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Making the world a better place with Mixed Reality in Education

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Full Paper

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Abstract

Mixed Reality (MR) is an emerging technology in which the real world is enhanced by an overlay of computer graphics-based interaction. The use of MR in the Information Systems (IS) pedagogy is becoming more and more to be taken as a reflection of reality. This study expands on the current literature to plan, design, test, and evaluate the use of Microsoft HoloLens a MR device in IS classroom. This study uses design science guidelines to introduce HoloLens to 205 students in a postgraduate and undergraduate class. Student responses were both positive and negative highlighting the advantages and disadvantages of the technology, the applications and its interface as presented in this paper. This study uses Socio-Technical Interaction Networks (STIN) analytical strategy for social informatics to compare the different forms of knowledge embodiment in the mixed reality system for education.

Keywords: Mixed Reality, HoloLens, Social Informatics

1 INTRODUCTION

The use of Mixed Reality (MR) in the Information Systems pedagogy is becoming more and more to be taken as a reflection of reality. MR is an emerging technology and it is an evolving form of experience in which the real world is enhanced by an overlay of computer graphics-based interaction (Milgram & Kishina, 1994). MR seamlessly overlays 2D and 3D objects such as audio files, videos and textual content into the real world (Azuma et al., 2001), and hence allows users to see the real world, along with augmented data. The user can view the real world through a handheld or head-mounted device by coating illustrations on the surrounding environment (Harborth, 2017). Microsoft HoloLens and Google Glass are examples of MR devices.

MR applications are used in various fields like health (Stretton et al., 2018), business (Soliman et al., 2018) and education (Leonard & Fitzgerald, 2018). For example, MR is found to be important in health as well as health education domain by using MR applications for conducting virtual bowel cancer surgery or communicating with virtual patients (Nicolau, 2011; Wu et al., 2013). MR in business and engineering grow towards the construction, production and maintenance processes (Riexinger et al., 2018). Studies also highlight how MR offer valuable contributions in facilitating emergency response and preparedness (Soliman et al., 2018). MR offers the opportunity to rethink and redesign clinical simulation spaces for learning and teaching in healthcare higher education (Magana, 2014). The educational value of using MR in learning design is to provide an exceptional student experience, by helping them not only to 'see the unseen' through the capacity of MR but also to visualise and interact with complex and abstract concepts (Billinghurst, 2002). Students in Information Technology (IT) field can have a work-integrated learning experience with MR by programming augmented reality applications (Jee et al., 2014, Chong et al., 2009).

This study takes mixed reality in the classroom by applying social informatics (Kling, McKim, & King, 2003; Meyer, 2006) perspective to understand the connections among students, teachers, and mixed reality. This study check how knowledge embodiment is embedded within and enabled by the mixed reality systems in a class room setting. Knowledge can be embodied in entities such as documents (Baptista, Annansingh, Eaglestone, & Wakefield, 2006), electronic repositories and expert systems (Bogers, 2011; Wei, Choy, & Yew, 2009) like mixed reality systems. This study looks beyond improving the convenience and reuse to emphasize on understanding the value of knowledge using mixed reality (Elena, Noelia, & Carmen, 2017; Johnston & Blumentritt, 1998; Maria, Souad, & Vlatka, 2017; Subramaniam, 2006). Social informatics offers an unparalleled opening to compare different forms of knowledge embodiment in the mixed reality system used in a class for education. A social informatics analysis of the knowledge embodiment indicates the various ways people (for instance, teacher, students) and technology (for example, HoloLens) are interconnected. Thus, the research question addressed in this study is: *How does knowledge embodiment in Mixed Reality systems affect people (Students and Teachers) and connections between them?* To answer the question, Socio-Technical Interaction Networks (STIN) analytical strategy for social informatics by Kling et al., (2003) is used to understand connections between people and mixed reality systems (Meyer, 2006). The STIN analytical strategy is used to go beyond technology determinism and to understand technology from multiple social actors' perspectives as used by Pee et al. (2019).

By expanding on the current literature to plan, design, test, and evaluate the use of Microsoft HoloLens, a MR device in an IS classroom at a University in Australia, design science guidelines are used. The design problem for this study is the use of MR in an IS class to understand and learn the technology by applying a social informatics perspective and to prepare the students for their future work. The solution to the design problem in this study is to introduce and evaluate Microsoft HoloLens in an IS class as an artifact based on the six activities of design science research (Baskerville et al., 2018). During the trial, Microsoft HoloLens was used to prepare the tutors, to design the task, to orient the students, to collect data and to gather the feedback after the use of the artifact in class. To answer the research question about how does knowledge embodiment in Mixed Reality systems affect the students, teachers and the connections between them, STIN analytical strategy for social informatics is used. The survey feedback highlights the transformation in education by the mixed reality system. This paper concludes with suggestions of specific pedagogical models that could be used in IS education.

2 LITERATURE REVIEW

The idea of MR, stems from Sutherland (1968), when a head-mounted three-dimensional display was introduced. MR system is defined by Azuma et al., (2001, pp. 34) to have the following properties: "combines real and virtual objects in a real environment; runs interactively, and in real-time; and registers (aligns) real and virtual objects with each other". Milgram (1994) presented a continuum of real-to-virtual environments as given in figure 1.

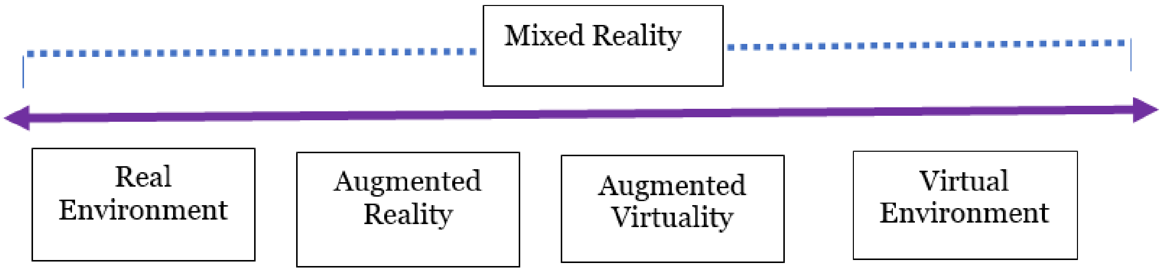


Figure 1. Reality–virtuality continuum (Adapted from Milgram and Kishino, 1994)

Today, the terms 'augmented' reality (AR) and 'mixed' reality (MR) are used interchangeably. AR refers to the overlay of data onto the visible world while MR technologies display virtual objects over the real-world background. Microsoft's HoloLens is an example of a MR device, while Pokémon Go is an example of a MR application. On a review of IS related literature, Harborth (2017) provides a detailed and systematic literature review of MR in IS research. It was highlighted that there is a need to be augmented by insights from IS so that the technology itself can be improved. Understanding the human centered behaviour when interacting with the technology is important.

With MR, there is an overlay of virtual objects over the real visible world and it enhance our sensory-motor engagement with the world (Lindgren et al., 2016). A systematic literature review by Harborth (2017), highlights a shortage of IS technology papers in developing or reviewing MR technologies and outlines many promising areas for future work on MR. A recent study used MR to help students learn the anatomy of the human body mediastinum. In this case, MR was found to strengthen the students' self-efficacy and motivation, improved learning, and provided a good learning experience (Nørgaard et al., 2018). The differences between VR and MR have important practical and theoretical implications for learning design and there is a strong argument available to set aside the technical similarities of the technologies and to treat them separately (Hugues, Fuchs, & Nannipieri, 2011). In many respects, the affordances of virtual reality have been well explored in the literature on the educational use of video games (Waddington, 2015), although the immersive nature of more advanced VR technologies does appear to enhance these effects (Clark, Tanner-Smith, & Killingsworth, 2016).

Visualizing is the next capable area in this MR related research. The first promising area in visualizing is a system with immersive analytics features of MR developed by Mahfoud et al., (2018). Przybilla et al., (2018) used design thinking and proposed a human-centric approach for recording chronic injuries using augmented reality smart glass application. Discovering on interactions with the neuropsychologist's avatar in virtual locations using a VR social network (Bernard et al., 2018) and making of a cross augmented knowledge merging physical and virtual worlds for immersive e-therapy (Gorini et al., 2008), are studies in a health-related area. Given the maturity and availability of MR technology, the adoption of MR applications to support the IS education process is a realistic application scenario within the context of digital disruption. Hence, the aim of this study is to design, trial and evaluate the use of a MR device - Microsoft HoloLens, as a teaching tool in an IS class. This study uses social informatics to compare the different forms of knowledge embodiment in the mixed reality system for education as discussed below.

Social informatics is a study of the social and institutional aspects of information and communication technologies as quoted by Pee et al., (2019). Social informatics can refer to social analysis, human-centered computing, and the sociology of computing and involves people and technology (Kling, 2007). Technology and social combines today and it is evident in the various application today starting from various types of social media (Kling, Rosenbaum, & Sawyer, 2005). Meyer (2014) highlights this concept of technology and social as socio-technical. Social informatics will involve material artefacts such as computers (HoloLens) and software (Holograms), and the rules, norm, and practices of people (teaching and learning) (Meyer et al., 2019). Social Informatics is also defined as "the interdisciplinary study of the design, uses and consequences of information technologies that take into account their interaction with institutional and cultural contexts." (Kling 2005). Knowledge embodiment of social informatics is the adaptation of knowledge into a form in which its cost becomes obvious (Demarest, 1997). There is a need to have an in-depth analysis of the effects of HoloLens on people and connections between them using the concept of knowledge embodiment. A recent study shows an in-depth analysis of how the assembly affects the knowledge work using social informatics perspective (Pee et al., 2019). This study will follow Pee et al., (2019) to determine the answer to the research question about how does knowledge embodiment in Mixed Reality systems affect the students, teachers and the connections between them. This study will use STIN analytical strategy for social informatics to understand the knowledge embodiment in the Mixed Reality systems in the given context

3 METHODOLOGY

Design science is a promising research paradigm in information systems (Gregor & Hevner, 2013). It is used to answer a research question by building socio-technical artefacts (Myers & Venable, 2014). The ultimate principle of design science research is that, the understanding of a design problem and its solution are developed in the construction of an artifact. For this study, the design problem is the use of MR technology in an IS class to understand and learn the technology as given in Table 1. The solution to the design problem in this study is to evaluate Microsoft HoloLens in an IS class as an artifact. During this trial study, Microsoft HoloLens was used in the following steps:

1. Prepare the tutors by conducting orientation lesson
2. Design the task by creating questions for students to answer
3. Orient the students by introducing them to the technology
4. Collect data using the survey questionnaire
5. Assess the feedback after the use of the artifact in class.

Guideline	**Description (Gregor & Hevner, 2013)**	**This Study**
Design as an Artifact	Design science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.	The use of a MR solution to teach Information Systems and the future of work is an instantiation of the artifact in this study. Microsoft HoloLens is the MR solution used for this study.
Problem relevance	The objective of design science research is to develop technology based solutions to important and relevant business problems.	The objective of this study is to use a MR solution to enhance teaching information systems and the future of work, with technology. This study, as a result, explores how knowledge embodiment in Mixed Reality systems affect people (Students and Teachers) and connections between them.
Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.	The use of HoloLens in class was evaluated by surveying 200 students taking the two units Information Systems in Organisation and Management Information Systems. The evaluation of the findings of this study, identify how knowledge embodiment in Mixed Reality systems affect the students, teachers and the connections between them. STIN analytical strategy for social informatics is used to understand the knowledge embodiment in the Mixed Reality systems in the given context.
Research Contributions	Effective design science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations and/or design methodologies.	This study gives a new way of introducing a design foundation by using a new artifact – Microsoft HoloLens to introduce the concept of MR and evaluate the usability and students feedback. The study also highlights the knowledge embodiment in the use of the Mixed Reality systems.
Research Rigor	Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.	The design of the lesson plan, working on the ethics approval, creation of the tasks for students to experiment on the HoloLens, conducting the survey and analyzing the results is the rigorous methods used in both the construction and evaluation of the design artifact.

Guideline	Description (Gregor & Hevner, 2013)	This Study
Design as a search process	The search of an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.	The search for the effective way of using and testing the new artifact - MR (Microsoft HoloLens) in education was conducted.
Communication of Research	Design science research must be presented effectively both to technology-oriented as well as management-oriented audiences.	The study and the findings were discussed with various organizations, health, education, and information technology department. The study will be presented in conferences and journals.

Table 1. The design science and how it is used for this study

Microsoft HoloLens was used by 25 students studying a postgraduate Management Information Systems unit and 180 students studying a graduate unit about Information Systems in Organisations. Six HoloLens devices were used in ten different workshop classes to review the concepts taught. Four tutors were involved in the orientation of the use of HoloLens in class. The lesson plan was prepared and shared with the tutors. Tutors were also oriented with the lesson plan and the HoloLens. Three members from the education team were also involved in helping the 205 students use the HoloLens in class for the first time. Figure 2 gives a demonstration of the use of HoloLens in class.

Figure 2. Use of HoloLens in Class

After an initial orientation to MR and the various applications of the technology, students formed groups of four. HoloLens was circulated between each of the group members for them to experience one of the available Apps. Students then discussed the opportunities and capabilities of the immersive tourism HoloTour App and the 3D hologram creation HoloStudio App. HoloTour application gives a view to explore the beauty and history of Rome or to uncover the hidden secrets of Machu Picchu. HoloStudio is a HoloLens app that allows developers to create holograms of your own design and turn them into physical objects with 3D print compatibility. Based on a previously chosen industry or business area for analysis, students were asked to consider how MR and these types of Apps might transform the future and associated opportunities for their chosen industry or business area. At the end of the class, students were asked to participate in a short survey to ascertain their views on the user experience and critique the affordances of the technology. This doubled as a formative learning moment to inform their final assignments which required students to analyse the impact of innovative technologies and the effect of a change in their chosen industry/business. At the end of the session, students were asked to rate their experience. The findings from the survey are presented in the next section.

4 FINDINGS

From the user experience point of view, the analysis of the data found that 84% of students evaluated HoloLens to be enjoyable to use, 71% found it easy to use and 78% found it worked well. Interestingly 74% of students indicated HoloLens would help them learn/work with others which may indicate a progressive view of working with others with more of a global reach. 82% of the students felt that it helped in visualising the main idea. 89% felt that it makes learning more interesting which scored the highest. For 79% of the students, it made them understand the main idea while 77% of the students agreed that it helped them move or place the objects. 82% of the students would like teachers to use HoloLens in class. This App would help me learn better than normal classroom activities scored 80% of students agreeing. Table 2 visualises the results of the survey.

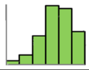
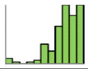
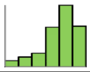
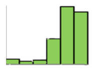
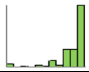
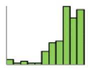
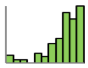
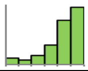
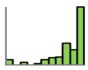
QNO.	Question	Mean	SD	Descriptive Graph
Q1	It was enjoyable to use	8.4	2.06	
Q2	It was easy to use	7.1	2.27	
Q3	It worked well	7.8	2.06	
Q4	It would help me learn/work with others	7.4	2.52	
Q5	This App helped me see or visualise the main idea	8.2	2.27	
Q6	This App would make learning more interesting	8.9	2.10	
Q7	It helped me understand the main idea	7.9	2.16	
Q8	I found it helpful to be able to move/place the object/s	7.7	2.45	
Q9	This App would help me learn better than normal classroom activities	8.0	2.50	
Q10	I would like teachers to use this App in the classroom	8.2	2.52	

Table 2. Survey questions with the mean, standard deviation, and the descriptive graph

What was the best about the Apps in HoloLens?	What was the worst about the Apps in HoloLens?
Next-generation digital native dependency	It made me feel nauseous.
In Holotour it was cool to be able to view a typical street setting and the daily activities of locals	The head restraint was annoying.
Allowing us to use new technology that is inserted into a learning experience, was great	Selecting motions
Learning is much more interesting	Found it hard to use as I was wearing glasses and it did not fit, making my head/eyes uncomfortable
360-degree visual world	Hard to move around and adjust
Interesting, very useful, new study technique	Not easy to use
Interactive and engaging	Operating the app was very difficult
To be able to see the real world combined with the apps, objects, and interfaces.	The controls were a bit difficult to use.
Being able to visualize things	It worked terrible, barrels functioned.
You are able to see a clear image and really immerse yourself in the world	Limited vision

Table 3. The best and the worst answers about the HoloLens Apps

Among the positive aspects of HoloLens, the promising future of MR technology was evident in the student comments to the open-ended question. A few examples quotes about the future of technology are, "next-generation digital native dependency" and "new, exciting, innovative, engaging and responsive". The students were confident about the interface experience and the human-computer interaction component of the HoloLens. "It was amazing to experience a place away from the classroom, and also be taken back to historical periods and move around and view the place as if you were there" and "Amazing user experience" are examples of quotes related to human-computer interaction. The feedback also highlighted that HoloLens is a good tool for teaching and learning as stated in the following quotes: "The best way for students to learn something new"; and "Excellent for teaching in class". These responses, perhaps not surprisingly, highlight the benefit of the innovative learning experience for students, as well as aspects of the user experience of the technology itself.

Student comments to the open-ended question about the negative aspects of HoloLens include: "Hard to use at the beginning"; and "Not easy to use". These responses indicate that students analysed the user experience while being immersed in the experience themselves. This sense of user empathy is an essential element for the future of work and the design and development of IS solutions. The students were also not comfortable with the eye view specially if they wear glasses. "Users can't use it without glasses"; "it could possibly hurt people's eyes" "eye strain" and "it was difficult to see at times" are some examples that highlighted viewing issues. There were also issues related to the view and the controls listed as "screen was too small" and "it was very hard to use the controls". The top ten results to the question about the best and worst experience of the HoloLens Apps are given in Table 3. To the final question about suggested improvements, some student responses indicated a limited view of the potential of MR. Comments about the gamification elements such as "Make it like PS VR Game" and "NBA games", while other student responded indicating that they are thinking about the potential future of the nexus between IS, MR, and human interaction/empathy. Some examples for the same are listed as "more options and more human-computer interactions" and "more interactive communication".

Thus, the research question addressed in this study is: **How does knowledge embodiment in Mixed Reality systems affect people (students and teachers) and connections between them?** To answer this question, Socio-Technical Interaction Networks (STIN) analytical strategy for social informatics (Kling et al., 2003) helps to explain and understand the networks between people and mixed reality systems (Meyer, 2006).

1. The first step in the STIN strategy suggests identifying a relevant population of system interactors. For this study, lecturers, tutors, students are identified as the relevant population.
2. The second step suggests identifying the core interactor groups. The tutors and students in the class of Information Systems in Organisation and Management Information System units are identified as the core interactor groups.
3. The third step was to identify incentives. The incentives for the use of HoloLens is based on student choice. The topic was established as a revision class. The tasks they do is in their group.
4. The fourth step was to identify excluded actors and undesired interactions. This strategy was considered by giving students the options to participate in this use of HoloLens.
5. The fifth step was to identify existing communication forums between the teacher and the student in the class.
6. The sixth step is to identify resource flows and in this case, faculty have sponsored the HoloLens to use in class.
7. The seventh and eight steps are to identify system architectural choice points and map architectural choice points to socio-technical characteristics. This research work and the paper is a way of sharing the lessons learned.

The study reveals four forms of knowledge embodiment in mixed reality systems. A social informatics analysis of the four forms of knowledge embodiment indicates four ways people and technology are interconnected.

1. **Declarative knowledge** is know-what in the form of facts, concepts, rules, or principles. An example of declarative knowledge is the use of HoloTour for visiting Italy. A student's comment related to declarative knowledge is *"visualization, fairly easy to use, you can see and learn instead of reading a book"*.
2. **Procedural knowledge** is know-how in the form of scripts, methods, processes, or operations. An example of procedural knowledge is the use of HoloPatient to practice the

procedure for patient diagnosis. A comment from a student highlighting the procedural knowledge is *"interactive and hands-on approach, something live never seen before so feels like the face front of technology"* student quoted.

3. **Conditional knowledge** is knowledge of when to apply what knowledge and requires an understanding of the situation or circumstance at the point of action. An example of conditional knowledge is using 3D hologram creator HoloStudio to create a car or a house. To quote a related comment from a student, *"I am able to design anything I want in my room"*.
4. **Teleological knowledge** is an understanding of the purpose, intention, rationale, or objective of using knowledge. An example of teleological knowledge is the use of HoloPatient to practice the procedure for the treatment of the patient after diagnosis. A related comment from a student is *"HoloLens could let me learn things in real feeling"*

Finally, to emphasise on the learning outcomes, student comments demonstrated that authentic experiential learning led to professional practice thinking about their potential future. The students brought their learning experience with HoloLens in their final assessment at the end of the semester. For example, one assessment presented how to use HoloLens in the watch repair industry. A quote from their assessment states that *"HoloLens, the virtual reality headset will allow watchmakers to solve the most intricate of problems as well as giving them a more unique solution of which they may not have previously thought"*. Another set of students proposed a personal trainer with HoloLens. A quote from their assessment states that "*with the development of HoloLens, the whole system of personal training could change. HoloLens could give a whole new look into personal training, as it would benefit both the trainer and the trainee"*.

5 CONCLUSION

To conclude, this study presents the trial and findings of the evaluation of using Microsoft HoloLens as a teaching tool in Information Systems (IS) class. The findings of this study shed light about how MR is succeeding in bringing the outside world into the classroom by making learning collaborative and interactive. The new learning experience with MR provided students with the opportunity to exercise authentic, critical and creative inquiry which was demonstrated by students' comments on both opportunities and limitations of the technology.

This study reveals four forms of knowledge embodiment in a mixed reality system, each with a distinct focus in terms of the type of knowledge embodied, the relationship between embodiment and human cognition, and transformation of knowledge work. The social informatics perspective has been used to study social interactions between human and mixed reality systems. This study also shows that the social informatics perspective is invaluable to our understanding of Mixed reality technology. Mixed reality embodies human knowledge and human capabilities. It is evident that knowledge of different types could be embodied in Mixed Reality Systems (Baptista et al., 2006; Gourlay, 2006). By this very nature, examining Mixed reality's social and institutional connections with people is essential for realizing its value. This study is one of the earliest to examine the social informatics of knowledge embodiment in mixed reality systems like Mircosoft HoloLens. This study contributes to the social informatics perspective by identifying that mixed reality technology like HoloLens can go beyond being a tool used by humans to become a more active, autonomous social actor. This extends the findings of prior social informatics studies (Sawyer, 2005) and has implications for understanding connections as the human-technology distinction blurs.

One of the limitation of this study is the cost of HoloLens. The HoloLens cost USD4500.00. Hence, we used only 6 HoloLens in workshop classes with nearly 20 students. The applications were also expensive. We used freely available applications like "HoloTour". In the future, we aim to develop applications for the next phase of the study. Developing applications not only helps us to use but also involves students focusing in software development to develop the application. Although we've seen much progress in the basic enabling technologies, they still primarily prevent the deployment of many MR applications. In the next phase of the study, there is a need to introduce HoloLens to students in various fields like business, health, and communication. This will help us to understand the way students from different domains can present the case. The eye sight issue highlighted in this study, and the convenience of use for the students' needs to be considered using the new model of HoloLens. Based on the results, there is a need to propose better ways to design the AR systems, so that the students find it usable.

HoloLens is an example of digital disruption in the way students see the unseen and experience a transformative technology that facilitates learning while simultaneously producing immersive classes that are entertaining and engaging for the student. While MR is resurfacing from previously discussed theoretical frameworks to actual implementations that are set to disrupt business and society alike, further investment in MR in IS education is clearly warranted as shown in this study. By using MR in IS classrooms, experiential and entrepreneurial learning can be fostered. We can hence prepare our students for disruptive innovation, evolving workforce, and lifetime success. MR is an emerging technology that can be used in education to support and challenge students to explore new possibilities in the future of work. It helps in building students' capability to approach emerging technologies with a sense of dynamic and progressive change. By nurturing a culture of innovation through embedding experimentation and an entrepreneurial approach into the learning experience, it also builds students' capability, resilience, and agility.

Information Systems research on the use of MR technologies for education is really in its infancy. The prevalent and affordable availability of these is still emerging (Melatti and Johnsen 2017). The new version of Microsoft HoloLens that was released in February 2019 worked with companies like PTC Vuforia solutions, Philips and Bentley to give transformative MR experiences for industrial customers. These are good leading examples of how work can change. This study points to a different set of affordances, and the early research in this area is overwhelmingly positive about its effects on both learning and motivation (Bernard et al., 2018; Leonard & Fitzgerald 2018). This research suggests that while the novelty value of the technology cannot be overlooked, there is also evidence that the motivational effects of the technology are due to the intellectual easing effects that they can provide. For tomorrow, experts estimate that the market for MR will increase to 162 billion dollars in 2020. MR will have an extensive impact on the future of work, education and life by making the world a better place.

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