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EMERGING TECHNOLOGIES IN ENGINEERING EDUCATION: CAN WE MAKE IT WORK?

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ABSTRACT

This paper deals with an explorative research into the use of emerging technologies for teaching and learning. An important stimulus for this research is the skills gap. The rapid changing demand puts a lot of pressure on education and the promise is that technology might help to solve the problem. The expectation is that indeed the next generation of technologies will affect education more profoundly, because of the increase and the vast integration of these technologies in our society at large. Engineering education has been reluctant in accepting technologies for learning, but the speed of change needs to be acknowledged and education cannot continue to say that the demand for new skills is a world we do not know yet. The exploration starts with an assessment about what kind of technologies are at stake and what their contribution might be for education. Recent research and reports are used to value the educational technological developments; representatives from industry and education have been interviewed and a small number of experiments are being executed to gather further knowledge and experience. At the time of writing these experiments are ongoing, but we allow to zoom in on Virtual Reality (VR) as one of the most promising technologies. The focus in this research is on the perceived value for education and therefor the exploration is very much related to the triangle perspective of student – teacher – organization as interrelated stakeholders and decisive for the usability of technology. The guiding questions are: what is the perceived value for the students; what is the value for the teacher and what are the consequences for the organization? The one thing that emerges is that engineering education needs to be much more proactive to master the question about technology in teaching and learning. This ongoing exploration is an initiative of the 4TU Centre for Engineering Education which is part of the 4TU Federation being an alliance of the four technical universities in the Netherlands.

KEYWORDS

Emerging technologies, 3D Environments, Virtual Reality, Higher Engineering Education Standards 6, 7, 8, 9.

INTRODUCTION

Higher education is poised to better prepare students for the labour market and therefore helping to endow vital innovative and creative skills (Kamp, 2016; World Economic Forum, 2015 & 2016). The increasing expectations also contain the believe that the use of technologies will help higher education to become more innovative and productive (Klopfer, 2016). However, technological adaptation does not necessarily suggest better performance. Some believe that technology is the way to go (Johnson et al. 2017), others (Bruyckere et al. 2015) believe that the effect of technology on teaching and learning has been limited and expect that it will not fundamentally change education. It is evident that our society at large, including education, has been infiltrated over the last decades 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 on a day-to-day basis. As such education shows the same pattern of technology use as society as a whole. The added value depends on the situation and the goal one has with the technology and which combinations of technological tools are used. The believe that technology should have a stake in making education more innovative and productive requires a 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).

Problem Statement

The purpose of this exploration into emerging learning technologies and emerging practices is the potential relevance for teaching and learning. The discussion on the value of Virtual labs was a starting point for the 4TU Centre for Engineering Education and it turned out that traditional Lab situations change rapidly using all kinds of other and new technologies to make things work according to today's standards. So, contemporary Virtual labs necessarily contain many more technologies which in general belong to the technologies we have qualified here as emerging technologies which also independently show to be of use for education. The purpose of this endeavor is to see what is being used already in HE and identify the added value for the learning process, to identify technologies that have the potential to contribute from the teacher's perspective and to see which experiments would be meaningful to help develop a strategy to deal with the emerging technologies and educational practices This research is ongoing and the outcomes presented in this paper comprise most of the findings from desk research and interviews, but only part of the experiences with the experiments, which are half way through at the time of writing.

The research context

What technologies are qualified as emerging technologies? These are recent developments that have not yet been widely adopted, but are expected to influence educational practices as there is 3D printing, Makerspace, BYOD (Bring Your Own Device), Internet of Things and such applications as Open Source, Learning Management Systems, Virtual Reality. They tend to be in a dynamic state of change as is the case with Twitter, Facebook and Virtual Reality which will most likely be further developed and refined. These also include tools that become obsolete, stop to exist, are withdrawn or merge with other developments (Johnson et al, 2014, 2015; 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 if a technology might help or not. This research is an attempt to develop a way of working that allow students and teachers to investigate, test, and assess the usability of a technology in their micro-environment of teaching and learning.

The general availability 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 technologies, in other words developed for use by the general public. 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, Power point, Google docs, Facebook, Skype, etc. In 2016, the first dedicated educational technology is the open source course management system Moodle on place 27.

Learning technologies as such play a minor role in technology development in general which underlines the fact that education is a follower and consequently lags behind. It seems there for encouraging that at this moment the investment in educational technology is ten times more than it was a decade ago (Goldman Sachs, 2016). The promise is that technology is poised to influence education in virtually every aspect of how we teach and how we learn. 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). 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 increasing variety in technologies and applications and the speed of development make it difficult to decide about the technology and about the integration in teaching and learning. The challenge is to ensure that technology contributes to improvement.

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 research the main questions are about the added value for students, for teachers and the consequences for the organization. The exploration is limited to technologies that are considered relevant and usable within a certain period of time (Gartner, 2016; King et al, 2017). The first part of the paper deals with the general review including a selection of emerging technologies. In the second part the focus is on the technology that is considered the most promising for the years to come, which is Virtual Reality (VR). As can be seen in the Gartner hype cycle (figure 1), VR is poised to

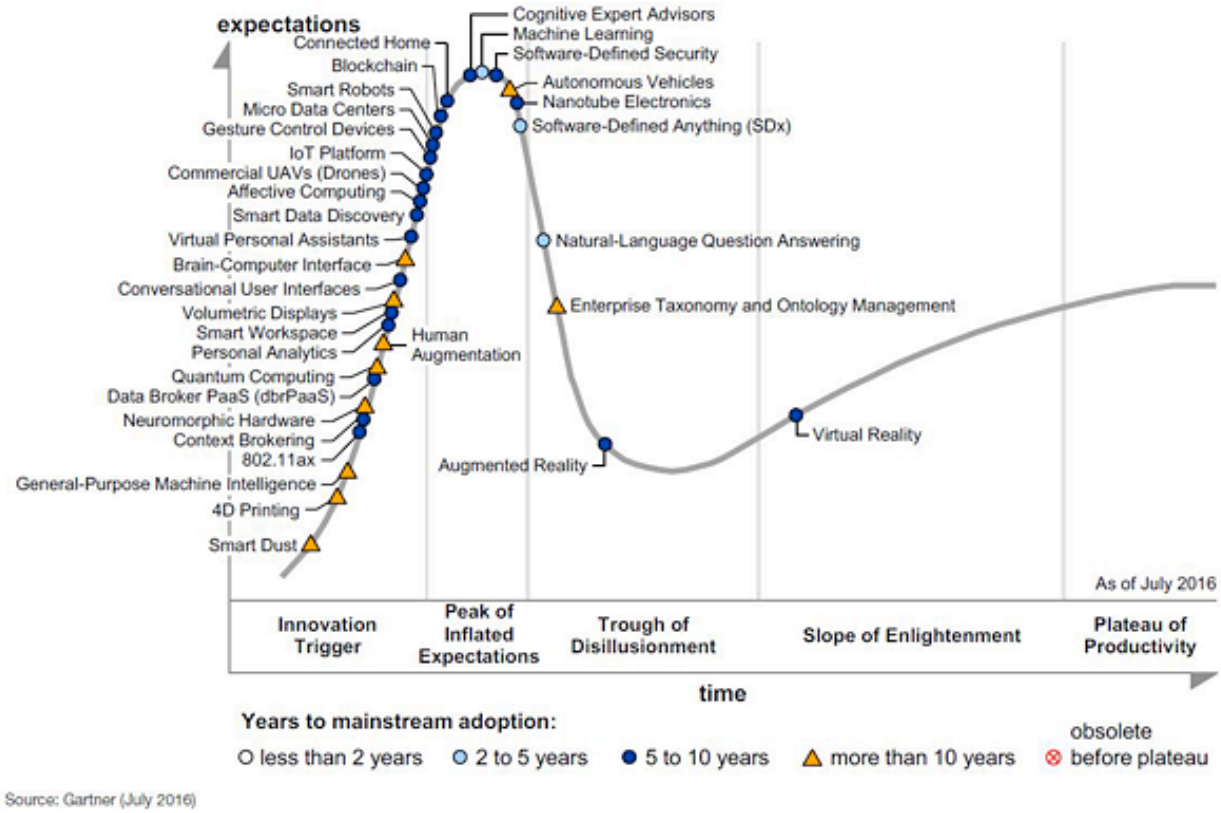

Figure 1 The Gartner Hype Cycle (2016)

enter the market rather soon. The hype cycle report on emerging technologies provides a cross-industry perspective on technologies one should consider in developing emerging-technology portfolios (Gartner, 2016). The Gartner analysis is an estimation about the timeline for technologies to reach maturity. The financial analysis by Goldmann Sachs (2016) on the emerging investments in VR seems to support this estimation. Therefor VR was selected to be used as an illustration of the kind of technologies and functionalities that are likely to affect education in the short run.

LITERATURE REVIEW AND OTHER RESOURCES

Emerging technologies and education

The emerging technologies considered here are not yet widely adopted, but are expected to increasingly influence educational practices. These technologies like 3D printing, the Internet of Things, Virtual Reality, etc., 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; Wikipedia). They are in a dynamic 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 Virtual reality 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, because the promise of a transformation mostly ignores a variety of factors that are hard to influence like politics and economics. Higgins (2012) confirms that the diversity of contexts and settings and the different methodologies make it difficult to identify clear and specific implications for educational practices. So, no general statement about the impact of technologies, but also no unified strategy of how to cope with these new developments.

The assumption in this exploratory research was that technology can help to improve education. 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 (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 normally experience.

The teacher plays a crucial role in all this. 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 organizational and individual factors with enablers like organizational strategy and support, training, equipment and applications and 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. Because of the diversity and the speed of development research in this area has become more complicated. In addition, the 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).

Virtual reality and education

Here we zoom in on Virtual Reality as an example of a technology that is poised to influence teaching and learning more than anything else. This explorative approach should allow for a better view on what it is, how it works and what the promises are for education.

Virtual reality (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 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 are head-mounted goggles with a screen in front of the eyes. Programs may include audio and sounds through speakers or headphones. Some VR systems 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 Pokémon Go (Carlton, 2017).

Figure 2. Virtual Reality Headset (Goggles)

The largest user group of VRs is the gaming world, but increasingly this 3-D 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, sports.

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 3-D Virtual Learning Environments (VLE) show five affordances which are: spatial knowledge representation, experiential learning, engagement, contextual learning and collaborative learning. These affordances directly relate to learning benefits. To design pedagogically sound 3-D 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). VR is seen as very helpful in subjects as engineering and architecture to design and manipulate virtual structures. The question still is if the students learn as well with VR as in the classroom. There will be no one answer, but the need to find out is urgent.

METHODS

This ongoing research into 'emerging technologies' started with an inventory of technologies and tools that potentially give way to innovation and are used or about to be used in one of the four Dutch technical university institutions. 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 key words used in the review were: emerging technologies, emerging learning practices, 3D environments, virtual labs, virtual experiments, remote labs, remote experiments, virtual reality, augmented reality, learning technology, educational technology, informal learning, self-directed learning, micro learning, design based education, skills gap, 21st century skills

The technologies selected for general review were: Virtual and remote laboratories, BYOD (bring your own device), Makerspace, Internet of Things (IoT) and Virtual reality. For the indebt analysis Virtual reality was selected for reasons of potentially high impact. Interviews were held at the Dutch Technical Universities (N=12) at 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 conversations. 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 should allow for a more thorough analysis of the what and how. These are at the time of writing halfway and will be reported in due time. The results chapter illustrates the outcome of the inventory and interviews, and represent an indication of the findings, which will eventually be complemented with the outcome of the experiments.

RESULTS AND OUTCOME

The main reason for this research was the assumption that the emerging technologies are expected to become highly relevant for teaching and learning. This exercise was guided by the question about the perceived added value for the student, the perceived added value for the teacher and the organizational consequences? This research so far is to be considered a first step to get a better understanding of the opportunities of these technologies for teaching and learning.

Emerging technologies

The purpose of this inventory was to verify what the educational benefits might be of these technologies. Most resources for this exercise were web based coming from stakeholders like producers and vendors who dominate the information channels and therefor the level of verification and argumentation of the educational benefit was at times trivial. 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. 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, which included the interviews, we used as the main point of reference the perceived value for the triangle of students and teachers in relation with the organization, which is reflected in table 1 with a summary of findings for virtual reality, Internet of Things, Makerspaces and BYOD (bring your own device).

Table 1. Emerging technologies: summarized findings

Virtual reality 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
• 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	• 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 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.
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	• Gains access to emerging technologies to transform ideas into realities • Aggregation of data that help to understand learning trajectories • Is expected to result in	• Need support for the usage of IoT in strengthening pedagogical capabilities • The need for rubrics to understand the educational impacts	• Institutions partnering with industry to enable and equip students with the latest skills • Connecting devices generate data on learning, campus activity, content

• Great potential for learning analytics • Powerful instrument for data collection • Stimulate learning experiences in a physical space	improved learning experience, feedback and support new learning experiences	• Dashboard-like tools to support students at the point of time and need.	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 modeling 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 modeling.	• 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 virtual reality equipment, digital editing software, 3D printers as such.
BYOD (Bring Your Own Device) 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 (mobile phone). 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 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 mobile 24/7 for communication and access.	• Need to integrate this option where relevant (organizational, 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 faculty to update the ways in which they deliver content and assess student learning
Resources: Adams 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 relevance for Teaching and Learning

The interviews in the institutions showed 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 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 use 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 organize education. So, 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. Therefor the link between technology and the advantages are considered crucial. This requires a healthy collaboration with the industry using experiments and pilots to deliver value for all partners. High on the agenda was the combination of the existing educational practices with the new approaches. A vision and strategy is 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. 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 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. Training should be up to date, focus on new developments, provide skills for just 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, across disciplines and with an understanding of the design and technology. AI, is at our doorsteps, 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 Amazon, Facebook on a national or even regional level to create a better alignment with regular education.

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 was a validated activity or organizational structure yet dealing with the question of emerging technologies for education.

CONCLUSION

An important driver for the analysis of emerging technologies is their assumed benefit for education. To find out what this could be is being hampered by the increasing number of different technologies, the speed of development, the multitude of educational settings and the time it takes to research all this. An increasing level of investment in educational technology will surely help, but it is evident that 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. Students will need to know, but clearly also teachers need to have a better understanding of what technology can do for education. Staff development seems to be the ultimate way to go, but the reality is that staff development in itself often is a slow follower and not capable of supplying the teacher with the support needed. As a consequence, there is a need to develop a way of working in which teachers are equipped to investigate, test, and assess the usability of a technology in their micro-environment. To make this happen, the institute will need to reconsider their innovation policies and develop a broader participatory design approach to better deal with the 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. Also doubts arise if the current research practice is capable of dealing with the new developments in a proper way.
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 3D environments for education. This is related to the speed of development of the technology and the current applications, which show nice results, but lack scientific confirmation yet. 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. Engineering education needs to become more proactive to master this question about emerging technologies.

Analytical Summary

This paper presents the early findings of an ongoing research into the value and implications of emerging technologies. 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. These will affect and change the skills set of our future workforce dramatically and influence the approach to work in general.

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BIOGRAPHICAL INFORMATION

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