field.

The general availability of technology implies that every technology can be considered to play a role. Interestingly the most used technologies in education are not developed for education, but are consumer products. Jane Hart (www.c4lpt.co.uk) has compiled a top 100 Tools-for-learning list over the last ten years and clearly the top ten of this list has always been tools like; YouTube, Google search, Twitter, Powerpoint, Google docs, Facebook, Skype, etc. In 2017, the first dedicated educational technology is the open source course management system Moodle on place 35. Learning technologies as such play a minor role in technology development in general which underlines the fact that education is a follower and therefore consequently lags behind. It seems therefore encouraging that at this moment the investment in educational technology is ten times more than it was a decade ago (Goldman Sachs, 2016). Gartner predicts that worldwide investment in technology will rise 1.2% in higher education. The focus has shifted from cost reduction and efficiency towards using technologies for the enhancement of competitive advantages and emerging business models. The promise is that technology is likely to influence education in every aspect of how we teach and how we learn (Adams Becker et al, 2017; Carlton, 2017). At the same time, we know that technology use in education has always been rather complicated as it is hard to decide about the value, because of the diversity of technology and educational methodologies being used and the perceptions of their impact on the learning results or students (Higgins, 2012; Kirkwood et. al, 2013). It is evident that technology engages and motivates young people (World Economic Forum, 2015; Carlton, 2017). However, this benefit is only an advantage for learning if the activity is effectively aligned with what is to be learned. So, the impact is not whether technology is used (or not) which makes the difference, but how well the technology is used to support teaching and learning (Brinson, 2015; Janssen et al, 2016, King et al, 2017). The challenge is to ensure that technology contributes to improvement.

Consequently, the added value depends on the situation and the goal one has with the technology and the combinations of technological tools used (Zhang et al, 2017). The believe that technology should have a stake in making education more innovative and productive requires an even better understanding of what technology can do for education. This is a rather difficult question, because the decision about 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 (Higgins, 2012). These are reasons why teachers, educators and institutions have a hard time to develop a strategy and, in the end, to select and apply technologies (Johnson et al, 2016, Adams Becker et al, 2017).

Problem statement

The exponential growth of technological developments and digital change caused schools of engineering, like many of us in society, to lag behind in adapting to technological change at an equal development rate. As these technological changes are more pervasive than ever before and require different ways of working, industry needs engineers who can deal with these emerging technologies. Currently the knowledge and use of emerging technology is limited in HEE and this asks for a first exploration. HEE cannot allow itself to not act on this problem. This report contributes to this exploration by answering essential questions on how to deal with emerging technologies. We therefore need to find out what emerging technologies are, what the perceived relevance is and what is needed to make these technologies work related to the importance of emerging technologies for education to learning innovation and the demands from industry.

The exploratory questions which we have used throughout the literature and interview study are:

1 What are emerging technologies?
2 What is the relevance of emerging technologies for education?
3 What do teachers need to make emerging technologies work?
4 What is the perceived value of using emerging technologies in education?

METHODS

This research into 'emerging technologies' started with an inventory of technologies and tools that potentially give way to innovation. The inventory was based on both a literature review (scopus, research gate) and a review of reports and web resources like blogs and others and included a series of interviews with stakeholders in tertiary engineering education and representatives of "emerging technology" industries. No preliminary scaffolding criteria for peer reviewed journals and such were included as the available literature was limited at the time. Stakeholders were found and selected via conference attendance, joint collaborations within and beyond 4TU and industries already incorporating VR in their working approaches. Similar to the literature resources there is no systematic sample selection of stakeholders as we tried to identify key persons in the field while exploring the topic.

The key words used in the literature review were: emerging technologies, emerging learning practices, 3D environments, virtual labs, virtual experiments, remote labs, remote experiments, virtual reality, augmented reality, internet of things, learning technology, educational technology, informal learning, self-directed learning, micro learning, design-based education, skills gap and 21st century skills.

The technologies selected for general review were: virtual and remote laboratories/experiments, Virtual Reality (VR), Internet of Things (IoT), Makerspaces and Bring Your Own Device (BYOD). In the research focus paragraph it is explained why we chose for these emerging technologies, as they are expected to have a high impact on education and/or industry within the next 0-10 year cycle, when starting this research. As we speak (2018) IoT, VR and makerspaces are still high on the list of emerging technologies.

Small scale experiments were used for further analysis using VR and IoT for reasons of potentially high impact (Gartner, 2016; Adams Becker et al, 2017). Another reason was the practical availability of teachers wanting to invest time in these emerging technologies, giving their time and courses as possible exploration grounds.

Interviews were held at the Dutch Technical Universities (N=12) with representatives of different disciplinary domains such as Electrical Engineering, Civil Engineering, Systems Engineering, Industrial Engineering, Math & Computer Technology, Science and Technology and the School of Education. The foreign universities and industry include site visits (N=4) and additional informal exchange and conversations at conference meetings or other settings. The interviews were semi structured and covered the following issues: the what, why and how of new technology use; the perceived value; the experiences; the type of technology and the expectations regarding the students' learning process. The small experiments planned as part of the inventory allowed for a more thorough analysis of the what and how.

Part of the explorative research were some small-scale experiments with the focus on collecting first time experiences regarding the use of such technologies in daily educational practice. There were four small experiments of which three with VR and one with the Internet of Things. The purpose was to show in more detail what these applications require from the teacher and the institution to make it work in a first instance and what these technologies on that beginners' level have to offer. VR is seen as very helpful in subjects as engineering and architecture to design and manipulate virtual structures. From research, it is clear that VR engages and stimulates, but more research is needed to see how affordances of a 3D Virtual Learning Environment (VLE) corresponds with spatial knowledge representation, experiential learning, engagement, contextual learning and collaborative learning and how this relates to learning benefits. The other application was the Internet of Things, which is a network of interlinked smart physical objects into a functional aggregation in which the whole is more than the parts. It is known as machine-to-machine learning (M2M) as shown in the Gartner hype cycle or as the Internet of Everything (IoE) that comprises all objects, people and data smartly interacting together. This experiment led to upgrading the educational laboratory equipment with IoT connected sensors, devices, and intelligent operations enabling new educational opportunities for students, professors and curricula.

LITERATURE REVIEW RESOURCES

In this section we will first discuss the answers to exploratory questions with respect to emerging technologies (1), the relevance for education, (2) teachers' needs (3) and perceived values (4). In the next chapter the case studies will be discussed.

1. Emerging technologies

The important first question was, what are emerging technologies (EQ1)? These are technologies not yet widely adopted but expected to increasingly influence society as a whole including educational practices. Illustrations of such technologies are 3D printing, IoT, VR, etc., These are progressive developments which ought to bring a competitive advantage, but the way they develop makes it rather difficult to grasp the value for education (Johnson et al., 2014, 2015; Veletsianos, 2016a). They are in a state of change, continuously refined and developed, which might even include the fading away of tools as they become obsolete with regard to new developments. This is even more noticeable when zooming in on VR as one of the most promising technologies for teaching and learning. Veletsianos (2016a, 2016b) 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 thoroughly researched yet. He also argues that we should stay away from techno-utopian and techno-deterministic thinking, the technology as the ultimate problem solver, because the promise of a transformation mostly ignores a variety of factors that is hard to influence like politics and economics. Therefore, no general statement can be given about the impact of technologies, but also no unified strategy of how to cope with these new developments, the technical and educational complexity and the heterogeneity of institutions.

2. Relevance for education

The assumption in this exploratory research was that emerging technologies can help improve education. In other words: what could be the relevance for education (EQ2)? Overall, the research evidence over the last forty years about the impact of digital technologies on learning consistently identifies positive benefits (Higgins, 2012). It is clear though that the diversity of contexts and settings and the different methodologies make it difficult to identify clear and specific implications for educational practices. In some cases, it seems that effective schools know how to use technology more effectively than others, but is this true under all circumstances? In general, it seems that technology use does not make the difference, but how well the technology is used to support teaching and learning practices and how well it is aligned with what is to be learned and the underlying pedagogical assumptions of the teacher (Brinson, 2015; Kirkwood et al. 2013; Janssen, 2016). No magic box here and no guarantee that technology use will logically lead to better results. So, why use technology? The meta-analysis by Higgins (2012) and the one by Zubia (et.al, 2016) support the assumption that technology indeed might be of help, but the role needs to be clear, which is related to the functional criteria for educational design, access to content, feedback, collaborative effective interaction.

These are no easy questions, also because digital technology is not introduced in a vacuum. It is therefore very important to identify carefully what it will replace or how the technology activities will be additional to what teachers and learners would usually experience (Higgins, 2012).

3. Teachers' needs

What do teachers need to make emerging technologies work (EQ3)? Teachers need some love to experiment with technology, others despise the fact that technology carries a substantial amount of uncertainty and prefer proven solutions. After all these years in which teachers have been confronted with technology it is obvious that a clear strategy is needed to make it work (Davis, 1989; Mesquita et al., 2016, King et al, 2017). Mesquita (2016) reveals that the success of technology adoption relates to several critical organisational and individual factors with enablers like organisational strategy and support, training, equipment and applications and straight solutions for constrainers like intellectual property, credits, development of new materials, etc. Surely not all factors are equally important at all times, but without a clear strategy, technology will continue to be very unpredictable and difficult to use for teachers in their micro-teaching and learning context. Teachers are known to be skeptical about the value of technology, the appreciation though seems to increase with the instructor's experiences (Jaschik et al, 2016). This appreciation is considered to increase as well with evidence-based confirmation that technology helps to improve teaching and learning practices. An important hurdle for the use of technology in education is the 'lacking awareness' of what the benefits and consequences are. In general teachers seem not aware of the 'affordances' of ICT (applications) and do not know how to appropriately apply the technology. From research, it becomes evident that teachers use ICT, but have no clear idea about the purpose or outcome and qualify these in very general terms (Voogt et al, 2016). The lack of appropriate skills combined with the increasing diversity and the speed of development increases the need for dedicated research into this area which shows an increasing level of complexity. In addition, because of the diversity in research concepts and instruments that have been used in formal environments like in the traditional classroom may not be the right approach to assess the value of new technologies (Poquet et al, 2017).

4. Perceived values

EQ4 was about what technologies are used in education and how these are being used. This exercise was guided by the question about the perceived value with a focus on the relevance for education in general using the student, the teacher and the organisation as first-time parameters to develop an overview of a series of emerging technologies (see Table 1, p.15). Most resources for this exercise were web-based coming from stakeholders like producers and vendors who dominate the information channels and therefore the level of verification and argumentation of the educational benefit was trivial at times. Next to these channels are the research institutions and larger companies that reflect on these technologies with their business in mind. Hardly any evidence-based research can be found, apart from some interesting findings in niche areas. Literature results from scopus articles have been incorporated in the overview. Experiments were, however, scant and few. In terms of data most likely of equal significance to the random websites visited, as the movement was at its very early stages. Interview results have equally been incorporated in the overview of the data. This is logically related to the fact that the overall diversity of technology and the very different teaching and learning practices are hard to deal with and takes time. For the inventory, the main parameters used, were the valuable triangle of students, teachers and the educational organisation, which is reflected in table 1 with a summary of findings for: virtual and remote laboratories/experiments, Virtual Reality (VR), Internet of Things (IoT), Makerspaces and Bring Your Own Device (BYOD).

Each technology is defined, followed by an overview of the most important elements mentioned in the resources related to the student, the teacher and the organisation with in addition remarks made in relation with the relevance for HEE in general.

Table 1. A selection of Emerging Technologies and their perceived value for education

Virtual and remote laboratories/ experiments			
A virtual laboratory/ experiment uses the metaphor of a real laboratory, to setup a variety of experiments from pre-designed components. These components are computer programmes that either simulates physical processes or theoretical models.			
Perceived value for education	Student	Teachers	Organisation
• Real labs and experiments can be too complex, expensive, dangerous • In principle, easily reproducible • More variable than real situated labs • Allows access for an unlimited number of students • Access 24/7 at time of need • Less laboratory capacity, financial and other constraints • Reduced or no supervision • Comparable with processes in today's industry	• Labs can be aligned with the student's needs • Less facility and time constraints to experience and experiment • 24/7 accessibility • Reduced or no supervision • Range of experiences extendable	• Integrate, develop and maintain the virtual applications • Hybrid lab approach • Mimics today's industry reality • Other and new educational designs to arrange the teaching and learning • Extended and variable offering of lab-situations	• The means and instructional purpose of the laboratory techno-logy becomes more manipulative, inter-active and more 'real' • Offering multiple dimensions to the virtual laboratory experience • Current science lessons and hands-on labs increasingly involve computer and technological mediation as part of their process • Stimulates a 'hybrid' (blended) approach to laboratory learning

Virtual Reality (VR)			
Is about computer-generated environments that simulate the physical presence of people and objects to generate realistic sensory experiences.			
Relevance for education	Student	Teachers	Organisation
• VR 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	• The VR world can be experienced with others • Provide a contextual learning experience • Enables students to construct broader understanding based on interactions and virtual objects • Deeper levels of cognition and new perspectives • Exposure to real world companies and technologies	• Enables students to have life like experiences • 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	• Incorporating VR learning environments into education programmes • Serve the geo-graphically 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

Internet of Things (IoT)			
Is a network of smart physical objects, which can be interlinked into a functional aggregation in which the whole is more than the parts. This sounds futuristic, but we all are experiencing how the connected home, the connected workplace, and the connected government is coming to life.			
Relevance for education	Student	Teachers	Organisation
• Skills shortage recommends that institutions work to increase diversity in STEM education • Have the potential to enhance aspects of campus life • Great potential for learning analytics • Powerful instrument for data collection • Stimulate learning experiences in a physical space	• Gains access to emerging technologies to transform ideas into realities • Aggregation of data that help to understand learning trajectories • Is expected to result in improved learning experience, feedback and support new learning experiences	• Need support for the usage of IoT in strengthening pedagogical capabilities • The need for rubrics to understand the educational impacts • Dashboard-like tools to support students at the point of time and need	• Institutions partnering with industry to enable and equip students with the latest skills • Connecting devices generate data on learning, campus activity, content delivery. • Implications for privacy and security

Makerspaces			
Makerspaces are informal workshop environments located in community facilities or education institutions. They offer tools and learning experiences to help people carry out their ideas. The driving force behind makerspaces is the maker movement.			
Relevance for education	Student	Teachers	Organisation
• Tools like 3D printers, robotics, and 3D modelling applications become accessible to more students. • New opportunities to stimulate creativity, design, and engineering. • Allow to gather and create prototypes or products in a collaborative, do-it-yourself setting.	• Makerspace aims to help its students develop digital literacies and engage in self-directed learning • Provide a place for users to engage in self-directed activities that help them identify passions and interest. • Supplies a space with multimedia and 3D print production, video, audio, animation and 3D modelling	• Hands-on design and construction engages students in creative problem-solving and higher-order thinking • Engineering curriculum primarily focused on theory and mathematical modelling • Makerspaces provide the opportunity to partake in hands-on activities	• Makerspace as a tool for learning space redesign. • Gained traction in only a couple of years • Often developed as an extension of the campus library • Dynamic collections of tools as VR equipment, digital editing software, 3D printers as such

Bring Your Own Device (BYOD)			
BYOD is a smart move to use all available technologies in the learning community to access and interact in a flawless way. It reflects the contemporary lifestyle and way of working (smartphone). Important question is how to most effectively integrate and support them.			
Relevance for education	Student	Teachers	Organisation
• The link between personal devices and learning • The question about how to most effectively integrate and support them • Facilitating ubiquitous learning and productivity gains • With home-made dedicated apps a faculty can update the deliverance of content and assess student learning	• Students expect to be able to use whatever devices • They choose to access learning content, take notes, gather data, and communicate • Using their smartphone 24/7 for communication and access	• Need to integrate this option where relevant (organisational, assignments) • Have a 'deck' to work from • BYOD enables students and educators to leverage the tools that make them most efficient • Could include location-based services, social networks, and video streaming	• Supporting technology and staff to develop and maintain developments in line with the 'technology policy' • BYOD policies are enabling a faculty to update the ways in which they deliver content and assess student learning
Resources: Adams Becker et al., 2017; Briggs et al, 2016; Carlton, B., 2017; Janssen et al, 2016; Jaschik et al, 2015; Johnson et al., 2015, 2016; King et al, 2017			

The most common findings concerning the student are the better options for alignment with the students' needs; less facility and time constraints; better situated contextual learning; more exposure to the real world of companies and technologies; improved learning experience like self-directed learning in a 24/7 type of communication and access. For the teachers it is also true that today's emerging technologies used in industry are becoming more accessible, but this requires other and new educational designs; avoidance of tricky lab sessions with much more options and variety and more hands-on activities and the leveraging of tool use. For the teacher to be able to handle these options, training and development are required in a very hands-on way to master the new situation, which can be characterised by continuous change. For the educational organisation it is a challenge to develop a sustainable strategy that supports these developments. Clearly this is not a one-sided situation. The organisation will be better able to serve the students and teachers using technology, like geographically dispersed students. It is an opportunity to equip teachers and students with the latest skills and means to select, test and decide about technology use; the technology generates data on learning, campus activity, content delivery and as such is very helpful for educational redesign.

From the analysis it can be shown that the relevance for HEE is present in different modes. The possibilities to construct or participate in authentic learning environments; with the increasing potential to train and learn practical skills; increasing diversity in STEM education; the increase and improved access for a broader range of students; the great potential for learning analytics.

OTHER RESOURCES

In this part the results of the interviews and non-literature resources such as conference contributions, web sources and the many informal conversations will be discussed.

The present reality in institutions and industry

This explorative research allowed for a few interviews and visits and certainly does not reflect a complete analysis of the current situation in the institutions and industry. Nevertheless, the information is meaningful and helps to develop a better understanding while combining the different perspectives.

The interviews in the institutions clarified that most of the emerging technologies were used for research goals in different disciplinary domains and not to support teaching or learning. There was no analytical framework or educational model available or an overview of technologies used in the available learning practices. If technologies were used, the people involved were highly convinced of the added value for education and those who did not use it for educational purposes were willing to take a closer look, but only if educational support would be available to help them master the situation.

The kind of technology used in education is quite fragmented. In the interviews, we specifically considered tools prepared for learning and teaching. In reality education is very much like the real world in which different types of technologies are used for all kinds of purposes. Technologies like Twitter, Facebook, YouTube, Google docs, etc. are consumer technologies not developed for education, but widely used to share, improve, validate and better organise education. Thus, emerging technologies influence emerging practices, but will do that in very different ways (Veletsianos, 2016a). In that sense, it is helpful to distinguish the different kind of technologies that are available for education, which are not necessarily developed for it and might serve very different purposes or even become contra productive.

The discussion with stakeholders from two technical universities abroad revealed that the use of technology is a must and is seen as a prerequisite for learning innovation. Therefore the link between technology and the advantages is considered crucial. This requires a healthy collaboration with the industry using experiments and pilots to deliver value for all partners. In universities to make sure staff is trained with new skills relevant to today's smart manufacturing and other extended digital practices, in industries to make sure the students are provided with the right skills to be employed in the labour market.

High on the agenda was the combination of the existing educational practices with the new approaches. A vision and strategy are needed, also to deal with the demand for new competencies. The outcome of the discussion with industry started with a broader view on the role of technology. High on the agenda is the need to bridge the skills gap for today's students, which is partly created by rapid technological change and short business cycles.

The use of technologies in industry is a must and consequently a must for learning and for learning innovation. VR is especially helpful when it comes to addressing issues that require imagination creativity and high problem solving ability (Huang, 2010). The response of Higher Education seems not efficient enough, which is limiting the collaboration with industry and that is considered detrimental for the economy. New technologies like VR-engines which support VR- platforms are used to support daily working practices, but also to bridge time and place and master quickly changing product knowledge.

There is a clear message from the industry: education needs a vision and strategy for the integration of emerging technologies and the engagement of institutions and teachers to master the process of using technologies to support learning activities (Mark, Fouget, 2018

Sefi). Training should be up to date, focus on new developments, provide skills for in time and self-directed learning and for transferrable and collaborative skills learning. Despite the fact that the competences level of students has increased in this area, it is not enough as industry needs people with multi-level skills that can work with cobots, robots and alike, across disciplines and with an understanding of the design and technology. The 4th industrial revolution with amongst others Artificial Intelligence (AI), is at our doorstep, albeit not very intelligent yet, but it will not take long before AI will guide systems for deep learning. Thus, education should keep pace, support and supply guidance for educational improvement to overcome the time to market pressure. VR engines co-created with education (technical universities) and companies like Philips, ASML, OCE, Dassault systems should offer numerous opportunities for collaboration.

Naturally a viable business model to assure sustainability is of utmost importance and in this context, it is to consider the possibilities for collaboration with market leaders like Microsoft, Dassault, Meaven, Facebook and such at a national or even regional level to create a better alignment with regular education. The emerging ethical issues companies are confronted with, will also have an impact on the possibilities and the willingness of institutions and teachers to intensify collaboration.

The one thing that surfaced was that emerging technologies in a technical environment do not stand out. Most teachers are in one way or another familiar with these technologies but use these predominantly as an asset in their research and not to improve education as such. Also, in none of the institutions a validated activity or organisational structure exists yet dealing with the question of emerging technologies for education.

FINDINGS CASE STUDIES

This last chapter deals with the case studies on VR and IoT. After a brief introduction on what VR means in education, the virtual speech and virtual tour experiments will be discussed. A similar structure is used for the IoT part of this chapter.

Virtual reality in education

Virtual Reality (VR) was selected as a technology to look into more profoundly with the purpose to better understand the characteristics of such an emerging technology in the teaching and learning environment. VR is an example of a technology that is considered highly influential (Gartner, 2016, 2017, 2018) in industry and is therefore poised to influence teaching and learning more than anything else.

VR is a computer technology that uses special headsets to generate images, sounds and other sensations that imitate a real environment or create an imaginary setting. It can also simulate a user's physical presence in this environment. It is a simulated 2D or 3D 360-degree environment which can be experienced or controlled by movement of the body or a computer. One can look around in the artificial world using VR equipment like the headset, which is a head-set in which a 360 display is shown. The headsets have many names to go by: head-mounted goggles with a screen in front of the eyes, head-mounted display etc. Programmes may include audio and sounds through speakers or headphones. Some VR used in video games can convey vibrations and other sensations to the user through the game controller. It also supports remote communication environments through a type of telepresence or tele-existence. The expectation is that VR will quickly develop and the goggles (figure 2) certainly will not be the end product as was shown by the success of the VR/AR game industry (Carlton, 2017).

The largest user group of VR is the gaming world, but increasingly this 3D technology is being adapted and used in sporting events, entertainment, marketing and real estate. Companies increasingly see the potential for recruitment, on the job training and teambuilding. Specific applications are developed for industries like the military, medical training, warehouse training and sports.

Figure 2: Virtual Reality Headset (Goggles)

The promises for education are that the learner is in control of the immersive environment, can move around, explore, try things out, take tests multiple times, explore different solutions. The one thing VR evokes is physical motion in a simulated real world, feel emotions, excitement, and curiosity. It is about the experience the learner has, how it engages and stimulates the senses and how this can help to improve the learning experience, in other words what are the benefits? The analysis of Dalgarno (2010) and Fowler (2015) of 3D-VLE (Virtual Learning Environments) shows five affordances which are: spatial knowledge representation, experiential learning, engagement, contextual learning and collaborative learning. On top of these affordances the technological immersion, acceptance and engagement (Fan et. al, 2017) in the VR environment and reflection on learning are crucial for the creation of learning benefits. To design pedagogically sound 3D VLEs though, more applied research is needed, because models and frameworks are missing to develop evidence-based experiences and most studies retain the existing pedagogy while using new technology (Fowler et al, 2015). Also, the research approaches are rather traditional, which means that it will be hard to capture what can be beneficial for very different VR supported teaching and learning practices (Poquet et al, 2017).

In 2016 and 2017 prices for VR headsets plumbed and the option of using your smartphone for a VR experience has enlarged the opportunity for education to experiment. An example of what is happening: Pennsylvania State University has received funding to build a virtual engineering lab where students hold, rotate and fit together virtual parts as they would with their real hands (Wertz, 2016). The question still is whether the students learn as well with VR as they do in the classroom. There will be no one answer, but the need to find out is urgent.

Virtual Reality case studies

Two VR experiments were executed and still partly are, at the time of writing this report, so this is a state of affairs. One experiment took place at the Centre for Language and Academic Skills of the Delft University of Technology (TU Delft) that offers a mandatory course on Presentation Skills for minors (VR-1). The second experiment took place at the department of Water Treatment at TU Delft, where a virtual tour in a wastewater treatment plant has been developed (VR-2). A guiding principle in the design of the experiments were the 4TU requirements aiming at the development of low threshold tools easy to implement without too much external support; contribution to the economy of scale aiming at accommodating large numbers of students and the strive for quick innovation which contains the intention that when it works (with positive learning effects) it is handed over to the institutional organisation. Ideally, the results of the pilot studies would create deliverables, which could guide the teachers with the decision making process for their own learning environments.

VR-1: Virtual Reality Speech practice

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 programme consists of lectures, reading materials, checklists and opportunities to prepare and present short pitches and five to ten minutes presentations in groups or individually. Since the groups were large, some 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 inquiry was made to clarify the demands and the requirements with teachers of the Centre for languages and academic skills. Administrative issues comprised financial

Figure 3: Analysis of speech in VR-app

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 drop the self-developed app option and use an existing app with a restricted set of options. Clearly improving the possibilities to practice presentation skills requires an in depth understanding of the new technology to be able to reframe the course in the existing context.

What follows is a summary of findings which have been described extensively in the research study by Klaassen, et al (2018). The sequence of the VR-experiment was as follows: The VR-1 research focus was on the experiences of an A and B group of students and the teachers' experiences. The analysis user data were collected, with survey outcomes and interviews to summarize the first experiences.

The ambition of VR-1 was to focus on maximum mobility, scalability and actual learning outcome. The application used was a virtual speech app, that allowed for "at home practice" with a smartphone and google cardboard and free body movement to emerge students more into the experience of being in front of a real-life audience and receiving feedback. It allows for a choice of multiple presentation settings, such as a classroom, a Ted talk and others. The app provides (objective) and immediate feedback on the following parameters: voice loudness, filler words like uh, speech-rate (time used per slide), eye-tracking (looking around across the room) and pauses. These facilities allowed students to individually drive their learning. Knowing that the effectiveness of virtual 3-dimensional interventions is a careful construction between task and immersion (chen, 2014), task and engagement (fan, 2017) and in general reflection upon learning of the students (lee, 2009).

The findings show that the speech app did not provide sufficient support for learning to take place. The included reflection exercise on what might be done with the feedback, did not spark useful insights into presentation performance. This might be due to 1. the lack of technological access, causing students not to have any feedback at all, 2. A lack of relevant feedback in the system. 3. A lack of bridging the information gap between standards and system. Teachers pointed out that what is "good" varies in different contexts and therewith cannot be gauged by objective metrics from a system.

One of the ambitions was to use the speech app for large groups. It would mean, however, that technological access, e.g. with devices that can handle a comfortable use of VR, requires equal access to gyroscopic phones, comfortable headsets with user friendly interfaces and interaction design, etc. Due to the problems occurring in the small setting, scaling up has not been addressed.

The relative negative to neutral experiences reported back with respect to feedback, reflection and performance were most likely severely affected by the technological state of the tools and results are therefore inconclusive. Based on the scientific literature we firmly believe that positive outcomes are around the corner. Yet the shaping of the instructional settings and using appropriate devices and feedback standards require revision and ongoing development.

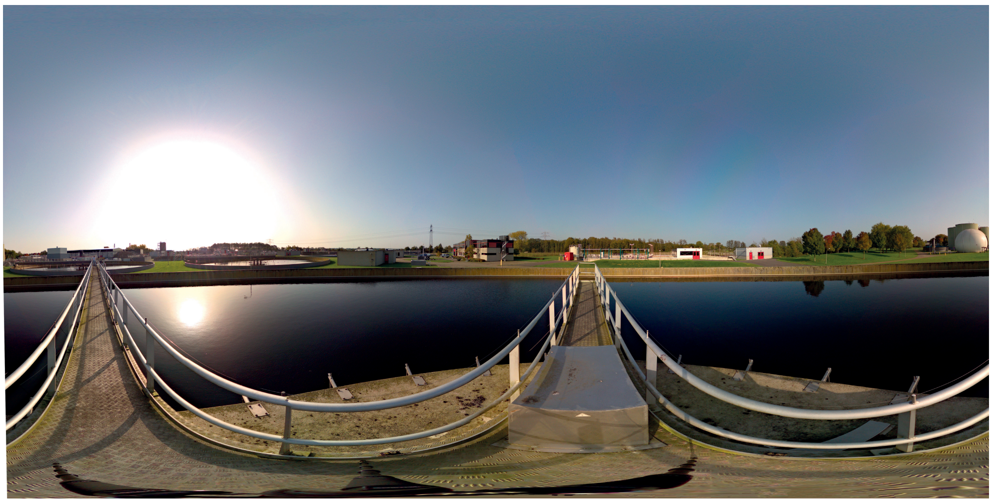
VR-2: Virtual Tour

VR-2 focused on developing a virtual tour in a wastewater treatment plant. The teacher considered such a field trip essential for the understanding of the students, but was troubled by the fact that these field trips are time consuming, difficult to plan and review and can only be attended by a limited number of students. As the course is also provided online, an increasing number of online students may not have the opportunity to visit such a plant either. 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 challenge was how to develop a virtual 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 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 challenges. Apparently, this effort evoked interest, as it is clear for what purpose the technology is being used.

The main question was whether a 360-degrees virtual tool proved to be an alternative for those students who cannot participate in a field trip. And possibly going beyond an alternative by adding value for learning and experiencing the actual site or multiple extra sites in a different way and in different modalities (individual 2D and 3D experiences).

Figure 4: 360-degrees tour of a wastewater treatment plant



It is a familiar problem, a class of 200 students and only 20 of them can participate in a field trip. The others will have to do with photos or schematic visualisations to familiarize themselves with procedures and plant processes. This is not an ideal situation for deeper learning. A 360-degrees virtual tool could prove to be an alternative for those students who cannot visit the actual plant. Such a tour has now been developed for bachelor students in Civil Engineering offering a 360-degrees virtual tour to a wastewater treatment plant. Prominent in the development are the design decisions to assure that the virtual tour provides the desired learning outcomes. A challenging task related to decisions on content, context, sequencing, on camera use, system software, headsets and storytelling. It shows to be a complex process since many design decisions have positive as well as negative effects. At the same time acceptance of the technology by the students is crucial.

An interdisciplinary approach is needed and demands good cooperation between the project partners: the faculty of Civil Engineering, TU Delft NewMedia Centre and the wastewater treatment plant in Amersfoort. The plant, combined with the expert knowledge on water treatment processes of professor Merle de Kreuk, contributed greatly to the thoroughness of the film. The impact of the design decisions on student comprehension needs to be further researched via design experiments with students. Extensive usability tests are now taking place to check elements such as technology acceptance with criteria as the length of the tour, the pacing, the risk of cognitive overload and possible discomfort in using VR headsets. This test should allow for further fine-tuning of the tour. Designing a 360-degrees tour is still a relatively unexplored field of study, but this pilot is expected to provide more insight into formulating proper design requirements for a clear decision-making process for future virtual tours that contribute to enhanced student learning.

Internet of Things in education

The second technology considered highly relevant for HEE 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. 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 practice and other practices.

IoT envisions a situation in which the objects of everyday life will be equipped with micro-controllers, 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 (Alam et al., 2015; Atzori et al., 2010; Voas et al., 2017). 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 other domains. A general architecture for 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, (Zanella et al., 2014).

Internet of Things case study

This case study dealt with the design and implementation of educational experiments in an electric drives laboratory with Internet of Things technology. The objectives were to upgrade and re-engineer 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 re-engineering of the existing educational laboratory included:

- Device connectivity directly or indirectly via a gateway: electric motors, power electronics, microcontrollers, sensors, measurement instrumentation, internet.
- Data analysis, processing, decision, control, visualisation and presentation, storage.
- Devices to facilitate bidirectional communication with the back-end system to provide device registration and discovery, data collection and analysis, logic design and visualisations. The concept includes visualising 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.

The apparent task of IoT is to connect the unconnected systems. It can benefit and bring added-value, after data analysis, to engineering and managerial decisions. A thing perspective brings unique insights about the relationships among objects and human practices, and ultimately presents new ways of framing and solving problems collaboratively with 'things', which have different skills and purposes than humans (Giacardi, 2016). The path from sensors to control and guide decision making processes 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.

For the educational laboratory, it is expected that IoT will result into a modernisation of the curriculum, plus improved operational efficiency and reliability. So far, the results in using this adapted laboratory show that there are multiple added values: new educational modules for existing curricula; well informed instructors in new technologies; better prepared and trained graduates and industries opening new jobs for better trained candidates in modern technologies. The initiative improved students' experience, benefits organisations, which hired them.

CONCLUSION

An important driver for the analysis of emerging technologies is their assumed benefit for education in relation to the ever-changing skills demand on the labour market. The increasing number of different technologies, the speed of development, the multitude of educational settings and the time it takes to research all this, makes it difficult to put a finger on these benefits. An increasing level of investment in educational technology will surely help in understanding the value for education. It is evident that the impact cannot be measured by the fact whether or not technology is being used, but by how well the technology is used to support teaching and learning. The main driver for this research in emerging technologies was to understand the value for education to support students, teacher and institutions and their relevance for teaching and learning.

The main conclusions of this explorative research are:

- Due to the complexity, the diversity, the speed of development and the decline, 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, sustainable strategy as part of an inter-institutional approach to deal with these challenges from an educational perspective

An important aim in engineering education is to ensure that students not only learn to understand theories and models, and their relation to objects and events in the real world, but also to learn how to use and apply these models and theories in design and engineering innovation. Making the transfer from theory and models to practice is one of the most difficult issues for students and teachers. Using extended environments such as offered in 360-degree environments, IoT labs or other upcoming technologies, might offer that practice opportunity to realise the transfer that is needed.

Staff development seems to be the ultimate way to go, but in reality staff development in itself is often a slow follower of educational innovations and is not always capable of supplying the teacher with the support needed. Additionally, teachers with high workloads are often slow and reluctant to change a good riding chariot. As a consequence, there is a need to develop a way of working in which teachers are equipped to make small scale innovations which help to investigate, test, and assess the usability of a technology in their micro-environment. To make this happen, the institute will need to reconsider its innovation policies and develop a broader participatory design approach to better deal with these demands for innovation.

The industry is worried about the capability of education to make the technologies work that are expected to help bridge the skills gap for today's students (Kiss, 2017; SEFI business panel discussion, 2018). As can be seen from the analysis of VR as a promising tool for learning innovation, there is no general consent yet about the value of 360-degree environments for education. It seems that the only way to find out what these technologies can do for education is to try it out and as such develop experience and knowledge to properly deal with the challenges and opportunities. HEE institutions need to become more proactive in shaping students' knowledge and skills by means of digital technologies and use the mismatch of skills between supply and demand on the labour market as a source of inspiration.

Reflections and recommendations

This explorative research presents the early findings of an ongoing research into the value and implications of emerging technologies for HEE. The scientific standard was not as tight as we would have liked it to be. Yet we feel it is a relevant starting point for further discussion about emerging technologies and how these will affect and change the demand for skills of our future workforce and the consequences for HEE.

The next question following from this research is: how to proceed? The urgency is evident and acknowledged by institutions and industries in varying degrees. What becomes clear is that education needs to develop a proactive role and show leadership to deal with the challenges and to enhance opportunities. HEE is bound to better illuminate her role and her competences in this digital timeframe. At this moment, new educational developments predominately take place outside the educational arena, initiated by commercial parties. HEE needs to claim ownership and show involvement when it comes to educational innovation and this means that digitisation must be on top of the list. This explorative research needs to be framed as part of this mission.

WHAT TO DO NEXT?

Clearly additional research would be very helpful to bring this endeavour a step further. As suggested HEE needs to develop a pro-active assertiveness and therefore we suggest the following:

Develop actions to be taken on macro-, meso- and micro-level to increase the likelihood that the emerging technologies movement is being recognised as a participatory action in which all participants associate with the same thing and develop a mutual understanding of the value of such actions.

Macro level

- **E-leadership**
  - Develop a proactive attitude, that is supported by prominent e-leadership in educational technology. It is argued that more critical, selective, strategic e-leadership approaches are needed to the adoption and use of educational technology, progressed through research, development and training as the field matures (Jameson, 2013).
  - HEE needs to claim ownership and involvement and not rely on hobbyism or altruism as an excuse for incompetence in the development of educational technology.

Meso level

- **Open research**
  - Research is considered instrumental to improve educational technology experience and effectiveness. With the emergence of technology in education another research dimension has arrived.
  - Open research is a way to cope with the complexity, diversity and the opportunity of large quantities of data, technologies and design instruments.
  - This is not limited to sharing data and results but entails opening up the research process to third parties (experts, organisations and industry), including the design of experiments and analysis of data.

- This research approach is rooted in design-based research, which is a systematic but flexible methodology aimed at improving educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings and leading to contextually-sensitive design principles and theories (Wang et al, 2005).

  Open research can help in sharing experiences and therefore contribute to the use of emerging technologies in HEE.

Technology acceptance model (Zhang, 2017)

- The technology acceptance model (TAM) is a systems theory that models how users come to accept and use a technology. The model suggests that when users are introduced to a new technology, a number of factors influence their decision about how and when they will use it, notably:
- Perceived usefulness: "the degree to which a person believes that using a particular system would enhance his or her job performance".
- Perceived ease-of-use: defined as "the degree to which a person believes that using a particular system would be free from effort"

  The TAM theory has been continuously studied and expanded and as such could be helpful to lower the resistance often observed by the integration of educational technology. Other theories and tools can be looked at in support of the acceptance process.

Micro level

Emerging technologies HUB

- The development of education technologies and certainly the influx of emerging technologies in education is increasing continuously, while educators are being asked to develop and teach courses with little or no prior training.
- Teachers are confronted with questions about the format (classroom, online, blended), the design, learning activities, assignments, and assessment, that all work differently in a technology supported environment. Questions exist about tools, communication, interaction patterns.
- How to keep up with new insights and developments, the emergence of useful technologies (Facebook, Twitter, Blogs, etc.) and the results of evaluation, educational data mining and learning analytics, emphasizes the demand for a strategy that entails ongoing staff development.
- Develop an Emerging Technologies HUB Staff Development Model that can cope with the rapidly changing teaching and learning contexts. The flexibility in the approach is key in the development of a model that can change incrementally, where active user involvement is imperative and testing is authentic and integrated throughout the lifecycle. A collaborative and cooperative approach is key in this agile development strategy.

REFERENCES

Adams Becker, S., Cummins, M., Davis, A., Freeman, A., Hall Giesinger, C., and Ananthanarayanan, V. (2017). *NMC Horizon Report: 2017 Higher Education Edition*. Austin, Texas: The New Media Consortium.

Alam, K. M., Saini, M., Saddik, A. E. (2015). Toward Social Internet of Vehicles: Concept, Architecture and Applications. *IEEE Access*, 3, 343-357. doi: 10.1109/ ACCESS.2015.2416657

Atzori, L., Iera, A., Morabito, G. (2010). The internet of things: A survey. *Computer Networks*, 54(15), 2787–2805.

Briggs, B., Foutty, J., & Hodgetts, C. (2016). Tech Trends 2016. *Deloitte University Press*.

Brinson, J. (2015), Learning Outcome Achievement in Non-traditional (virtual & remote) versus traditional (hands-on) laboratories: A review of the empirical research. In *Computer & Education*, nr 87 (2015) 218-237

Bruyckere, P. de, Kirschner, P.A., & Hulshof, C. D. (2015). *Urban Myths about Learning and Education*. London: Elsevier (Academic Press)

Carlton, B. (2017). *Virtual Reality and Learning*. A MASIE report.

Chen, Yu-Li (2014), A Study on Student Self-efficacy and Technology Acceptance Model within an Online Task-based Learning Environment, *Journal of Computers*, VOL. 9, NO. 1, pp 34-43 academy publisher, doi:10.4304

Davis, F. D. (1989), “Perceived usefulness, perceived ease of use, and user acceptance of information technology”, MIS Quarterly, 13 (3): 319–340, doi:10.2307/249008

European Commission (2016). A new skills agenda for Europe. Working together to strengthen human capital, employability and competitiveness. Document 52016DC0381.

European Commission (2018). Employment and Social Developments in Europe. Annual review. DG for Employment, Social Affairs and Inclusion. doi:10.2767/875456

Liu Fan, Xinmin Liu, Bingcheng Wang & Li Wang (2017) Interactivity, engagement, and technology dependence: understanding users’ technology utilisation behaviour, Behaviour & Information Technology, 36:2, 113-124, DOI: 10.1080/0144929X.2016.1199051

Gartner (2016, 2017, 2018). The Gartner Hype Cycle for Emerging Technologies. https://www.gartner.com/smarterwithgartner/5-trends-emerge-in-gartner-hype-cycle-for-emerging-technologies-2018/ Latest access on 10th October 2018.

Goldman-Sachs (2016), *Technology driving Innovation* (Accessed on 11th Nov 2016) http://www.goldmansachs.com/our-thinking/pages/tech-transforming-the-classroom.html

Higgins, S,. Xiao, Z., Katsipataki, M. (2012). *The Impact of Digital Technology on Learning: A Summary for the Education Endowment Foundation*. School of Education, Durham University.

Klaassen, R. , Ceulemans, D., Strous, J. Kam, A. De Vries, P. (2018). Virtual Speech. SEFI 2018 Yearly Conference, Kopenhagen (in print).

Jameson, J. (2013). E-Leadership in higher education: The fifth “age” of educational technology research. *British Journal of Educational Technology*, 44(6), 889–915. https://doi.org/10.1111/bjet.12103

Janssen, D., Tummel, C., Richert, A,. Isenhardt, I. (2016) Higher Education – Immersion as a Key Construct for Learning 4.0. *International Journal of Advanced Corporate Learning*, Vol 9, No 2 (2016).

Jaschik, S., & Lederman, D. (2015). The 2016 Inside Higher Ed Survey of College and University Chief Academic Officers. *Inside Higher Ed*.

Johnson, L., Adams Becker, S., Cummins, M., Estrada, V., Freeman, A., & Hall, C. (2016). *NMC Horizon Report 2016* – Higher Education Edition. Austin, Texas: The New Media Consortium.

Hart, J. (2017, 2018). Centre for Learning and Performance Technologies (C4LPT). www.c4lpt.co.uk, last time accessed 11 September 2018.

Kamp, A. (2016), *Engineering Education in a Rapidly Changing World*; Rethinking the Vision for Higher Education. Second Revised Edition. 4TU.Centre for Engineering Education.

Klopfer, J. (2016), *Augmented Learning*; Research and Design of Mobile Education Games, MIT Press.

King, J., South, J. (2017) U.S. Department of Education, Office of Educational Technology, *Reimagining the Role of Technology in Higher Education: A Supplement to the National Education Technology Plan*, Washington, D.C., 2017.

Kirkwood, A. & Price, L. (2013), Examining some assumptions and limitations of research on the effects of emerging technologies for teaching and learning in higher education, *British Journal of Educational Technology*, Vol. 44 (4) pp 536 – 543, doi:10.1111/bjet.12049

Kiss, M,. (2017). Digital skills in the EU labour market. EPRS | European Parliamentary Research Service, European Union. ISBN 978-92-846-0367-1, doi:10.2861/451320

Lee, E.A. Lee, WaiWong, K, & CheFung, C. (2010), How does desktop virtual reality enhance learning outcomes? A structural equation modelling approach, *Computers & Education*, Vol. 55 (4), pp. 1424 - 1442

Mesquita, A., & Peres, P. (2016). Critical Success Factors in the Adoption of Technologies in Education in Higher Education: The Case of ISCAP (Polytechnic of Porto). *International Journal of Online Pedagogy and Course Design* (IJOPCD), 6(1), 29-41. doi:10.4018/IJOPCD.2016010103

Onderwijsraad. (2017). *Advies: Doordacht digitaal; onderwijs in het digitale tijdperk* (pp. 1–62). Retrieved from https://www.onderwijsraad.nl/upload/documents/publicaties/volledig/Doordacht-digitaal-a.pdf

Poquet, O., Kovanović, V., Vries, P. de, Hennis, T. A., Joksimović, S., Gašević, D., & Dawson, S. (2018). Social presence in Massive Open Online Courses. *Internet and Higher Education*.

Veletsianos, G. (2016a). *Defining characteristics of emerging technologies and emerging practices*. Publisher: Athabasca University Press, pp.3-16.

Veletsianos, G. (2016b). *Emergence and innovation in digital learning: Foundations and applications*. Athabasca University Press.

Voas J., Laplante P. (2017). Curriculum Considerations for the Internet of Things. *IEEE Computer*, Vol. 50, No.1, pp. 72-75, doi: 10.1109/MC.2017.27.

Voogt, J. Sligte, H.W., Beemt, A. van den, Braak, J. van en Aesaert, K. (2016) *E-didactiek*.

Welke ICT-applicaties gebruiken leraren en waarom? Amsterdam: Kohnstamm Instituut

Wang, F., & Hannafin, M. J. (2005). Design-Based Reserach and Technology-Enhanced Learning environments. *Educational Technology Research and Development*, 53(4), 5–23. https://doi.org/10.2307/30221206

World Economic Forum (2015). *New Vision for Education: Unlocking the Potential of Technology*. Industry Agenda.

World Economic Forum (2016). *New Vision for Education: Fostering Social and Emotional Learning through Technology*. Industry Agenda.

Zanella, A., Bui, N., Castellani, A., Vangelista L., M. Zorzi, (2014). Internet of Things for Smart Cities. *IEEE Internet of Things*, Vol. 1, No. 1, pp. 22-32. doi: 10.1109/JIOT.2014.2306328.

Xi Zhang, Shan Jiang, Patricia Ordóñez de Pablos, Miltiadis D. Lytras & Yongqiang Sun (2017) How virtual reality affects perceived learning effectiveness: a task–technology fit perspective, Behaviour & Information Technology, 36:5, 548-556, DOI: 10.1080/0144929X.2016.1268647

Zubia, J.G., Cuadros, J., Romero, S., Herandez – Jayo, U., Orduna, P., Guenaga, M., Gonzalez- Sabate, L. , Gustavsson, I. (2016), Empirical Analysis of the Use of the VISIR Remote Lab in Teaching Analog Electronics, *IEEE, Transactions on Education*

https://www.techrepublic.com/article/9-industries-using-virtual-reality/

Liu Fan, Xinmin Liu, Bingcheng Wang & Li Wang (2017) Interactivity, engagement, and technology dependence: understanding users' technology utilisation behaviour, Behaviour & Information Technology, 36:2, 113-124, DOI: 10.1080/0144929X.2016.1199051

www.4tu.nl/cee