Roadmap for augmented reality (AR)

Description and state of the art	
Definition	Augmented Reality (AR) is the real-time use of information in the form of text, graphics, audio, video, GPS data and other virtual enhancements integrated with real-world objects, whose elements are thus augmented.[33] It is this 'real world' element that differentiates AR from virtual reality, which in contrast replaces the real world with a simulated one. Augmentation is conventionally in real time and in semantic context with environmental elements. With the help of advanced AR technology, the information about the surrounding real world of the user becomes interactive and digitally responsive. Information about the environment and its objects is overlaid on the real world. This information can be virtual or real. Overall, AR brings out the components of the digital world into a person's perceived real world and enhances one's perception of reality.[34]
Addressed societal /business or public sector need	Societal need: Experiential education and training

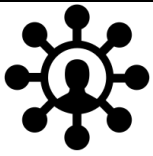
Existing solutions /applications /services	• The technology for visual augmentation is already in use, especially by private persons for gaming purposes
	• There are several **databases of augmented reality apps for the classroom** in the internet, e.g. [35–37] – some examples are:[38]
	  ○ Quiver (get 3d-pictures from textbooks)
	  ○ Elements 4 D (visualisation in chemistry)
	  ○ Blippar (visualisation of the Brainspace magazine)
	  ○ Arloon Plants (watch growing plants)
	  ○ Aurasma (create ones one augmented reality experience)
	  ○ Math alive (visualization of mathematics)
	• In general the following forms of AR are used in the classroom:[37]
	  ○ AR technology has an ability to render in **3D model** anything that may be hardly visualized

	in a classroom, at a computer, in minds of students. ○ Including AR into lessons may help educators **directly involve students** into the studying process by interacting 3D model. Taking part in such kind of things helps motivate students ○ AR books provide deeper understanding of complex content. It also helps making the process of learning **brighter and engaging**. • The **French Ministry of National Education** was also expressing their support of augmented reality technologies in the classroom. In their revised national curriculum, the Ministry included AR as a recommended technology to be used in middle school technology courses.[39] • AR training is also already in use the **automotive industry** (BMW, VW [40]) or in the **printing industry** [40]. Other educational apps are **Construct3D** for students of mechanical engineering or AR apps for students of **chemistry, anatomy or astronomy**.[34] • **Fire Departments** are using a mobile Augmented Reality Training Unit made by Resolve Fire & Hazard Response, Inc. to train participants to fight fires.[41] • **Brain Power**[42] is working to teach life skills to children and adults on the autism spectrum • **Eye Decide**[43] allows healthcare professionals to demonstrate how certain conditions impede eyesight • **VR Dentist**[44] is a dental app that uses virtual and augmented reality for educational purposes • The **"Augment" augmented reality (AR) app** and platform enables students and teachers to visualize 3D models (e.g. used in career tracks like architecture, engineering, 3D animation and design, medical sciences)[39] • AR is also used in **military training**: In 2009 the first augmented reality training system was demonstrated for US Warfighters in what the military calls its Future Immersive Training Environment (FITE) Joint Capability Technology Demonstration (JCTD).The 36 Million dollar experiment allowed soldiers to train at home to prepare for small, urban and borderless conflicts around the world.[41]
 Main actors regarding R&D of this technology	• Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V. • Centre National de la Recherche Scientifique • Ethniko Kentro Erevnas Kai Technologikis Anaptyxis, Teknologian Tutkimuskeskus VTT • Technische Universität Graz • Technische Universiteit Delft

 Current research activities	Research activities for AR applications in education: • ARISE[45] • MOBILE AUGMENTER[46] Current Research activities for AR in general: REALITY (eyewear), VOSTARS (medical domain), LARA (for Galileo and EGNOS), AEROGLASS (aviation), Augmented Commerce (e-commerce), iMARECULTURE (cultural heritage), TARGET (e.g counterterrorism), SPARK (prototyping), DBRLive (cameras), INSITER (energy-efficient buildings), Wear3D (wearables), ARVisS (medical domain), MARWIN (for welding installations), MARCUS (urban settings) **National projects:** Overview – virtual technologies (BMBF)[47], AVILUS, AVILUSplus[48], ViERforES[49], AR4DOC [50], ARVIDA [51], AUGUR [52], MIRACLE [53], SMART Vidente [54], MARIN2 [55], **BMBF:**[56] AR-UROLO, VIERforES II, Kognit, ENDOGUIDE, E! 5547, TOUAREG, ARinFLEX, ERANET, MANUNET, ARSGuide, itsowl, MMI, SPIRIT, THIN but Great Silicon 2 Design Objects, Professionelles Wireless Industrie LAN,EFA2014/2 **BMWi:**[56]CRUMBS, EXIST research transfer **EUREKA** projects: COMINDED[57], MOVAR[58], HIVIP[59], AR-LEAN[60], HDF DOR CSF[61, 62], Pocket Pet[16] **EUROSTARS** projects: [63], TouAREG[64], HISARTOUR[65], CAMILIS[66], ORBIPS[67], LBSAAS[61],
 Impact assessment	**Public sector modernization:** ○ Efficiency and productivity **Public sector as innovation driver:** ○ Quality of education ○ Equity & inclusiveness ○ Public safety ○ Transport infrastructure
Necessary technological modifications	
 Potential use cases	• Surgeon could use AR to learn e.g. open-heart surgery without risking patient's life[68] • AR could simulate hazardous workplace conditions (e.g. in the construction industry)[68]

 Technological challenges		Marker-based AR as mentioned in the results section is the most used approach for supporting the development of AR learning experience, followed by the location-based AR. A possible explanation for this result is that currently **the tracking process of markers is better and more stable compared to the marker-less tracking techniques.** Besides that one of the advantages of marker-based AR is the facility of implementation due to the available libraries which support the development process. There is a **challenge around the improvement of recognition algorithms for human forms** as a promising feature in the process of achieving more immersive and not intrusive AR learning experiences.[69, 70] **Accessibility and usability of the AR learning experiences** are two important issues to be addressed in future research since few studies have reported research on this field. Further research need to be undertaken in usability studies for AR applications in education as well as guidelines for designing AR-based educational settings.[70] The evolution of AR environment development tools in the last decade has been considerable; today there is a range of solutions available. Nevertheless, these solutions **still require a high technical knowledge and/or considerable time to generate content**, which makes it a challenge to create AR educational environment and to generate content in an easy and effective way. [71]
Necessary activities (in or for the public sector)		
 Development of a specific training necessary	**Open task**	The advantage of Augmented Reality is that the learning experiences can be **as easy or as complex as one wants**. It is possible to create own apps or download the numerous already-made apps connected to various content.[72] But although AR is very attractive, it is quite complicated to introduce it in the educational system and adapting it, because most of the people are **accustomed to a traditional way** of teaching; a change is needed, but above all, training is needed, because with it, the use of all these devices will come to better meet the needs of education that we have right now.[73]
 Advanced or adapted ICT infrastructure needed		Modern mobile computing devices like **smartphones and tablet computers** contain these elements which often include a camera and MEMS sensors such as accelerometer, GPS, and solid state compass, making them suitable AR platforms.[74] Other more advanced displays of AR information are e.g.-head-mounted displays, eyeglasses or contact lenses.[74] Thus it depends on the form of education or

		training needed. For basic education in the classroom smartphones or tablets are sufficient, but for a more specialised training for e.g. medical students more advanced displays are needed.
 Change of (public sector internal) processes necessary	Open task	AR-enhanced content has to be developed as part of a unified pedagogical philosophy and teaching strategy. AR is not something you can simply patch to existing curricula as a way of making children and teenagers more excited about going to class. A proper introduction of AR in the world of education will force a lot of **programs to be redesigned from scratch and re-developed** with the possibilities of the technology fully in mind.[75]
 Promotion / information of stakeholders necessary		A recent survey by Gfk and Samsung found **85% of teachers agree** that virtual reality would have a positive effect on their pupils. They believe it would be an asset to help students better understand learning concepts and collaborate in the classroom, and see it as a way to allow students to engage in new experiences related to course content via virtual field trips to faraway places or historical events. **Eighty-four percent of teachers believe** that virtual reality would increase student motivation too.[76]
 Need to deal with cyber security issues	Open task	For example the following issues have to be dealt with when using AR for education and training: • Illegal **recording and theft of user behaviour data** – hackers recording users' behaviour in their VR/AR environment and threaten to publicly release the recording unless a ransom is paid • Interjection of information or data into VR/AR to mislead or entice users into selecting items that **exfiltrate personal identifiable information** • Using fake VR/AR applications that steal personal information or **exfiltrate behavioural data** • Replacing learning or training content with **malicious content** or malicious applications to deceive users about the real world • Always-on cameras and other sensors will also create a **privacy risk** for bystanders [77, 78]

 New or modified legislative framework or regulations necessary	**Open task**	Especially when dealing with geospatial data the following areas have to be covered by regulations or a legal framework: • Privacy • Intellectual Property Rights (e.g copyright aspects) • Data Quality/Liability • National Security
 Development of a common standard necessary	**Open task**	There is **no common standard** on how to deploy AR applications for education and training. However, there are some common approaches that are followed by a large number of studies. One of the most common approaches is to use AR to augment the content of books where traditional educational or training material is explained in the form of text and images. The content used for the augmentation may cover a wide range of multimedia elements (3D models, animations, videos, webpages, etc.) and also several means of interaction that provide an added value to the books.[79]
 Need for a more economical solution		Chen and Tsai[80] in particular highlight the low cost in executing manpower and moderate costs for de-signing and renewing the courses. Andujar et al.[81] agree on this benefit, especially for virtual laboratories. They add that **AR applications not only reduce direct costs**, such as needed materials, but also time for preparing classes. While AR technology is accompanied with high acquisition cost, this investment is most likely to pay off in the long term.[82]
Dealing with challenges		
 Ethical issues	**Open task**	There are some (individual) privacy concerns – probability of access to information that one should not readily possess about a given person.
 Societal issues	**Open task**	No literature regarding societal issues and the use of augmented reality in education has been found. However, there might be issues regarding the technologisation and digitalisation of society in general. It is also necessary that the students do not become too dependent on technology.[71]

 Health issues		No issues identified in this area.
 Public acceptance		A nationwide survey conducted by Samsung (US) in June of 2016 found that the education industry is more than ready for virtual reality and augmented reality learning. According to the survey, teachers and students alike had very positive notion about this technology • 68% of Teachers who would like to use the Technology • 86% of Teachers find it challenging in keeping students engaged and interested in the topic • 93% of teachers surveyed believe that their students would be excited to use VR The findings of a recent study[83] suggest that the parents see that there are a lot of benefits in using a technological competitive tool based on AR.