Inclusive Peer Learning with Augmented Reality Apps

IO3 iPEAR Pedagogy and Assessment Tool

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Erasmus+

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Executive summary

Inclusive Peer Learning with Augmented Reality Apps (iPEAR) is a three-year Erasmus+ KA3 project with a mission to streamline the adoption of Augmented Reality (AR) technology in educational practice. The project combines the collaborative expertise of technology-enhanced learning researchers, computer scientists, and educators to build a strategic partnership.

Peer learning frames the new capital of the infosphere (Themelis, 2022). Social media usually takes advantage of our online friends to sell goods and services (the power of an online user is the number of followers). On a positive note, students and educators find 'learning friends' as co-travellers to help them acquire new skills or digest information as creative work with others that provide micro-scaffolding in class and online. The Peer-to-Peer instruction model, originated by Eric Mazur in 1997, offers significant evidence that it could make learning more efficient, collaborative, and empowering for students.

Educators and students must develop creative visual content as a new form of reading, writing, and disseminating information and identities. Visuals are the new language to be explored and efficiently used. AR is a rapidly growing market amongst ICT technologies as a form of visual literacies in many fields, such as education, marketing, and medical training. AR provides an enriched view of the physical world, adding layers with contextually helpful information delivered visually or by stimulating other senses using hand-held or wearable devices.

The project targets higher education (educators and their students) research and maps the educational use of AR, focusing on collaborative and peer learning approaches. It intends to facilitate the adoption of AR in education by creating open-access teaching and learning material for educators. It also aims to develop and maintain a community of experts in educational AR and other stakeholders to ensure the project's sustainability and keep the most valuable results up-to-date.

The document road map consists of 4 parts. PART 1 introduces the problem statement, the term of pedagogy in the frame of iPEAR, and the scope of learning theories from the iPEAR perspective. PART 2 introduces informed grounded theories and briefly describes the research findings, the advantages, disadvantages, and contextual factors of P2P and AR in learning, the general theoretical framework, and benefits, challenges, and contextual factors specified in the project's research and literature review. PART 3 elaborates on the elements of an iPEAR pedagogy as a framework and illustrates generic guidelines. PART 4 describes the rationale of the competence assessment tools designed in iPEAR and the subject of PART 5. The document covers the 4 working packages of the iPEAR project in Intellectual Output 3:

O3.1 General pedagogical strategy for educational AR
O3.2 Peer learning approach to AR-based education
O3.3 Educational AR competence framework
O3.4 Educational AR competence assessment tool

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Development of the document

1	01/04/2022	Chryssa Themeli	Draft	First draft version before the research
2	12/12/2022	Chryssa Themeli	Draft	Research findings added and pedagogy finalised
3	01/04/2023	Chryssa Themeli	Draft	Literature review, assessment framework and online tool questionnaire updated
4	28/06/2023	Chryssa Themeli	Final	Final version for publication

Table of Abbreviations

iPEAR	Inclusive Peer Learning with Augmented Reality Apps
AR	Augmented Reality
EUCEN	European university continuing education network
FAU	Friedrich-Alexander-Universität Erlangen Nürnberg
NTNU	Norges Teknisk-Naturvitenskapelige Universitet
IHU	Diethnes Panepistimio Ellados
AKTO S.A.	AKTO
HE	Higher Education
HEIs	Higher Education Institutions
MOOC	Massive Open On-line Course
P2P	Peer to Peer
IO (IO1-IO3)	Intellectual Outputs from 1 to 3
TPM (TPM1-TPM5)	Transnational project meeting from 1 to 5

Partners

FRIEDRICH-ALEXANDER-UNIVERSITAET ERLANGEN NUERNBERG (E10209513, DE) FAU	Germany	Applicant Organisation
NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET NTNU (E10209399, NO) NTNU	Norway	Partner Organisation
EUROPEAN UNIVERSITIES CONTINUING EDUCATION NETWORK (E10082854, BE) EUCEN	Belgium	Partner Organisation
DIETHNES PANEPISTIMIO ELLADOS / INTERNATIONAL HELLENIC UNIVERSITY IHU (E10162117, GR) IHU	Greece	Partner Organisation
AKTO S.A. (E10162068, GR) AKTO	Greece	Partner Organisation

"If we teach today as we taught yesterday, we rob our children of tomorrow."
Anonymous

PART 1: Introduction – the problem statement

After the pandemic, reflections led to different perspectives in every aspect of life. Educationalist Alexandra Mihai suggests rethinking our priorities as lifelong learners and educators. She summarises her article with five recommendations to brainstorm.

1) Noticing is a radical act of critical thinking. We must notice how technologies change, young people learn, and educators unlearn or re-learn.

2) An act of resistance against distractions. Reclaiming our students' attention lost in the never-ending notifications and fake information is crucial. (Themelis & Sime, 2020).

3) An act of choice among the myriad things that require our attention. Offering options for learning may be a way to help students design a more self-directed professional path.

4) An act of reclaiming our time and mental space. We must design tasks that allow people time to work without stress and cognitive overload within their proximal difficulty level with support from peers, mentors and online resources.

5) An act of awakening our senses and curiosity. Our students deserve more experiential and discovery learning that stimulates their senses and interest to engage in more profound understanding.

The overarching problem statement is how could we make higher education motivational, engaging and empowering?

We must consider the before-mentioned challenges, technology, creativity, and human/social norms to address this challenge. iPEAR embraces immersive technologies of AR, a creative approach to working and learning with others and inclusivity as a human/social norm.

1.1 Introduction to the term pedagogy

The iPEAR project (Inclusive Peer Learning with Augmented Reality) was designed to explore active and social learning methods for higher education. In the post-digital era, educators and students are lifelong learners who need to learn how to acquire new skills constantly; thus, be competitive in the job market and adapt to the fast-technological advancements. According to the Oxford dictionary, Pedagogy is the method and practice of teaching, especially as an academic subject or theoretical concept. The Merriam-Webster Dictionary Online (2023) defines pedagogy as "the art, science or profession of teaching" (p.1). The term comes from the Greek terms *paid* and *agogos*, which mean leader of a child (Holmes & Abington-Cooper, 2000). The term originated in Greece (paidagogia, paidagogos pedia), travelled in France in the late 16th century and was translated into pedagogue and pedagogy in English.

In post-digital educational research, there is a shift from pedagogy (teacher-centred education) to andragogy (learner-centred education) and then to heutagogy, i.e. to self-designed and self-determined learning through formal and informal pathways (Parslow, 2010). Heutagogy aims to teach lifelong learning and "learners who are well-prepared for the complexities of today's workplace" as Lisa Marie Blaschke (2012, p.56) stresses. Hence, the iPEAR project aims to facilitate students to work with peers and technologies to become gradually self-determined learners in a hyper-connected society. Heutagogy is not a well-known and widely accepted term; therefore, we will continue using pedagogy (as a process of self-actualisation) to avoid confusion.

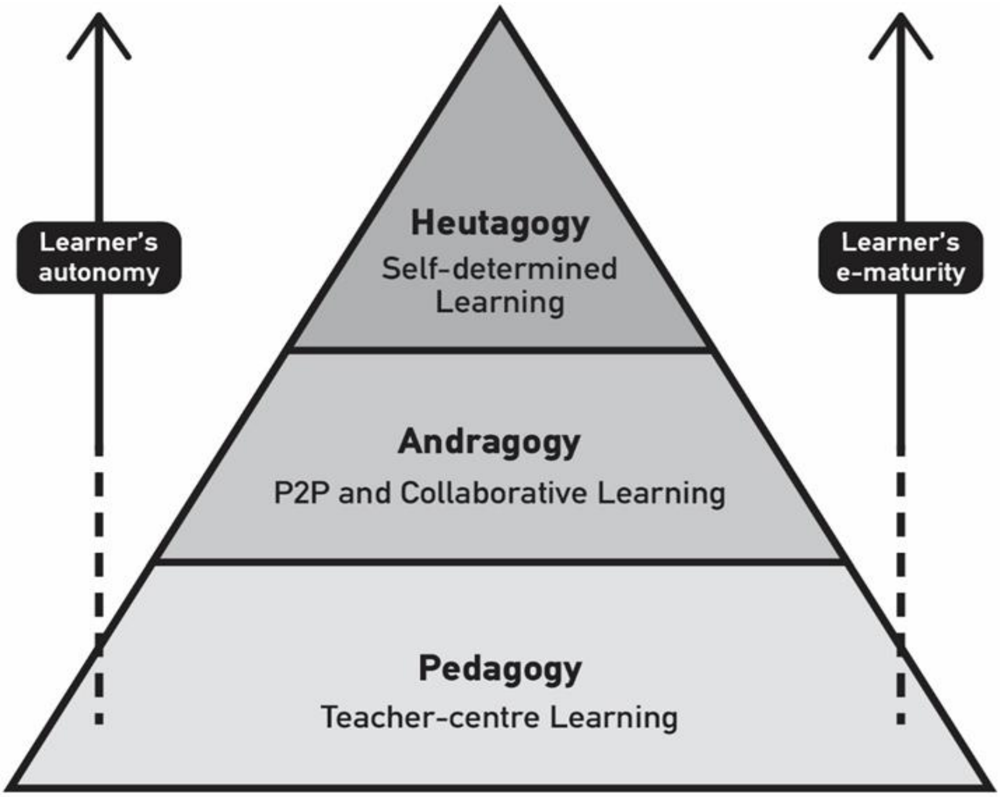

Figure 1: Pedagogies
(based on Canning 2010 and Themeli 2022, edited by Eleni Tsampra)

Figure 1 shows the gradual steps from pedagogy to andragogy and then to heutagogy, self-efficacy, and awareness (Canning, 2010, p. 63). It additionally shows two prerequisites based on social learning theories: learning with others (Learner's maturity) and self-efficacy (Learner's autonomy & empowerment) (Themeli, 2022).

Another issue to be addressed is rationalising technology use in terms of pedagogy. We use AR to make learning creative and provide choices to students and peers to support the cognitive processes and reinforce inclusiveness and social values.

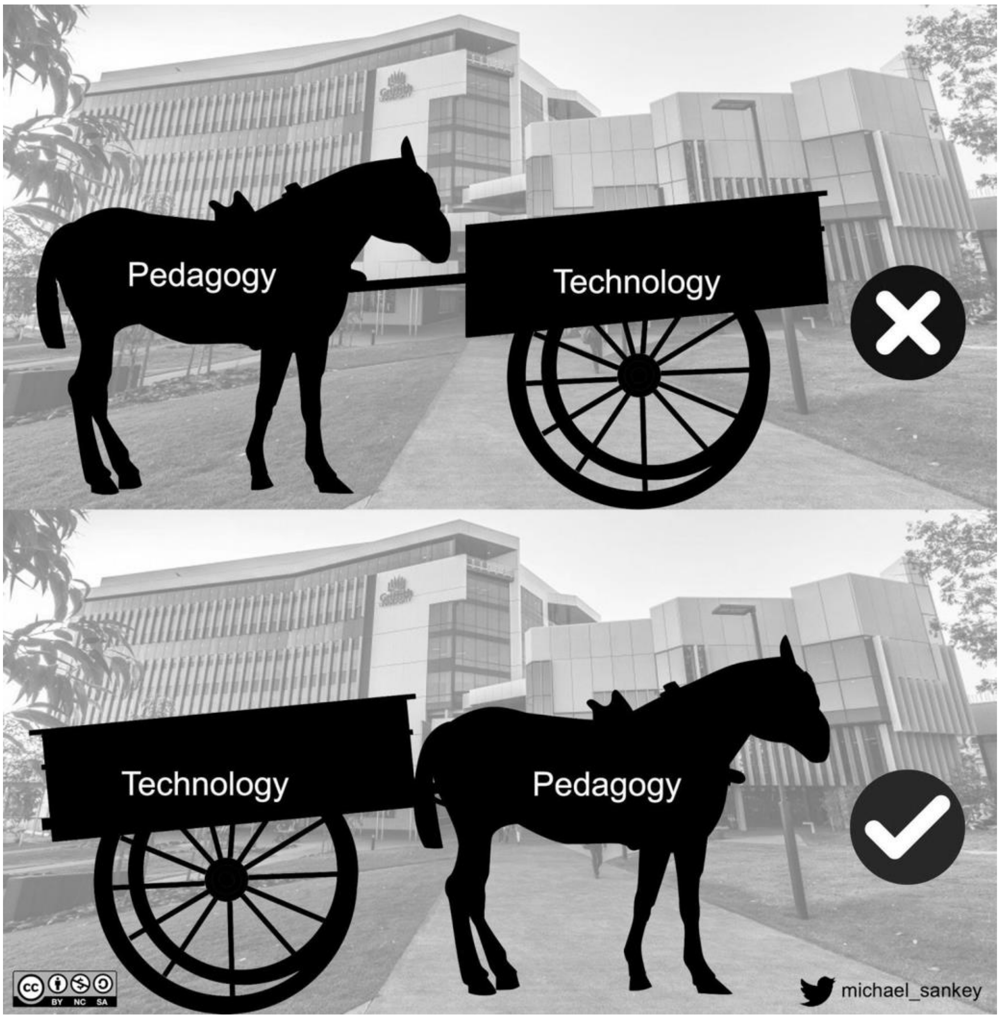

Figure 2: Relation of pedagogy and technology

Figure 2 illustrates how important it is to design the rationale for teaching before choosing digital tools (Sankey, 2020).

This document consists of 4 parts. PART 1 introduced the problem statement, the need to use creative and social processes in teaching and learning (the iPEAR perspective), and the pedagogy used by iPEAR (1.1). The next step will elaborate on the scope of learning theories from the iPEAR perspective (1.2). PART 2 briefly describes the research findings based on informed grounded theories. It elaborates on the advantages, disadvantages, and contextual factors of the P2P methodology (2.1) and of using AR as enriched realities for learning (2.2), as shown in the literature. PART 3 describes the general theoretical framework (IO3.1), the benefits, challenges and contextual factors that can be traced in the project's research and the literature reviewed for this purpose. The iPEAR pedagogy (IO3.2) describes the elements of the iPEAR pedagogy as a framework and offers generic guidelines. PART 4 includes the competence framework for AR that the iPEAR project developed (IO3.3) and describes the rationale of the competence assessment tools that are the subject of PART 5 (Online competence assessment tool for AR, IO3.4).

1.2 Scope of pedagogy in social learning theories, role-modelling and social physics

As mentioned above (figure 1), the road to self-determination and responsibility for learning is paved by social learning. **Social Learning** is an ancient perspective on learning; Plato and Aristoteles used to teach through dialogue with their students. In the contemporary history of learning theory, the father of social learning is Albert Bandura (1997, 1971 &1977). He claims that learning is not an isolated act, but we can learn by observing others. Another critical element of his theory is self-efficacy. He explained that self-determination and self-confidence in learning (beliefs as determinants) are crucial to how people behave and think in every field. Social learning theory, originated by Albert Bandura, proposes that learning occurs through observation, imitation, and modelling and is affected by factors such as attention, motivation, attitudes, and emotions. The theory embraces the interaction of environmental and cognitive elements that affect people's learning. Bandura's social learning theory explains that learning can also occur simply by observing the actions of others.

In the same train of thought, Ahn, Hu and Vega (2020) claim that social-cognitive processes involved in **role modelling** tend to be ignored. Their work provides an overview of role model research in education, detailing researchers' focus and emphasis on identifying aspects of role model effectiveness. They focus on role models' attentional, cognitive, and motivational processes and ask for more research on imitation in education.

In the same line of thinking, Pentland (2014), in his work on the science of **social physics**, explains that social interactions are the element that can significantly improve performance, creativity and innovation. Christakis and Fowler (2011) further illustrate that how we are connected with others online or offline describes who we are and even predicts future changes in behaviours through social contagion.

Overall, P2P (peer-to-peer) learning aims to obtain skills and knowledge as a dynamic learning process and develop positive beliefs about learning and teaching as a lifelong endeavour.

The implication of the pandemic: Sense of belonging (SoB)

Due to the pandemic, we have experienced long-lasting lockdowns and social isolation that challenged mental health and any aspect of life. People starved for social gatherings, and eliminating touch had implications that should be investigated shortly. Students were forced to stay home, and many newcomers faced the so-called transactional distance. Moore (1997) defines transactional distance as the psychological and communication separation between the learners and the educators in distance courses. Transactional distance can negatively influence learning and students' well-being (Christakis, 2020; Themelis, 2013; Kassandrinou, Angelaki, Mavroidis, 2014). Therefore, the need for social spaces and tele-proximity (Themelis & Bougia, 2016, p.1) is fundamental.

Maslow (1962) states that students cannot fulfil higher education goals without a 'sense of belonging'. According to Maslow (1962), belongingness prioritises self-confidence and self-efficacy. That is why we need to prioritise students' needs for well-being before thinking about Bloom's taxonomy and learning objectives. SoB is equally essential for the faculty working for eLearning or in class. Due to the transactional distance and the emotional barriers of lockdowns, the SoB is the first prerequisite for establishing a learning space that safeguards well-being. Goodenow (1993a, p. 25) defines SoB as the emotions of

> […] being accepted, valued, included, and encouraged by others (teachers and peers) in the academic classroom and feeling oneself to be an important part of the life and activity of the class. Beyond simply perceived liking or warmth, it also involves support and respect for personal autonomy and the student as an individual.

P2P Learning can enhance social integration (Byl, Struyven, Abelshausen, Meurs, Vanwing, Engels, and Lombaerts, 2015), bridging the transactional distance gap by bringing people together in distance courses and close proximity in real classrooms.

PART 2: Research findings and literature reviews

The iPEAR framework introduced in PART 4 was designed as an experimental approach tested and elaborated in the co-funded Erasmus KA2 project for higher education. As a form of social learning theory (Bandura,1977), peer-to-peer task designs (Mazur, 1997) and visualisation (micro-learning) are widely used in vocational training and marketing via AR tools. The AR tools used were free versions of mobile apps, except for a case study from the IMTEL lab in Norway that uses Microsoft HoloLens. During the research process, two more elements were derived from the surveys with students, the interviews with educators, and the literature in the field. They need to understand better the roles (social and ethical) of visuals or visual content creation in learning (visual literacies and media) and gradually build a peer feedback culture (critical thinking). This peer feedback perspective is based on students; previous experiences and cultural background, but it could be reinforced with rewards or incentives initiated by educators. This sharing attitude could make courses more inclusive and help students take more responsibility for their studies and the growth of the learning community. The i-PEAR pedagogy is formulated as a product of the research within informed grounded theory (research approach) boundaries that combine research analysis with updated literature reviews (Themelis, Sime, and Thornberg, 2022). The approaches based on informed grounded methodology are in a never-ending evolution as it needs frequent revisions by the literature and new studies. That is why reviewing the literature was an ongoing process during the project's three-year duration.

Data collected in the 22 interviews and 214 surveys heighten the role of the **iPEAR approach** as a motivational driver that can potentially engage students and enhance agency -choices. The research informants regarded the iPEAR approach as a source of creativity, fun with classmates and deeper understanding. The disadvantages were costs, lack of training and technical problems such as device compatibility and internet availability.

The following sections discuss the literature on P2P learning and on AR in higher education.

2.1 Literature review on P2P learning

Working on a strategic plan for new pedagogy literature is essential in every study, especially in the boundaries of informed grounded theories. The literature review is the academy's cornerstone, aiming to connect the dots, map uncharted territories and frame theories. However, it is a very complex task due to the fast pace of research and the interdisciplinary and multidisciplinary perspective of technology-enhanced learning fields. Technology-enhanced learning considers developments in educational research, cognitive psychology, brain science and technologies, to name a few. The most common approaches to literature review are systematic, semi-systematic and integrative or narrative. The first research question of this study in reviewing the literature is: **How could P2P learning be used in Higher education (advantages, disadvantages and contextual factors?** A systematic perspective to review existing studies is not appropriate for multidisciplinary research questions (Snyder, 2019). Thus, this is an integrative approach starting with a research question.

> In some cases, a research question requires a more creative collection of data; in these cases, an integrative review approach can be useful when the purpose of the review is not to cover all articles ever published on the topic but rather to combine perspectives to create new theoretical models (Snyder, 2019 p.334).

There are abundant resources regarding P2P learning or Peer Instruction, Peer Mentoring and Peer Feedback. Hence, the integrated/narrated research focused on keywords and publications from 2018-2023 to answer the before-mentioned research question.

2.1.1 Advantages, disadvantages & contextual factors for P2P

This section is written on the integrated/narrated literature looking for information regarding the pros and cons of P2P learning and contextual factors. The narrative aim to map the territory and show the case studies that could be role-models for P2P courses or task design. The research was based on the Norwegian University of Science and Technology library resources, Google Scholars and the Journal of Peer learning. The open-access journal publishes research articles about peer learning, predominantly higher education, across various contexts and continents.

2.1.2 Advantages

Peer-to-peer learning is the process of teaching one another, sharing questions and examples, solving a problem, working to develop a collective understanding or even co-create a project-based assignment. The roles in the groups could be equal participation or different contribution, including mentoring. The following resources show research on P2P learning that not only does it enhance motivation, engagement, and understanding of the course outcomes but also provides an equitable and inclusive experience for students. It boosts students' confidence and promotes insightful teaching through role-playing, multi-channelled communication and explorative inquiries. A positive side-effect is empathy – to know the learning challenges of fellow students and try to assist them and social peer pressure that makes changes less uncomfortable. Overall it is a cost-effective way to learn and teach, making the process more enjoyable and effective for students and less tiring for educators while offering professional salience. It is important to note that working with others and co-creating and designing the learning process is the capital students need to invest as a form of competence, which is evident in how social media works.

The latest edition of the journal of Peer learning editorial (Power et al., 2022) focuses on peer leaders and peer teaching in different national and disciplinary contexts. All cases present advantages in the deployment of the approach.

Cofer et al.'s article (2022) similarly focuses on peer educators. The context for this article is predominantly learning centres in the United States and includes some comparison between two different modalities of peer educators: peer tutors and Supplemental Instruction Leaders. The researchers employed a survey to explore the perceived gains of peer educators across three subcategories, including academic performance and learning, non-cognitive skillsets, and self-confidence and fulfilment. The findings show that the three subcategories had gained. Based on these findings, greater resource allocation for peer educators is recommended to enable ongoing training and reflection.

The article by Rawson and Rhodes (2022) reports on a study investigating the motivations and perceived benefits for students who volunteered to become online peer-assisted learning (PAL) leaders at the University of Derby in the UK. Their study draws on theory and research related to the intrinsic and extrinsic motivation of students who study by distance. However, they have identified a gap in the research that specifically relates to what motivates online students to volunteer as PAL leaders. This has, of course, gained urgency as a result of COVID-19. Their study identified that intrinsic motivation was related to an altruistic and empathic approach to helping other students adapt to online research. Extrinsic motivation included the potential for PAL leaders to improve their study skills, gain transferable work-related skills, and the possibility of an award to acknowledge their involvement. While admitting that they drew on a small sample, their study includes some exciting suggestions from participants, such as providing digital badges or other tangible rewards, which could serve as incentives and aid in recruiting new leaders. Their study ultimately provides an equitable and inclusive experience for online students.

Szeto et al.'s article (2022) concentrates on a General Education Foundation (GEF) Programme at The Chinese University of Hong Kong. To help students read classic texts and discuss challenging topics, Peer Assisted Study Sessions (PASS) were piloted as part of the programme. The programme's interdisciplinary nature makes this an unusual context for PASS. Szeto et al.'s article, examines how PASS could improve student learning in seminar-style courses through a mixed-method study from a student perspective. The results show that PASS successfully improved students' understanding of the course content at a cognitive level, that it assisted and motivated them to prepare better for the seminar discussions, and that it also improved confidence and motivation.

Safari et al. (2022) examine the experiences and attitudes of midwifery student tutors and tutees as part of a reciprocal peer tutoring program that involves a certain degree of role-playing. In this peer learning approach, students can assume the role of a teacher in the classroom, followed by group Q&A sessions and case reporting to assess the overall efficacy of the exercise. In addition, this article discusses how the alternation of roles from student to teacher and vice-versa can lead to rich and insightful learning and teaching. The authors argue that this reciprocal peer tutoring approach can enhance motivation and positive attitudes towards the learning and teaching process while increasing multi-channel interactions between students and instructors.

Simulation-based learning has proven to be a valuable learning tool in many practice-based disciplines. In their article, Dennis et al. (2022, as cited in Power et al., 2022) present the findings of an investigation that combined simulation-based learning with peer-assisted learning to address a scarcity of clinical placements for physiotherapy students during the COVID-19 pandemic. Their study utilises a prospective qualitative observational design using feedback from peer learners concerning the efficacy of the peer-assisted learning approach. In addition, the authors discuss the enablers and barriers towards a successful learning and teaching experience while pointing out how this combination of simulation and peer-assisted learning model can be further improved. This approach has the potential to become a sustainable solution when health systems worldwide struggle to cope with extraordinary demand due to a range of challenges on multiple fronts.

This learning approach has become increasingly popular in education and work training because it offers cost-effective, efficient and enjoyable options for acquiring skills, retaining knowledge and creative thinking. It improves Engagement, autonomy and empowerment, critical competencies for learning for a living. The power of P2P is social pressure that creates standard etiquette and values, micro-scaffolding and P2P support that helps students overcome challenges if used with an inclusive perspective.

As a teaching praxis, when students interactively teach each other, they share a sense of empathy, micro-scaffold information, and fully understand the learning difficulties (Mazur, 1997; Gupta, 2020).). Educators feel relieved from the workload of overexplaining subject matter and share a feeling of professional salience when they see their students learning effectively and enjoyably with their classmates' assistance. Research on peer mentoring revealed that structured peer interaction can positively impact both sides of a peer program partnership (Tredinnick, Menzies, & Van Ryt, 2015). There is little awareness about the implications of peer learning within online communities of practice: the degree of invisible understanding and interactions and the transformative powers that make individuals more social and change their roles and identities (Merry & Orsmond, 2020).

A good example is the Peer Mentoring Project at Kent State University. A programme has increased students' academic performance, social skills, self-efficacy, and ability to realise their professional preferences. More importantly, P2P learning creates a relational approach to education, and mentoring connects learners on a university campus and diminishes transactional distance by associating with each other (Taosinstitute.net, 2021; Gurjee, 2020). Another study showed (Hayes and Fulton, 2019) that P2P could positively impact PhD candidates, who narrated enhanced confidence and a sense of social inclusion and belonging to the university.

> Being facilitated by students who had experienced the same academic pathway was perceived to have widened networking opportunities and to have positively impacted the capacity of the participants and leaders to build relationships and prepare skills of direct relevance to the

> requirements of an employer, such as teamwork and initiative (Hayes and Fulton, 2019, p.1)

During the Covid-19 pandemic, the P2P approach provided a supportive alternative to monotonous and alienated distance courses based on lectures (Vergroesen, 2020). Students were allowed to co-create content, share personal experiences, analyse, evaluate and retain knowledge while working with peers. Peers were an antidote against the passive learning approach (online lecturing) and loneliness of the two-meters society. Studies (Cohen, Kulik, Kulik, 1982; Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014) provided some evidence that students had more chances to pass the class and a better understanding of the subject matter if they were working with others. Student-led seminars, peer reviews, and discussion topics in breakout sessions are peer-to-peer active learning approaches that have become popular in remote teaching. Students enjoy personalised attention from their peers and take more responsibility for their personal growth (Vergroesen, 2020).

Peer feedback was a reliable source for scalable learning under two conditions. Firstly, the students had to use rubrics and templates that were easy to comprehend successfully, and the activity of reviewing was with an optimal level of difficulty. Secondly, the people within the peer culture were willing and able to teach each other. The students should have built trust, and a learning community spirit must be evident in online and offline social interactions. Another concept is Feedforward, which illustrates constructive criticism to students and focuses on general advice about future efforts. (Baker & Zuvela, 2013; Walker & Hobson, 2014).

P2P could be either a synchronous or asynchronous intervention in distant learning spaces. We mainly think about in-class activities or homework assignments when discussing peer instruction. In distance education, synchronous approaches such as breakout sessions during web conferencing or peer working and communicating out of the eLearning setting using transmedia strategies: chatting online, talking on the phone, videoconferencing or even meeting in virtual reality platforms. Asynchronous peer instruction could work with e-mails and discussion threads, Still, asynchronous media create a fragmented communication pattern, enforce misunderstanding, and the dialogues usually lbecame chaotic. (Hrastinski et al., 2010, as cited in Themelis, 2013). The lack of immediacy still makes it difficult for students to connect quickly and trust each other online to invest more time working together (Schullo, 2005). Still, asynchronicity could embrace more reflective thinking before responding to a question in a forum. Synchronous video communication among students is a sensory-rich approach more closely related to face-to-face in-class peer learning and requires immediate feedback that some students could not offer unless the educator provided a rubric. Some older studies claim combining asynchronous and synchronous means of communication is preferable since different types of communication promote various types of participation (Haythornthwaite, 2000; 2001; Hrastinski, 2007a). The combination of means of communication supports several ways for e-learners to get to know each other and collaborate on teaching and learning (Haythornthwaite & Kazmer, 2002; De Freitas & Neumann, 2009, Themelis, 2013).

The Kukulska-Hulme et al. Open University Report (2021, p.36) on innovative pedagogy recommends 4 ways to enforce active Learning: The report suggests the students could be representatives, consultants, co-researchers and pedagogical codesigner in online curricula. The roles of students are similar to the theoretical background of communities of practice where people join forces and meet regularly to improve their skills and have a commitment to learning and a shared interest. "Students and teachers working in such a community can experience more of a peer-based working relationship, and it can lead to greater empowerment of students, reducing hierarchy between teachers and students" (p.36). In the report, telecollaboration for peer-to-peer language learning provided real-life examples of how learners can design activities and teach each other within a community of practice.

Another angle worthy of consideration is the rise of peer production and organisational structure as a driving force in society and the economy. Peer instruction and co-creation are social competence needed in the post-digital community**.** "Educational strategies frequently involve placing students as the protagonists of the learning process, scaffolding techniques, including various learning scenarios, considering high thinking skills and focus on real problems" (Garzon et al., 2020). Bauwens talks to Jandric (2021. pp. 576-577) about P2P as "a relational dynamic that allows any individual in the world to connect to any other individual through digital networking to self-organise or create new value streams. P2P is not just about communications; it is about the capacity to organise beyond the physical level and the open, collaborative systems that allow such an organisation. We are no longer in a world of competing entities: we now have ecosystems, where people can come in and out, and contribute or not". He explains that we need to consider a new form of humanism. We realise a human identity is an extended form of our interdependence for communities of learning and practice to produce, innovate and continue learning. Social collaboration is a new value system that companies such as Facebook, Twitter, and LinkedIn profit from our collaboration with friends and peers or complete strangers.

Peer-to-peer gaming also prepares students for active, concerned citizenship, uptake of necessary emotional intelligence competencies, and increased ethical leadership (Ferreira et al., 2019; Rojas, 2017; Sutton & Allen, 2019). A new paradigm for higher education could emerge in the coming years if institutions could shift their paradigm from professor-centric to learner-centric andragogy (adult education). Game-based P2P learning has a unique opportunity to become the centre of focus in online education, which will continue after the pandemic but must be revamped.

Robert Frank (2020), author of the book: "Under the Influence: Putting Peer Pressure to Work" explained the potential of P2P learning for social values**.** The author claims that ideas, behaviours, aesthetics, and perceptions disseminate quickly and influence all of us in epidemics. Still, we could use it effectively to uphold social values and avoid conflicts such as polarisation. Similarly, Bunting (2020) considers peer learning as a process of sharing aesthetic experiences. Aesthetics can also describe immersive and transformative experiences (Parrish, 2009).

Despite the overwhelming narrative on the advantages of P2P learning, the disadvantages cannot be ignored.

2.1.3 Disadvantages

Inclusion and diversity as social values are prerequisites for using P2P learning. However, the Open University report (2021) highlights the importance of facing obstacles that hinder social learning perspectives. These challenges may be a lack of students' commitment, teachers' reluctance to employ the new methods, or a sense of control of the learning process. Moreover, people working in peer-to-peer learning need to have interpersonal skills and intercultural awareness to provide feedback in a non-judgmental way and be aware of the different learning obstacles students face (Garcia-Melgar, East, and Meyers, 2015).

Szeto et al. (2022) also identify significant challenges, including differences in peer leaders' approaches and organisational difficulties. Peer learning is inherently collaborative, where students search for knowledge, solutions, and deeper meanings, but they must sufficiently organise their study time.

2.1.4 Contextual factors

The contextual factors based on research findings and literature review that strongly affect peer-to-peer instructions are:

1) the optimal level of difficulty; activities designed step by step

2) preparedness for working together, social etiquette, individual preferences

3) the working pair relationship, maintaining a positive attitude (Yale, 2020).

4) social norms, cultural awareness, and cross-cultural communication (Alan et al, 2020).

5) length of the activity – studies show that shorter interventions maximise learning gains (Balta, Michinov, Balyimez, Ayaz, 2017).

6) Time is essential for more extended peer-learning activities like mentoring (Woolhouse and Nicholson, 2020)

It is essential to think about the universality of P2P Learning (Balta, Michinov, Balyimez, Ayaz, 2017). Countries can be broadly framed as collectivist or collaborative; active learning approaches must be according to their educational system and social studies. Hofstede's (1980) famous classification of countries ranked their level of individualism on a scale of 0 to 100 (Hofstede, 1980; Hofstede, Hofstede, & Minkov, 2010). For example, on the Hofstede scale of countries, 20 is for Thailand, 37 for Turkey, 38 for Brazil, 46 for Argentina and Japan, 63 for Finland, 71 for France, 74 for Denmark, and 90 for the USA and Australia. According to the meta-analysis of Balta, Michinov, Balyimez and Ayaz (2017), educational systems higher on the individualistic scale may not benefit from P2P learning as much as countries with more collective behaviours where students are used to helping each other as social behaviour. On the other side of the argument, although Finland's and Denmark's individualism scores high, they favour a collaborative approach and collective thinking in their educational institutions. Future social norms and expectations are essential to enhance cultural awareness and cross-cultural communication, especially for eLearning that involves an 'anyone, anytime, from anywhere' mentality.

2.2 Literature review on AR – enriched realities for learning

This section aims to present the role of AR in the learning process as a visual approach, the benefits, challenges and contextual factors that emerged in the iPEAR research process, and an updated literature review.

The Merriam-Webster.com dictionary (2022) defines AR as "an enhanced version of reality created by the use of technology to overlay digital information on an image of something being viewed through a device (such as a smartphone camera)''.

AR technologies can be divided into several categories. For the purposes of the project, they are generically categorised in the following:

1) Mobile apps are a common way to experience AR through a mobile device (phone or tablet). The user opens up the device camera and sees the real world with digital augmentations added to it. The quality of the experience heavily relies on the quality of the camera, the quality of the visuals and the device's processing power.

2) WebAR lets users view the AR experience using their browser (PC or mobile device). WebAR experiences are available for PCs if a web camera is connected to the computer.

3) AR Head Mounted Displays (HMDs) are mainly designed by Microsoft and Apple, the leading companies in this sector (iPEAR toolkit).

Augmented Reality (AR) has been developing rapidly and growing among the users of smartphones and tablets. Educational applications and resources that use AR technology are improving in number and quality.

2.2.1 Semi-systematic process to identify themes

AR technologies can potentially use visualisation in class and out-of-class activities, online and offline. Based on the iPEAR research, as illustrated in the iPEAR compendium of praxis (IO2), there are several advantages to using the iPEAR approach. It can boost creativity, autonomy, engagement and empowerment. Digital skills were also enhanced by working with portable devices and visual media (editing videos or images), tackling compatibility and connection challenges. To investigate more case studies, a semi-structured literature review was conducted. The semi-structured approach could be a good strategy for identifying themes (Snyder, 2019), as presented in the following questions:

- What are the advantages that AR could offer to higher education?
- What are the disadvantages that could hinder the adoption of AR in higher education?
- What contextual factors could play a key role in adopting AR in Higher education?

The literature review follows narrow time criteria. Case studies and research conducted in the last two years were considered because of the rapid technological advances in immersive tools. In other words, many AR tools are developed, changed and adapted, while others become obsolete and vanish. One such case is the Aurasma, often used in higher education, and then it was sold and renamed as HP Reveal, but for the time being, it is not available. Journal papers and books take at least one year to get published, so the two-year period is a reasonable time frame to look for AR studies.

Looking for findings via the NTNU library included 18 resources (books and papers) written within the last two years. Several documents summarise findings regarding the use of AR in specific areas such as STEM disciplines, health sciences, architecture, art and language learning. The cases refer to in-class and remote approaches. Furthermore, some studies consider the needs of students who face physical or mental challenges. Experimental tools not widely available to the public were excluded because educators couldn't test them. Full-text scanning spotted potential advantages, disadvantages and contextual factors affecting the adoption of AR in higher education. Selective publications suggested by iPEAR partners (Ens et al., 2019; Billinghurst, 2021; Radu et al., 2021). were taken into consideration, that added value to the narrative of themes. That is why it is considered a semi-structured approach.

Chat.openai was checked for triangulation as a new form of exploration of whether AI is worth using in the quest for education research.

Disciplines or teaching mode	Publications	Type
1. STEM (science, technology, engineering and mathematics)	Mystakidis, Christopoulos, A., & Pellas, N. (2022)	Systematic literature review 2010-2019
2. Fashion design	Elfeky, & Elbyaly, M. Y. H. (2021)	Case study
3. Physics – Mechanics with mobile distance learning.	Gurevych, Silveistr, A., Mokliuk, M., Shaposhnikova, I., Gordiichuk, G., & Saiapina, S. (2021)	Case study
4. Chemistry	Lu, Wong, C. S. K., Cheung, R. Y. H., & Im, T. S. W. (2021)	Case study
5. Health Sciences	Rodríguez-Abad, Fernández-De-la-Iglesia, J.-D.-C., Martínez-Santos, A.-E., & Rodríguez-González, R. (2021)	Systematic literature review
6. Multidisciplinary higher education	Olasina (2022)	Literature review on educators' readiness to use AR
7. Chemistry	Wong, Tsang, K. C. K., & Chiu, W.-K. (2021	Case studies
8. Bussiness/ Entrepreneurship	Situmorang, Kustandi, C., Maudiarti, S., Widyaningrum, R., & Ariani, D. (2021)	Case studies
9. English	Irina V. Dukalskaya, Irina N. Tabueva (2022)	Case studies
10. Computer Sciences	Alshamrani Alshaikhi, & Joy, M. (2021)	Case studies
11 Special challenges	Jdaitawi, & Kan'an, A. F. (2022)	Literature review

12. Multidisciplinary higher education – Remote education	Nesenbergs, Abolins, V., Ormanis, J., & Mednis, A. (2021)	Literature review
13. Mathematics	Jabar, Hidayat, R., Samat, N. A., Rohizan, M. F. H., Rosdin, N. 'Ain, Salim, N., & Norazhar, S. A. (2022)	Literature review.
14. Satellite remote sensing education	O'Banion, Lewis, N. S., Boyce, M. W., Laughlin, J., & Majkowicz, D. C. (2022)	Case studies
15. Multidisciplinary higher education	Yildiz. (2022)	Case studies
16. Architecture and construction education	Hajirasouli, & Banihashemi, S. (2022)	Case studies
17. Social Sciences	Soutthaboualy, Chatwattana, P., & Piriyasurawong, P. (2022)	Case studies
18. Ethics	Chan, Hafiz, M., Kwong, T., & Wong, E. Y. W. (2021)	Case studies
19. Multidisciplinary higher education- research in Collaboration, social norms and ethics	Billinghurst, M. (2021)	Literature review
20. Multidisciplinary higher education- collaboration	Radu, J., Joy, T., Bowman, Y., Bott, I., Schneider, B. (2021, April)	Case studies
21. Multidisciplinary higher education	Ens, Lanir, J., Tang, A., Bateman, S., Lee, G., Piumsomboon, T., & Billinghurst, M. (2019)	Literature review

Table 1: Summary of the 18 studies found applying AR in Higher education from 2021 to 2023.

2.2.2 Advantages

As the iPEAR research specified, the advantages of AR refer to visual learning for better understanding, student agency for motivation and engagement, inclusion as social value and valuable digital skills for the job market. The data from the students' surveys show that the students were creatively engaged and worked collaboratively to help each other understand the assignment or the AR tool's unique features. Empowerment was also evident in some participants, who felt ownership of their collaboration's outcome. Surprisingly, some groups adopted an inclusive mentality, embraced participants without technical skills or mobile devices, and shared tools and ideas. To combine research and literature review (from 2021 to 2023) in PART 3, this section concentrates on the benefits of using AR in higher education.

Regarding the literature of the last two years, Mystakidis, Christopoulos, and Pellas (2022), in their systematic review from 2010 to 2019, found that 114 case studies were designed in the field of STEM, the most implementations took place in engineering. They used desktop computers, smartphones, and mobile devices with AR wearable equipment and sensors, such as AR glasses and projection-based AR. The instructional strategies that were identified in forty-five articles reviewed were: Experiential, Cooperative/Collaborative, Presentation, Activity-based, and Discovery (scientific inquiry In terms of instructional techniques, the reviewed STEM studies in HE settings could be categorized into (1) instruction through Simulation, (2) Project, (3) Observation, (4) Problem-solving, and (5) Question–answer.

Mystakidis, Christopoulos, and Pellas (2022) note that the advantages focus on learner motivation and engagement. That being said, a common denominator across the reviewed studies can be identified as researchers and educators collectively underline the positive emotional effects of such technology on learners' interest, attention, and motivation. Furthermore, researchers that have examined such elements in greater depth also reported positive outcomes on learners' satisfaction and achievement.

In the same study, another benefit that the integration of AR brings to the modern classroom concerns the deconstruction of complex devices, such as oscilloscopes, function generators in electronics engineering laboratories, and multidimensional scientific scenarios such as stability assessment of linear control systems (which cannot be demonstrated conveniently in the real-world).

Aligned to the context of such scenarios, the experienced cognitive load in AR-based systems is significantly lower compared to conventional solutions, although a comparative study reported no differences. Several studies (Akçayır et al., 2016; AlNajdi et al., 2018; Odeh et al., 2013; Vassigh et al., 2018; Wang, 2017; Yip et al., 2019 as cited in Mystakidis, Christopoulos, & Pellas, 2022) also reported positive outcomes on the individual or collaborative efforts that students make to grasp the scale of the problem and reach a solution or complete a task faster. The users' experience with specific applications in mobile devices, such as video conversation applications in the work environment, seemed to positively impact their learning performance and outcomes (Mystakidis, Christopoulos, & Pellas, 2022).

Also, the use of AR tools enables learners to practice from anywhere and at any time, following students' needs and pace, as it lifts the need for real-time supervision, which, otherwise, would have been essential to prevent the misuse of the specialized laboratory equipment (e.g., robots, current meter, oscilloscope, sewing machines, computer electrical components) and ensure students' safety (AlNajdi et al., 2018; Andujar et al., 2011; Mejías Borrero & Andújar Márquez, 2012; Odeh et al.,2013, 2015; Singh et al., 2019; Westerfeld et al., 2015; Yip et al., 2019 cited in Mystakidis, Christopoulos, & Pellas, 2022).

Indeed, the unlimited practising with AR tools – and thus, reflection and rethinking – that is offered to learners facilitates the comprehension of theoretical knowledge and promotes the development of conceptual understanding (Ke & Hsu, 2015; Opriş et al., 2018; Ozdamli & Hursen, 2017; Schneider et al., 2013; Shirazi & Behzadan, 2015b; Singh et al., 2019; Vassigh et al., 2018; Wang et al., 2014, 2018 as cited in Mystakidis, Christopoulos, & Pellas, 2022).

Elfeky and Elbyaly (2021) explored the use of AR in a course on fashion design. Findings indicated that the fashion products of students taught via augmented reality technology achieved higher success and acceptance in all aspects (the functional, aesthetic, creative) and the fashion design skills as a whole than the products of students taught via the traditional teaching method (educational videos). It enhanced independent thinking, creativity and critical analysis (Bower et al., 2014, as cited in Elfeky & Elbyaly, 2021). It motivated students by creating a distinguished learning environment where a student did not feel bored. When adequately designed for pedagogical purposes, augmented reality can inspire the authentic practice of twenty-first-century skills (Schrier, 2006, as cited in Elfeky & Elbyaly, 2021). Moreover, the ability of augmented reality technology to change images into animated objects as soon as students look at them using the cameras of their smartphones or tablets was also exciting and attracted students to learn better.

Gurevych et al. (2021) designed physics courses and holistically enlisted the AR approach's pros. Firstly, it was found that augmented reality technologies stimulate the educational process and provide the opportunity to implement knowledge because it increases interest in educational material, self-study and learning new things. Then, the visibility of training increases its quality and efficiency. In addition, there is an improvement in spatial imagination and thinking. There is also evident that interactive learning prevails. It is equally essential to consider how user-friendly the AR is because it is an element of the task's success and attracts students' interest. Finally, it provides a micro-learning technique for students to learn information quickly. Overall, the effect of students' enthusiasm and satisfaction plays a crucial role in learning and memorisation.

Lu et al. (2021) claim that students lose interest in chemistry because they cannot relate theories to praxis and end up with rote learning (memorization technique based on repetition) of the subject matter. They consider AR as a competent pedagogical facilitator. Their pilot survey about students' perception of the AR showed positive feedback for the AR app in enhancing awareness, learning, understanding, and engagement. It addresses the concerns of retaining students' attention during teaching and learning real-life chemistry. The questionnaire results show that students generally had a positive evaluation and satisfaction toward the AR software because it allows easy observation and manipulation of real-world environments or elements. Students appreciated the AR software as a valuable tool in a flipped classroom context. It allowed them to better prepare and understand the intended learning outcomes before face-to-face online classes.

Furthermore, significant positive correlations between learner attitude and perception of the AR software were found. Despite the high p-value in the construct of Cognitive Accessibility, its score was still within the positive category. Still, it may bring an implication for further consideration during the design and introduction of the software to minimise students' overhead to access the AR. This result also aligns with Cai et al.'s (2014, as cited in Lu et al., 2021) conclusion that promoting learners' initiative toward chemistry enhances learning effectiveness via AR software.

Wong, Tsang, and Chiu (2021) indicate that spatial skills are essential in chemistry education. However, acquiring these skills can be monotonous if learning is limited to memorising Newman projections or 3D molecular kits. Existing approaches to learning using visualizing tools require physical models, which limit learning activities to within the classroom. Augmented reality (AR) in chemistry education allows students to see actual compound representation in a 3D environment, inspect compounds from multiple viewpoints, and control interaction in real-time in any location. This facilitates the understanding of the spatial relations between compounds. Quantitative questionnaire feedback results from students showed that 87% found that using AR technology for chemistry subjects was an effective teaching method that enhanced their learning. Students were satisfied with the AR educational app and the AR materials used. In a pre-and post-test evaluation of a group activity, students learned better and remembered more information about functional groups and drawings of complicated compounds after using AR technology. Based on the case study, results show that using AR positively impacts enthusiasm and learning in higher education chemistry courses for sub-degree students. This technology should be broadly used as a digital tool to promote active learning during the COVID-19 pandemic.

Abad et al. (2021). have written a systematic review of augmented reality in health sciences: A guide to decision-making in higher education investigating the impact of AR on learning outcomes and students' skills. They are also digging more profound into the advantages and disadvantages of AR in health studies. This review highlighted the motivational drive because AR enhances students' involvement. In four cases, satisfaction was also reported and linked to the realism of the training, and as a result, the technologies could enhance understanding and performance. Using AR positively influences learning outcomes and long-term - retention; regarding chronic wound diagnosis, human anatomy includes the musculoskeletal system and neuroanatomy.

Regarding acquiring clinical competencies, AR improved clinical decision-making skills in treating chronic wounds in nursing students. For the acquisition of cognitive skills, studies underlined the excellent assessment that Phonoaudiology students make on using a methodology based on AR, contributing to the construction of learning and collaborative work. The students positively valued using AR as support for teaching human anatomy, providing student-centred learning and facilitating a three-dimensional understanding of human anatomy.

To recap, Rodríguez-Abad et al.'s (2021) systematic review of AR used as an educational, technological tool in university studies in Health Sciences improves the teaching-learning process by influencing it in a multidimensional way. The use of AR in higher education in the field of Health Sciences reduces the cognitive load and increases the motivation and satisfaction of the students. It is a learning support tool that improves spatial understanding and promotes autonomous learning, per the European Higher Education Area guidelines. Given that AR provides clinical simulation environments with greater realism, we can conclude that using this technology in Health Sciences is especially useful in those courses with a significant component of 3D vision during the teaching-learning process.

Olasina (2022) supports the view that professors and lecturers must take full advantage of AR despite the challenges. AR apps help improve students' understanding of spatial geometric concepts through manipulation and multiangle observation of AR objects. For instance, fine arts students used HP Reveal to create an exhibition for galleries using a green screen app. The students and gallery visitors create their realities by taking ownership of projects while increasing their engagement and responsibility with learning materials. The reviews strongly indicate that AR can compensate for the shortcomings of online teaching and learning and enhance the quality of lectures and students' performance. The lessons learned show that AR-led teaching and learning should be supplemented in line with the characteristic features of each program and level of study based on new ideas during and beyond the COVID-19 pandemic. Also, soft and hard skills such as emotional intelligence and social abilities using programs and strategies to cultivate emotional competencies via mobile apps, software, and games can be driven by AR.

Situmorang, Kustandi, Maudiarti, Widyaningrum, and Ariani (2021) studied entrepreneurship education through mobile augmented reality in Higher Education in Indonesia. Students view that the mobile augmented reality application's most exciting function lies in displaying information and characteristics of SMEs. These findings confirm that Augmented Reality can increase learning motivation and provide students contextual information about the learning environment. Therefore, science and technology development increasingly encourage renewal efforts in using technology results in the learning process. The results show that mobile augmented reality can make learning activities more exciting and fun.

On the other hand, it can significantly improve student learning outcomes. The novelty of augmented reality in this study can be seen in the aspect of watching the virtual of various products available o and the ease of accessing information due to its visual appeal. These factors impact students' emotional acceptance of augmented reality and their performance.

Dukalskaya and Tabueva (2022) discuss the advantages of using AR technologies in language learning. AR applications can be widely used in English language classes to introduce professional and country studies in ways that increase the efficiency and motivation of students. In addition, AR applications help form students' cross-cultural and sociocultural competencies. They include practical-oriented training aimed at improving and developing the skills and skills of students in the professional field and the readiness of students to use the obtained theoretical knowledge in solving practical problems. They have formulated the main characteristics of AR in the learning process, which reflect the authors' approach to the implementation of this technology:

1. **Contextuality** – the students can experience the real world and virtual elements simultaneously
2. **Interactivity –** it gives the possibility to interact with AR through the manipulation of both
3. Real objects and virtual properties offer novel possibilities for interaction
4. **Spatiality** – virtual elements placed inside the 3D real world appear as if they were really

This technology allows educators to:

- offer students links to authentic materials (vocational-oriented texts, articles);
- organise classroom and out-of-audience independent work of students;
- listen to audio material and view authentic videos;

- organise project activities;
- offer access to links for downloading electronic textbooks, literature or additional information on a given topic;
- provide students with links for testing to control the formation of knowledge in students (ClassTools.NET, QRTreasureHuntGenerator) in a foreign language;
- post up-to-date information in the form of QR codes on university stands (schedule of teachers, competitions, Olympiads, project protection, and conferences).

Alshamrani, Alshaikhi and Joy, M. (2021) focus on investigating a new approach to emerging and integrating computing education with AR technology in Saudi Arabia. Data further support students' acceptance of new educational tools, and AR might be effective.

Jdaitawi and Kan'an (2022) wrote a literature review on a decade of research on the effectiveness of augmented reality on students with particular disabilities in higher education. The results also showed that AR technology was mainly used in intellectual disability settings. Finally, the result evidenced that AR assists students in enhancing their social skills, relationships and engagement. The results from this systematic review provide valuable information regarding enhancing physical, cognitive, personal, and social abilities. Based on the findings, most of the studies in the literature supported positive outcomes. They reinforced the potential of AR to contribute to and satisfy special education and its needs, particularly for students with learning and other disabilities types. AR has also been evidenced to improve those with visual impairments and to promote social interaction among disabled individuals, motivating them and encouraging them to participate in social and daily activities. The results also revealed the usefulness of AR in developing special education students' skills, bringing them real-life experiences while increasing their individual social interaction and environmental collaboration (with peers and teachers, etc.). Thus, AR is a potential tool to assist special-needs individuals' learning and skills development (social and academic).

Concerning the assisting learning outcomes among special needs students, more than half of all studies on AR primarily concluded that AR improved students' learning outcomes. AR can improve skills such as increased knowledge, supported learning and perception. It is a supportive tool for students with low vision, enhances social skills and decision-making, improves academic and functional skills and navigation skills, and increases independence and motivation (Bacca et al., 2018; Benda et al., 2015; Bridges et al., 2020; Cate et al., 2017; Chang et al., 2013; Huang et al., 2019; Lorenzo et al., 2019; McMahon et al., 2015; Smith et al., 2017; Zhao et al., 2018 as cited in Jdaitawi and Kan'an, 2022). The current results extend the past systematic reviews, such as Baragash et al. (2020) and Barton et al. (2017), on the importance of assistive technology in facilitating the learning outcomes of individuals with special needs. The results of this study also supported the development of Garzon et al. (2020), who confirmed the potential of AR in reinforcing the skills acquisition and learning skills of students with special needs. Based on these, it can be anticipated that students benefit from AR technology as it can augment information and combine it with contextual information to provide new experiences in their learning (Bacca et al., 2014).

Nesenbergs, Abolins, V., Ormanis, J. and Mednis, A. (2021) wrote a systematic umbrella review on using augmented and virtual reality in remote higher education. The authors research the impact of AR on learning outcomes as performance and engagement in all stages of higher education, from course preparation to student evaluation and grading. This review was a state-wide research effort in Latvia to mitigate the impact of COVID-19 and provide a framework for a technological transformation of education in this context. In this work, they organised laboratory or practical exercises within virtual or augmented reality when physical presence is not feasible. The results were very encouraging in these cases, especially in medical education. In addition, the literature also suggests that virtual/augmented reality cannot wholly replace on-site studies because whenever it was tried, the student grades suffered.

Jabar et al. (2022) wrote a systematic literature review on augmented reality learning in mathematics education. This process resulted in a total of 20 articles in a wide range of countries: Indonesia, followed by Malaysia, and a few studies were conducted in China, USA, Turkey, USA, Saudi Arabia, United Arab Emirates, United Kingdom, Bangladesh, Taiwan, Spain, Mexico, Germany, and Chile. The findings identified that AR learning was implemented in several mathematics topics: geometry; algebra; statistics, probability; and others, including mathematical modelling and mathematics technology. The effectiveness of AR learning towards mathematics education also included cognitive, affective, and psychomotor effects. The most substantial impact was on the cognitive domain as it consisted of several aspects: knowledge, comprehension, application, analysis, synthesis, and evaluation, which were crucial in learning (Syahtriya Ningsih et al., 2019, cited in Jabar et al., 2022). Thus, this study discovered a significant influence on students' interest through the implementation of AR learning by its ability to apply visualisation in mathematics while allowing students to keep up with technological advancements.

On the other hand, the affective domain plays a role in enhancing the effectiveness of AR in learning, as previous studies found that AR-based technology promotes student's motivation which can strengthen them to acquire mathematics knowledge (Elsayed & Al-Najrani, 2021, cited in Jabar et al., 2022). That being said, motivation increases when using interactive technology (Lainufar et al., 2021, cited in Jabar et al., 2022) and can potentially reduce student's level of mathematics anxiety (Saha et al., 2020, cited in Jabar et al., 2022). Finally, it aids students' high self-efficacy in mathematics through reflection (Cai et al., 2018, cited in Jabar et al., 2022). Studies also found that AR technology integrated with body-based activities was more effective in learning mathematics (Smith, 2018). In the study of Saha et al. (2020), they identified that students could develop a strong positive attitude toward mathematics because of AR, which assisted them in overcoming their mathematics fear.

O'Banion et al. (2022) designed a case study for an augmented reality sand table for satellite remote sensing education that was evaluated by 400 students investigating the retention of foundational remote sensing knowledge. The findings indicated that using the AR sand table in a classroom environment improves the retention of foundational remote sensing knowledge and elevates the assessment performance for subjects identified as lower performers. The authors highlighted the need to explain to educators how advanced visualization technologies can enhance the learning experience and enable excellent knowledge retention.

Yildiz (2022) wrote a report on augmented reality applications in Higher Education in Turkey. The case study focused on giving examples designed with AR. The qualitative research embraced the students' perspective and found the use of augmented reality applications in education helpful in making the lesson fun, providing permanence in learning, and improving creativity skills.

Hajirasouli and Banihashemi's (2022) literature review focuses on the state of the field and opportunities of augmented reality in architecture and construction education. They presented in this study utilised the qualitative methodology and thematic data analysis method to identify the effects and implications of using AR in technology-enhanced teaching and learning environments. It was determined that immersive 3D virtual content results in deeper learning and long-lasting knowledge for students, creating more fluid learning, improving students' experience and knowledge-acquisition process, and developing in-depth perception and spatial representation. Integrating AR into the curriculum can provide students with a more realistic and practical learning experience, adaptable to tangible and physical sites. AR allows students to adapt their design to the actual scale of construction. It also provides unlimited access to otherwise limited opportunities to participate in real-life experiences. It was also confirmed that AR enhances the participants' understanding of complex assembly procedures in teaching construction processes. Overall, it can be concluded that the application of AR improves students' academic performance and learning in the short term and long term.

Soutthaboualy, Chatwattana, and Piriyasurawong (2022) designed an interactive augmented reality technology case study via a blended instruction lesson on the cloud. The results show the following:

(1) The quality assessment results of developed blended instruction lessons on cloud overall had a very high level.

(2) The post-test has an achievement score higher than the pre-test, which is statistically significant at 0.01.

(3) The result of the assessment of the digital literacy score of students after studying had a reasonable level.

(4) The student satisfaction results study with the developed blended instruction lesson on the cloud were high.

Chan et al. (2021) presented a case study that reinforces Academic Integrity and Ethics (AIE) through augmented reality (AR) learning trials. This project utilises the latest technological advances in augmented reality (AR) and mobile technologies to bring scenarios of AIE in real-life situations to students. Students make use of their mobile devices to retrieve information, give responses, and even consider ethically related decisions in different circumstances and locations. The project focuses on finding out how students perceive the use of AR for learning AIE and the influence of cultural background on their perception and understanding of AIE. Students were generally satisfied with the help of AR in learning AIE. The findings suggest that the AR blended learning approach could help enhance AIE learning. In addition, variations in learning AIE among students of different cultural backgrounds were found.

Billinghurst (2021) writes about emerging Empathic Computing (Piumsomboon et al., 2017, cited in Billinghurst,2021) that explores how physiological cues can be linked with AR in a collaborative virtual environment to enable remote people to share what they see, hear and feel. There is also the opportunity to study how to support viewing large-scale social networks in AR interfaces, including using visual and spatial cues to separate out dozens of social contacts (Nassani et al., 2017, cited in Billinghurst, 2021). However, there is still very little research conducted on collaborative AR. A survey of 10 years of user studies until 2015 found that only 15 of the 369 AR studies reviewed were cooperative, and only seven used AR HMDs (Dey et al., 2018, cited in Billinghurst,2021).

The AR application into teaching and learning supports many of Maslow's needs for working in a safe environment and collaborating democratically with others while protecting digital well-being. It is also aligned with Bloom’s taxonomy. Hence, AR has the potential to help students regain their enthusiasm for learning, creating student agency and leading them to self-directed life-long learning and efficacy (Heutagogy).

2.2.3 Disadvantages

iPEAR informants highlighted the technical issues (compatibility issues, internet connection) and the digital divide. Typical with technologies, different AR tools can facilitate various tasks and resolve compatibility issues. Overall, the cost of the internet and the lack of updated tablets or mobile phones could hinder the implementation of the iPEAR assignments. Studies which have adopted the 'Bring Your Own Device' approach reported issues related to the limited affordances of the students' phones. The same findings were reported in many studies (Mystakidis, Christopoulos and Pellas, 2022; Olasina, 2022).

Mystakidis, Christopoulos, and Pellas (2022) reported that the main problem in architecture and construction is the accurate and correct scale integration of virtual objects with actual images in a physical space. The marker-based AR could use different pictures in the exact location, which can cause challenges in the presentation order.

Gurevych et al. (2021) designed a physics course and enlisted the AR approach's cons. The authors claim that more specialized AR should be developed with particular applications within disciplinary boundaries or a single educational platform that could accommodate the needs of all disciplines in higher education. Accessibility must be addressed to tackle technical issues for smartphones, tablets and other devices. In agreement with Mystakidis, Christopoulos, and Pellas (2022), they claim that marker recognition should be facilitated to avoid complications regarding the lighting, the angle at which the user points the camera and the quality of the camera itself.

Lu et al. (2021) claim that the students were looking for more content, better control, and a more excellent presentation of the AR software to enhance their satisfaction with it, thus suggesting possible improvements for future works. In more detail, they have asked for more images in the AR software, gaming and interaction elements. Gaming and interaction may enhance the immersive effect of AR. Overall, better training for educators and students is reported as the key to the efficient use of AR software.

Rodríguez-Abad et al. (2021) have enlisted the disadvantages in their systematic review of augmented reality in health sciences. Despite the vast array of AR tools, it is poorly implemented as a didactic tool in health sciences. Nevertheless, its application in this field has increased in the last few years due to students' widespread use of mobile devices and readability and ease of use. The difficulty in using and handling some devices can be underlined. Participants talked about technical challenges. They pointed out problems in adjusting the glasses, instability of the projected image and the need to keep the head still, among others. Also, when using smart glasses as a display device activated by gestures that had to be very precise, causing difficulties among the participants. Likewise, most AR tools did not allow tactile feedback in studying brain anatomy. In addition, the participants found challenges in handling the materials necessary to visualize the contents, concluding that these difficulties in interaction negatively affected the learning process.

Rodríguez-Abad et al. (2021) report that AR is a new technology with little implementation in education. Its incorporation as a teaching technology tool is recent, so research on this topic is novel but scarce. In addition, ignorance about its use can cause difficulties in its handling by students. The findings showed adverse effects reported by students who used AR in a teaching intervention. The analysed symptoms were classified into general (discomfort, fatigue, boredom, nausea or headache) and ocular (eye fatigue, blurred vision or double vision). Sometimes AR has a high cost of implementation. Bogomolova et al. (2020, as cited in Rodríguez-Abad et al.2021) used the highest level of AR, augmented vision, with smart glasses that provide stereoscopic 3D vision. They identified as a disadvantage the high cost of the development of the experience, which, on the other hand, facilitates the learning of students with low spatial-visual skills, an improvement compared to other cheaper AR levels (for example, mobile devices allow monoscopic vision). In addition, a lack of content developers was found. One of the main obstacles to integrating AR technology in classrooms is the development of 3D multimedia content. This technology is still under-utilized because insufficient experts can generate AR-based interactive teaching materials.

The Olasina (2022) review of existing literature frames a high fragmentation among various tools, software, and AR apps, leading to increased complexity in adapting the systems to teaching and learning. There is a need for a well-thought-out approach to integrating AR apps into online and blended learning in higher education, addressing stakeholder needs, diversity, and inclusion and expanding a critical discussion on transformative AR teaching and learning. In short, Olasina's (2022) findings indicate that teaching approaches have changed, particularly during COVID-19. Many students and faculty are not ready, just as some are ready to accept and use ARs as any emerging technology owing to their affordances. However, most research reports that mobile devices such as iPads, smartphones, and tablets are vehicles for sharing AR content, research and learning materials with students. Training for faculty and students in connected learning should include a relevant introduction to AR forms for current and future readiness formation for professional activity.

Dukalskaya and Tabueva (2022) present the negative aspects of implementing augmented reality in language learning

- leading to the breakdown of interpersonal relations (connections) between the participants of the training (teacher-student);
- a significant gap between the development of information and computer technologies and technologies that are used in the actual practice at universities, the lack of teaching literature and recommendations;
- There is a lack of training or retraining of faculty and the formation of necessary digital skills to work with advanced educational technologies.

Alshamrani Alshaikhi and Joy (2021) focus on investigating a new approach to emerging and integrating computing education with AR technology in Saudi Arabia. A preliminary analysis of both the qualitative and quantitative data confirms our initial hypothesis that there is a lack of hardware equipment in computing labs and that accessibility is difficult.

Jdaitawi and Kan'an (2022) wrote a literature review on a decade of research on the effectiveness of augmented reality on students with particular disabilities in higher education. Hence, limitations stem from the purpose and time of activities. The development of AR applications should cater to the perception and needs of the users (Huang et al., 2019; Zhao et al., 2018, as cited in Jdaitawi and Kan'an, 2022). AR limitations also relate to the user's skill and ability to use it. Hence, AR technology development should be directed towards meeting the learning needs of students, and it should be made flexible to enable the student's completion of the activities efficiently. The current results extend the past systematic reviews, such as Giglioli et al. (2015, as cited in Jdaitawi and Kan'an, 2022) and Blattgerste et al. (2019, as cited in Jdaitawi and Kan'an, 2022) who focused on specific needs. Although AR technology is helpful for individuals with disabilities to learn various skills, literature highlighted that AR activities design is a core challenge in the form of learning using AR. This multi-task technology could be complicated for some students to manoeuvre.

From a different angle, Yildiz (2022) explains that despite all these positive aspects, the fact that some AR apps are expensive makes their implementation difficult for some audiences. Apart from this, "physical discomfort" (eye pain, neck pain) was also emphasised by students.

Radu et al. (2021) pointed out that sometimes AR designers lack an understanding of what collaborators need during an interaction or what features have already been designed to solve those needs. AR creators will spend time redesigning features that have already been created or, worse, creating applications that do not contain the necessary features. While much work has been done on designing virtual reality (VR) collaborative environments, AR environments are a relatively newer design space. Designers lack a comprehensive framework for describing needs that arise during collaborative activities and the features that could be designed into AR applications to satisfy those needs.

Overall, there is still very little research conducted on collaborative AR. A survey of 10 years of user studies until 2015 found that only 15 of the 369 AR studies reviewed were cooperative, and only seven used AR HMDs (Dey et al., 2018, cited in Billinghurst, 2021).

2.2.4 Contextual factors

In the iPEAR study, **lack of training** and assignment clarity needed to be considered in depth. Educators must be aware of tools to use for a visual approach and facilitate the adoption process. Professional development courses within educational institutions or outside of it could make the transition process smoother and more manageable for educators and, consequently, their students in higher education. The students' and educators' expectations should be aligned to successfully adopt experimental approaches such as the iPEAR perspective.

In the literature review of Mystakidis, Christopoulos, and Pellas (2022), other contextual factors concern **the weather conditions** when students are outside the classroom settings and want to use mobile devices. Pejoska-Laajola et al. (2017 as cited in Mystakidis, Christopoulos, and Pellas, 2022) mentioned that **external factors like the environment's noise, screen visibility under direct sunlight, rain, and low temperatures** can negatively affect the learning experience.

Rodríguez-Abad et al. (2021) believe that despite the boom experienced in recent years, the use of AR as an innovative technological educational tool is still quite limited, despite the significant advantages that have been found. This is mainly due to **teachers' reluctance** and lack of training and means to generate 3D content. Perhaps this is due to the scarcity of research demonstrating the efficacy and effectiveness of this technology since most of the studies analysed have a small sample size in a single institution, making it difficult for the data to be generalizable.

Mota et al. (2018, as cited in Olasina, 2022) identified vital predictors, including **motivational readiness, values, beliefs, personality, and professional interest.** Teacher engagement incentives include personal development, self-affirmation, and **professional and financial incentives** (Vlasenko et al., 2021, as cited in Olasina, 2022). Jarrar, Awobamise, and Sellos (2020, as cited in Olasina, 2022) employed a technology readiness index (TRI) to explain individual attitudes toward technology readiness perspectives concerning AR applications by tourists in Dubai. The fundamental findings revealed a relationship between the TRI dimensions of optimism, innovation, insecurity, discomfort, and the intention to use mobile phone AR applications. The researchers highlighted the cruciality of innovation and optimism for users to be motivated by the perceived benefits of AR. The **benefits led to an intention to use it**, and the discomfort and insecurity in the setting made the tourists demotivated to use AR. Mupfunya, Roodt, and Mwapwele (2018, as cited in Olasina, 2022) used AR readiness dimensions such as discomfort, insecurity, innovativeness, and optimism to examine teachers' acceptance in township schools.

Álvarez-Marín, Velázquez-Iturbide, and Castillo-Vergara (2021, as cited in Olasina, 2022) determined how technology innovativeness and optimism predict the use of AR in education. They explained the role of **attitude, technology innovation and optimism, subjective norms, and behavioural intention** to use. Their core findings were that the student characteristics of technology innovation and optimism moderated their attitude to use. Factors such as **sociocultural background, historical norms, race, class, gender, age, and sexuality predicted students' beliefs** regarding the uptake of new digital media. They concluded that a deep understanding of the **nature of the educational setting** informs students' attitudes toward AR use at universities and affects intervention policies to facilitate AR-led teaching activities.

Osadchyi, Valko, and Kuzmich (2021, as cited in Olasina, 2022) and Oberdörfer et al. (2021, as cited in Olasina, 2022) have outlined some of the requirements for smartphone use in the classroom. These include an **internet connection, mobile devices, educational AR apps, objects, images, locations, and tangible AR learning user experiences** that trigger actions on device screens via the AR app.

It is recommended that individual needs, preferences, attitudes, perceptions, and fears be bridged with institutional silos (Tella and Olasina, 2014, as cited in Olasina, 2022). AR achieves this through the practical nature of handheld AR, ease of use, promotion of exploratory behaviour, and students' interactive understanding of learning aspects, allowing for self-observation and reaction when using AR tools (Alalwan et al. 2020, as cited in Olasina, 2022).

Nesenbergs, Abolins, V., Ormanis, J., & Mednis, A. (2021) regard **novelty** as a contextual factor. The fact that in all interventions where engagement was measured, the engagement increased leads us to speculate that the novelty of technology directly impacts engagement. If this is the case, novelty is a potential intervention, and any newly hyped technology could provide similar results. Another question should be researched if this is true – whether a cumulative novelty resistance exists.

Nesenbergs et al. (2021) suggest:

1. **Creating courses** for teachers and lecturers on how to prepare/adapt courses for AR/VR
2. **Creating a framework** that would allow teachers easily prepare/adapt their material for AR/VR
3. **Not to overload students** with the need to quickly get familiar with AR/VR. There should be a possibility to use classical methods to get through the course; At the same time, AR/VR proved that it could help to understand abstract and complex content more quickly due to good visualisation capabilities and interactivity. In multiple reviewed articles, it was shown that kinaesthetic learning, when instead of a classic lecture, students are working in the 3D world, performing experiments alone or together with a teacher, is much more efficient than, previously mentioned, classic method.

The creation of AR/VR-adopted courses could significantly affect knowledge availability. An opinion in the educational community and society reinforced by the 2020 lockdown is that online learning could be the future of education. Suppose this is the case because multiple papers show that AR/VR labs are of similar benefits as traditional "offline" labs with actual equipment. In that case, it could be argued that properly adopted AR/VR-based courses could potentially raise good, qualified specialists all around the globe, not only in local regions**, democratising education** in hands-on skills. Performance is not the only factor we need to consider; emotional wellness is at least as essential as performance regarding grades. Outfitted with VR/AR technologies, where students could arrive to work, but educators would connect remotely.

Overall, Chan et al. (2021) and other authors emphasised **variations in learning** among students of different cultural backgrounds.

Billinghurst (2021) supports the view that several ethical issues may arise when AR devices become more widely used. Who should be allowed to place AR content in the view of a person, and what are the ethics around AR advertising? Brinkman also discusses the privacy implications of AR as an extension of home and AR advertising (Brinkman, 2014, cited in Billinghurst, 2021).

PART 3: iPEAR Pedagogy and Pedagogical Framework

"The first challenge for education is to think how to even describe the more abstract contours of the present in a way that is neither old wine in new bottles nor new wine in old bottles."

(Jandrić, 2017, p. 115)

Developing pedagogy as a theoretical framework is rare because educators, instructional designers, and researchers have difficulty grasping philosophical approaches. Pedagogy is a fearful term (Goodyear, 2019). Themelis (2022) recommends that educators reflect on their pedagogy as philosophy, science, and the artistic repertoire of lifelong learning. The ultimate learning outcome of the pedagogy is students' self-efficacy and self-direction.

Due to the pandemic, students and educators have all experienced long-lasting lockdowns and social isolation that challenged mental health and all aspects of life. People starve for social gatherings, and eliminating touch has implications that should be investigated shortly. Students were forced to isolate and study alone.

Scientists have shown that 'learning friends' make a difference. Students and educators, especially in the remote emergency setting, have chosen the inclusive visual language of the internet using all forms of visuals: emoji, videos, 3D animation, QR codes, and augmented reality whenever possible. Visual reading and thinking are inclusive for two reasons: it assists students facing learning challenges (Sime & Themelis, 2020); and convey meaning by providing a concise and memorable micro-learning experience.

The UN Goal 4 on Quality Education emphasises inclusive and equitable education, defining it as

> '. . . a process of systemic reform embodying changes and modifications in content, teaching methods, approaches, structures and strategies in education to overcome barriers with a vision serving to provide all students of the relevant age range with an equitable and participatory learning experience and environment that best corresponds to their requirements and preferences.' (United Nations, General Comment No. 4, 2016, p.4)

Therefore, the iPEAR project embraces **students' needs and personal approaches to learning**. Before presenting the pedagogy, it is vital to illustrate the terms peer learning and Augmented reality.

There are many explanations for peer learning, including different roles and responsibilities. Boud, Cohen, and Sampson (1999, 2014) define it as “the use of teaching and learning strategies in which students learn with and from each other without the immediate intervention of a teacher” (1999, p. 413). It is also a form of reciprocal peer learning. Wessel (2015, p.14) says that when students engage in P2P, they can learn practical skills to give critical feedback and thus teach effectively. Palmer and Blake (2018) note in the Harvard Business Review that peer-to-peer learning fits naturally with how we naturally acquire new skills with the *Learning Loop*:

> People gain new skills best in any situation that includes all four stages of what we call the "Learning Loop": gain knowledge; practice by applying that knowledge; get feedback, and reflect on what has been learned. Peer-to-peer learning encompasses all of these.

Augmented Reality (AR) connects with the help of technology and visual information in the real world. Its technical means include multimedia, 3D modelling, real-time tracking and registration, intelligent interaction, sensing, and more. Its principle complements computer-generated virtual information, such as text, images, 3D models, music, video, etc., to the real world (Hu Tianyu et al., 2017) and people.

The theoretical underpinnings are described in those mentioned above in sections 1.1 and 1.2. The next step is to discuss the elements of the pedagogy that need to be considered before using the technology.

3.1 The iPEAR elements of pedagogy

As derived from literature and research findings in the frame of informed grounded theory, the pedagogical frame is categorised into four elements and broken down into guidelines and a checklist to make the iPEAR approach easy to use.

The research of iPEAR was designed as an experimental approach tested and elaborated in the co-funded Erasmus KA2 project in higher education. The initiative aims to join social learning through **peer-to-peer task designs (**Mazur, 1997) and visualisation as a form of microlearning widely used in vocational training and marketing via **AR tools**. The AR tools used were free versions of mobile apps, except for a case study from the IMTEL lab in Norway that uses Microsoft HoloLens. During the research process, two more elements were derived from the surveys with students, the interviews with educators, and the literature in the field. They need to understand better the roles (social and ethical) of **visuals or visual content creation** in learning (visual literacies and media) and gradually build **a peer feedback culture** (critical thinking). This peer feedback perspective is based on students; previous experiences and cultural background, but it could be reinforced with rewards or incentives initiated by educators. This sharing attitude could make courses more inclusive and help students take more responsibility for their studies and the growth of the learning community. The pedagogy is formulated within the boundaries of informed grounded theory that combines research analysis with updated literature reviews (Themelis, Sime and Thornberg, 2022). The approaches based on Informed grounded theory are in a never-ending evolution as it needs frequent revisions by the literature and new studies.

3.2 The iPEAR Schema

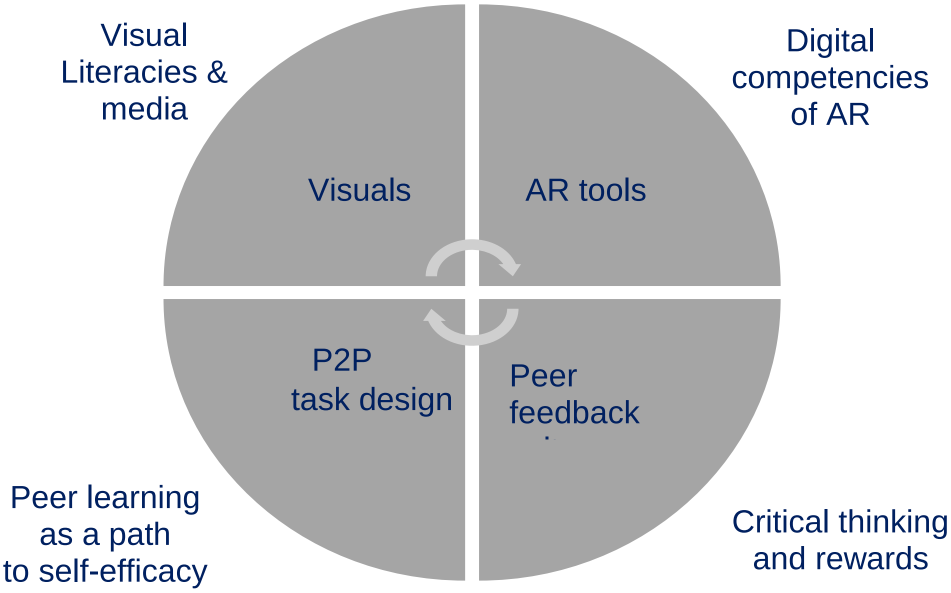

Figure 3: the elements of iPEAR pedagogy

Figure 3 shows the iPEAR schema's purpose to visualise the pedagogical framework. It is separated into four sections in constant interaction: Visuals (visual literacies and media), AR tools (digital competencies), P2P tasks design, and peer feedback culture (rewarding collaboration and critical thinking).

The first element of the iPEAR pedagogy is visuals or **visual literacy**. The following definition comes from the 2011 ACRL Visual Literacy Competency Standards for Higher Education:

> Visual literacy is a set of abilities that enables an individual to effectively find, interpret, evaluate, use, and create images and visual media. Visual literacy skills equip a learner to understand and analyse the contextual, cultural, ethical, aesthetic, intellectual, and technical components involved in producing and using visual materials. A visually literate individual is both a critical consumer of visual media and a competent contributor to a body of shared knowledge and culture. (ARCL, 2011; Association of College and Research Libraries, 2019)

The term visual literacies is used in the plural to connote the use of different forms of visuals produced by various media, from comics and animation to video and avatars, to name a few. Learners and teachers could consider the role and potential of visuals in education, especially from a technology-enhanced learning perspective. Visual literacies could also be used in the plural (because of the abundance of visual media and visual creations) and be part of professional training (Themelis, 2022). The visible capital has much to offer. Educators must know that visuals disseminate meaning faster, but different audiences can interpret it differently. In other words, visual experiences, aesthetics, and ethics are crucial in understanding visual media and its products. Thus, educators and students could spend some time discussing the role of visual literacies, pros, and cons before the assignment. The standards of visual literacy could be equally helpful, as explained below.

The ARCL (Association of College and Research Libraries, 2011 & 2022) has studied visual literacy for over 12 years. It states that in an interdisciplinary, higher education environment, a visually literate individual can:

- determine the nature and extent of the visual materials needed
- find and access required images and visual media effectively and efficiently
- interpret and analyse the meanings of images and visual media
- evaluate images and their sources
- use images and visual media effectively
- design and create meaningful images and visual media
- understand many ethical, legal, social, and economic issues surrounding the creation and use of images and visual media and ethically access and use visual materials.

Thus, the educators could be trained on visual approaches and media within the disciplinary framework to understand the visual landscape better and what needs to be created for the course. How could they communicate and share visuals? What kind of copyrights and ethical questions could they pose, and what ethical considerations should they consider? Regarding the level of autonomy (pedagogy, andragogy), learners may ask for a different level of control and independence. In peer learning, a rubric with critical questions may trigger attention to the criticality and ethical implications of the visuals - conscious and unconscious bias. It is crucial to note that audio files could be added with AR tools, but there is always a visual marker that triggers the AR experience.

The second pillar of the iPEAR schema is **AR tools** (digital skills)**.** Visual literacy is part of AR technologies that aim to extend realities with information. Educators must invest significant time in choosing technologies to serve the disciplinary requirements, and they must rely on the assistance of instructional designers or learning technologists. Educators could choose from a variety of AR apps that are marker-based (e.g., recognising a QR code), markerless (scanning the room) or location-based (relying on the device's GPS location, such as Pokémon Go). They could also consider different hardware platforms, from regular mobile phones to the more elaborated HoloLens 2 (augmented reality glasses). Unfortunately, educators face many challenges, such as engineers' technical jargon, complicated tutorials, and lack of training – complicating AR adoption in Higher Education.

The third pillar is **P2P task design** (according to the level of autonomy). The students need to fully understand why they get involved in an assignment, what they could get out of it and the usefulness of using technology. The students' and teachers' explanations may differ (Pask, 1975). The peers may find ways to instruct others more gradually or vividly because they have done so for themselves. For educators, explaining something they know very well could be automatic and may break down information into bigger chunks than the students can digest (Mazur,1997).

The University of Kentucky gave some evidence that P2P instruction:

- enhances students' conceptual understanding of science (Crouch & Mazur, 2012)

- improves retention of knowledge (Lambert, 2012, para 10)
- enhances course satisfaction and comprehension (Crouch, Watkins, Fagen, & Mazur, 2007)
- improves motivation and participation (Simon and Cutts, 2012).

The P2P task design using AR heavily depends on AR's affordances for supporting remote or co-located collaboration. This includes mutual awareness (e.g., of peers represented by virtual avatars, as well as of shared spaces and objects such as anatomical models), communication (e.g. through voice chat and gestures) and mutual interaction and sharing (e.g. manipulating shared objects) (Radu et al., 2021). The task design might differ depending on whether the peer-to-peer interaction is remote or collocated: for example, remote peers need to be provided with some form of communication, such as voice chat, which is unnecessary for co-located ones. Co-located peers depend on consistent anchoring of shared models (e.g. a virtual house model) in the physical space, which is less relevant for remote learners. Both remote and co-located peers need to maintain awareness of their peers' actions (e.g., by pointers in the shared workspace).

The fourth pillar of the iPEAR schema is the **peer feedback culture, inclusive praxis,** and **rewards** before, during, and after the designed activity. In creating a culture of constructive feedback, the students could create social netiquette and a growth mindset initiative. Social netiquette refers mainly to productive ways to offer feedback without judgment and help everyone in the peer group participate. Educators' feedforward and rubrics could help students imitate the example for providing constructive feedback to peers. A growth mindset embraces mistakes as a way of knowing and regards learning as a life-long process. In plain words, a growth mindset is a concept in which skills and performances can be enhanced, and research shows that students' growth mindsets can predict higher achievement, well-being, and inclusive praxis (Dweck & Yeager, 2021). It is also crucial to reward those students who teach others, share their devices with others, enhance inclusive values and act as good models for others to imitate.

During the two-meter society of the pandemic, the P2P approach offered a supportive mechanism against alienated distance courses based on lectures (Vergroesen, 2020). Students were urged to co-create content, share personal experiences, analyse, evaluate, and retain knowledge while working with 'class partners'. Peers were the cure against the passive learning approach (online lecturing) and isolation of the pandemic. Research (Cohen, Kulik, Kulik, 1982; Freeman et al., 2014) showed that students could pass the courses and deepen their understanding if they worked with peers. Student-led assignments, collaborative reviews, and dialogues in breakout sessions are peer-to-peer active learning approaches that have become popular, especially during lockdowns. Educators and students enjoy personalised instruction from their peers and take more responsibility for their personal growth (Vergroesen, 2020). The neuro pedagogy and neuroandragogy projects offer more information about brain research related to engagement, attention and associative memory.

Peer feedback could be a reliable source of scalable learning under three conditions:

a) The students should be offered rubrics to explain the role of collaboration and inclusive etiquette of interactions.

b) The activity should be designed with appropriate difficulty or different options that accommodate students' needs.

c) The students are willing and motivated to teach each other (rewards for peer collaboration).

Students need a rewarding system to work with peers and to enhance motivation. Some educational systems concentrate on collaborative praxis from a young age, while others are more teacher-led and competitive. Therefore, students must understand why they must commit to the task, work, and teach each other as a form of inclusive and democratic engagement. The reward needs to be noticeable: grades, more choice, student agency, or peer recognition that promotes mutual respect. Parchoma (2005) and Pentland (2014, 2020) consider rewards as the social glue that builds excellent teamwork and boosts motivation and engagement. Pentland's studies at the MIT Human Dynamics Lab (2014) proved that better performance and innovation are the product of effective and democratic collaboration rather than the high intellectual potential of a few. If using AR technologies, the affordances of AR will also influence modes for giving and receiving feedback and rewards.

3.3 Basic guidelines

Following the iPEAR elements of pedagogy described above, educators are recommended to

1) be aware of the digital divide (ensure that the tools are inclusive and everyone has acquired the devices and the know-how). This could be done with training (by educators or peers) and sharing approaches. Sharing mobile phones with people, they cannot afford to have

2) allow their students to form teams, as research shows that when students choose their peers, there is a better collaboration (Zhang, Ding, & Mazur, 2017)

3) design the task within the optimal level of difficulty that serves the learning outcomes

4) explain copyrights issues and visual ethics

5) provide peer feedback templates whenever needed

6) be cautious of visual culture (the impact of visuals in everyday life as the source of information, aesthetics, and learning)

7) promote student agency in designing the task according to the disciplinary boundaries.

8) talk about group dynamics to especially avoid domineering behaviours (all voices heard). It is essential to note that the roles and abilities could be similar or different according to the P2P task design scenarios.

9) enhance inclusive praxis for P2P instruction (facilitate learning for those with learning challenges with visual material and facilitate the update of the digital competencies.

The following checklist may help educators when designing task scenarios with the iPEAR approach.

Technical issues, digital skills for AR

- ☐ Am I fully aware of the AR tools I will use?
- ☐ Do I have an alternative plan if, for some reason, the AR tool is not working for all mobile phones?
- ☐ Have I designed a pilot assignment to ensure all students are on the same page (technical skills)?
- ☐ Have the students the digital skills to work in an iPEAR scenario?
- ☐ Could students work remotely?
- ☐ Could students work synchronously and asynchronously?
- ☐ Would the chosen software and software support the selected work mode (remote/co-located, synchronous/asynchronous)?

Visuals – content creation and media

- ☐ Have the students discussed the role of visuals in learning?
- ☐ Are the students informed of the visual data copyrights and ethics?
- ☐ Are students aware of visual media to use?
- ☐ Is the visual quality of media sufficient for the purpose?
- ☐ Is there visual support for P2P processes, such as peer avatars, pointers indicating user activities, and other ways of maintaining awareness of shared virtual workspace?

Peer learning task design

- ☐ Have the students had prior collaborative learning experiences?
- ☐ Are the students satisfied with collaborative learning?
- ☐ Are the students able to produce visuals for the learning outcomes?
- ☐ Are the students able to use the specific AR tools?
- ☐ Are the students aware of the inclusive nature (Sharing ideas, devices and assessment) of peer learning?
- ☐ Have the students had choices in the visual by-product?
- ☐ Could the students choose their peers?
- ☐ Could the students have different roles?
- ☐ Does the peer learning task design consider AR technology's affordances?

Peer feedback culture

- ☐ Is the iPEAR assignment rewarding (grades) and motivational (creative and critical thinking) for the students?
- ☐ Could students, according to their level of autonomy, assess each other's work?
- ☐ Have I provided assessment criteria?

3.4 Conclusion based on Chat.openai: Peer learning with AR

We cannot ignore the latest advent of open Artificial Intelligence. Hence, for triangulation purposes, we have included a section with the latest references of peer learning combined with AR at the end of the references. The following input is aligned with iPEAR research findings and the separate literature review for peer learning and AR in higher education (ChatGPT, 2023).

Peer learning with augmented reality (AR) refers to a collaborative learning approach that uses AR technology to enhance the learning experience. AR overlays digital information on the physical world, allowing learners to interact with virtual objects in real time. This technology can create interactive, immersive learning experiences that engage learners and promote collaboration and communication.

In peer learning with AR, learners can work together to explore and manipulate virtual objects in a shared physical space. This can be particularly useful in STEM (Science, Technology, Engineering, and Math) fields, where learners can use AR to visualize complex concepts and work together to solve problems. For example, learners can use AR to explore the human body, visualize complex mathematical equations, or explore the inner workings of machinery.

AR can also create virtual simulations and scenarios that allow learners to practice skills in a safe, controlled environment. For example, healthcare professionals can use AR to simulate medical procedures and practice working together to diagnose and treat patients.

Peer learning with AR benefits improved collaboration and communication skills, increased engagement and motivation, and enhanced learning outcomes. By working together in a shared AR environment, learners can develop critical thinking, problem-solving skills and a deeper understanding of complex concepts.

Overall, peer learning with AR can effectively enhance the learning experience and promote collaboration and communication among learners (ChatGPT, 2023).

PART 4: Competence Framework for AR

The iPEAR project developed an online tool for assessing the generic digital competencies in AR (O3.3) as adapted from the European Framework for the Digital Competence of Educators DigCompEdu.

The project supports the European skills frameworks: the "Digital skills framework" and the "Digital Competence Framework for Educators (DigCompEdu), by extending them into a framework for specific skills educators need to integrate AR in their teaching.

iPEAR mainly extended the DigCompEdu. Each of the extended components focus on enabling technology-enhanced learning approaches and thus, both the digital AR skills and the pedagogical competences. By doing so, the DigCompEdu is an inspirational site and not a basis of correlation.

According to the DigCompEdu, educators need more training in 6 areas:

1) Professional Engagement as the competence to use digital technologies (AR) to enhance teaching and professional development training with colleagues, students, and other interested parties.

2) Digital and Visual Resources as the competence to identify good educational resources and modify, create, and share digital resources such as video, infogrames, 3D models etc., that fit their learning objectives, student group, and teaching style. At the same time, they must be aware of how to responsibly use and manage digital content, and respect ethics, copyright rules and personal data regulations.

3) Immersive Teaching and Learning as the competence to adapt to immersive AR technologies framework is designing, planning, and implementing digital technologies in the different stages of the teaching and learning process. However, when doing this, the aim must be to shift the lesson's focus from teacher-led to student-centred approaches (see also section 1.1).

4) Assessment as the competence to use immersive technologies to enhance existing assessment strategies and assess experiential learning. Additionally, educators can offer more targeted feedback and support by analysing the wealth of (digital) data on individual students' (inter-)actions (see also sections 3.2 and 3.3).

5) Empowering Learners as the competence to let learners identify digital and immersive technologies to boost students' active involvement and creativity in the learning process and their ownership of it. Digital technologies can also offer learning activities adapted to each student's level of competence, interests, and learning needs. At the same time, attention must be taken not to exacerbate existing inequalities (e.g., access to digital technologies) and ensure accessibility for all students, including those with particular learning challenges.

6) Facilitating Learners' Digital Competence and Visual Literacy as the competence to promote students' digital competence and visual literacy from a technology-enhanced learning perspective.

A practical example of an online assessment tool is the following from DICTE Developing ICT in Teacher Education and European Framework for the Digital Competence of Educators: DigCompEdu 2017.

Ten educators/ instructional designers from European countries (from Greece, Germany, Spain, Portugal, and Norway) were asked to give feedback on the iPEAR framework. They were asked to check if the iPEAR framework is similar to the generic DigCompEdu and aligned with the iPEAR assessment tool, which basically was the case according to the reviewers' opinion.

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3) Professor Salvador Sanchez-Alonso, University of Alcala, Spain
4) Professor Lucília Santos, University of Aveiro, Portugal
5) Professor Alfredo Soeiro, Universidade do Porto, Portugal

PART 5: Online competence assessment tool for AR

Task O3.4 implements the iPEAR framework as an online assessment tool adapting the already mentioned European Framework for the Digital Competence of Educators DigCompEdu to AR (immersive technologies). Immersive technologies or augmented reality tools focus on digital skills, visual (immersive) media, and the awareness of visual literacies (theories and competencies) for teaching and learning.

This online assessment tool allows educators to evaluate their skills and get recommendations on which skills to improve. Additionally, educators could find information about tools in the iPEAR toolkit and case studies on AR and peer learning in the iPEAR Compendium of good praxis. The online assessment tool assists educators in reflecting on their educational praxis in 6 areas similar to the DigCompEdu but focusing on immersive technologies and visual literacies:

- Professional Engagement
- Digital and Visual Resources
- Immersive Teaching and Learning
- Assessment
- Empowering Learners
- Facilitating Learners' Digital Competence and Visual Literacies

Proficiency levels in immersive technologies

In general, the following characterisations apply to the different competence stages:

Self-description

Newcomer (A1): Newcomers are aware of the potential of immersive (AR and VR) technologies and visual approaches for enhancing pedagogical and professional practice. However, they have had minimal contact with these technologies. Newcomers need guidance and encouragement to expand their repertoire and improve their digital competence in the pedagogical realm.

Explorer (A2): Explorers are aware of the potential of immersive technologies and visual/experiential approaches and are interested in exploring them to enhance pedagogical and professional practice. They have started using these technologies in some areas of digital competence without following a comprehensive or consistent approach. Explorers need encouragement, insight, and inspiration, e.g. through the example and guidance of colleagues embedded in a collaborative exchange of practices.

Integrator (B1): Integrators experiment with immersive experiential technologies in various contexts and for various purposes, integrating them into many practices. They creatively use them to enhance diverse aspects of their professional Engagement. They are eager to expand their repertoire of approaches. However, they are still working on understanding which tools work best in situations and fitting digital technologies to pedagogic strategies and methods. Integrators need more time for experimentation and reflection, complemented by collaborative encouragement and knowledge exchange to become Experts.

Expert (B2): Experts confidently, creatively, and critically use various immersive technologies to enhance their professional activities. They purposefully select digital technologies for particular situations and try understanding the benefits and drawbacks of different digital strategies or ethics. They are curious and open to new ideas, knowing that there are many things they have not tried out yet. They use experimentation to expand, structure and consolidate their repertoire of strategies. Experts are the backbone of any educational organisation regarding innovative practice.

Leader (C1) or Pioneer (C2): Leaders have a consistent and comprehensive approach to using immersive technologies to enhance pedagogic and professional practices. They rely on a broad repertoire of digital strategies from which they know how to choose the most appropriate for any given situation. They continuously reflect on and further, develop their practices. Exchanging with peers, they keep updated on new developments and ideas. They are a source of inspiration for others who pass on their expertise. Pioneers question the adequacy of contemporary digital, immersive, and pedagogical practices, of which they are leaders. They are concerned about the constraints or drawbacks of these practices and are driven by the impulse to innovate education even further. Pioneers experiment with highly innovative and complex digital technologies and/ or develop novel pedagogical approaches. Pioneers are a unique and rare species. They lead innovation and are a role model for younger teachers.

Survey Questions

This self-assessment tool is based on the European Digital Competence Framework for Educators (DigCompEdu). DigCompEdu sets out 22 competencies organised in six Areas. The competencies are explained at six proficiency levels (A1, A2, B1, B2, C1, C2). The focus of the adopted framework is to support and encourage teachers to use visual media and immersive tools to enhance and innovate education.

This tool allows you to reflect on your strengths and weaknesses in using digital and immersive technologies in education. We invite you to self-assess yourself against six areas adapted for the iPEAR project from DigCompEdu.

Current Digital Competence Level

How do you currently assess your digital competence as an educator? Assign a level of competence from A1 to C2, where A1 is the lowest and C2 is the highest level.

- ☐ I am probably a(n)
- ☐ Newcomer (A1)
- ☐ Explorer (A2)
- ☐ Integrator (B1)

☐ Expert (B2)

☐ Leader (C1) & Pioneer (C2)

Area 1: Professional engagement in general

Educators' digital competence is expressed in their ability to use digital technologies to enhance teaching and professional interactions with colleagues, students, parents, and other interested parties. This is the focus of Area 1.

Please choose the option that best reflects your current practice.

Development of digital teaching skills: I actively develop my digital teaching skills in immersive technologies such as AR.

☐ I rarely have the time to work on my digital teaching skills
☐ I improve my skills through experimentation and reflection
☐ I use various resources or training to develop my digital teaching skills
☐ I discuss with peers how to use digital technologies and improve educational practice
☐ I help colleagues develop digital teaching strategies

Online training: I participate in online training opportunities, e.g. online courses, MOOCs, and webinars, to learn about AR...

☐ This is a new area that I have not yet considered
☐ Not yet, but I am definitely interested
☐ I have participated in online training once or twice
☐ I have tried out various online training opportunities
☐ I frequently participate in all kinds of online training

Area 2: Digital and Visual Resources

One of the critical competencies any educator needs to develop is identifying good educational resources and modifying, creating, and sharing digital resources such as video, Infogrames etc., that fit their learning objectives, student group, and teaching style. At the same time, they must be aware of how to responsibly use and manage digital content, respect copyright rules and protect personal data.

These issues are at the heart of Area 2. Please choose the option that best reflects your current practice.

Modification of visual resources: I create digital visual resources and modify existing ones to adapt them to my needs.

☐ I do not use visual resources
☐ I use ready-made visual resources for my courses and presentations
☐ I create my own visual resources: photos, infographics, and comics
☐ I create immersive 3D videos for my courses
☐ I create and modify complex interactive resources such as AR tools

Sensitive Data: I protect visual content: copyrights, and personal data protection restrictions.

☐ I do not need to do that because the University takes care of this
☐ I avoid storing personal data electronically

- ☐ I protect some personal data and copyrights, e.g. photos, videos, and texts
- ☐ I password-protect files with personal data
- ☐ I comprehensively protect personal data and respect ethics and copyrights, e.g. combining hard-to-guess passwords with encryption and frequent software updates

Area 3: Immersive Teaching and Learning

The most fundamental competence of DigCompEdu, adapted for the immersive technologies framework, is designing, planning, and implementing digital technologies in the different stages of the teaching and learning process. However, when doing this, the aim must be to shift the lesson's focus from teacher-led to student-centred approaches. This is the real power of digital technologies and the focus of Area 3.

Please choose the option that best reflects your current practice.

Value creation: I carefully consider how, when, and why digital technologies in class to ensure that they are used with an added value linked to learning theories.

- ☐ I do not or only rarely use technology in class
- ☐ I make primary use of available equipment, e.g. digital whiteboards or projectors
- ☐ I use a variety of digital strategies in my teaching
- ☐ I use digital tools to enhance teaching- immersive AR or VR learning occasionally systematically
- ☐ I use digital tools to implement innovative pedagogy strategies and immersive experiences

Digital technologies in group work**:** when my students work in teams, they use digital technologies such as AR apps

- ☐ My students do not work in teams
- ☐ I cannot integrate digital technologies into group work
- ☐ I encourage students in groups to search for information or visual resources online and critically reflect on them
- ☐ I require my students to work in teams to use the internet to find resources and visuals to present their results in digital format
- ☐ My students exchange evidence, content and interpretations and jointly create knowledge in collaborative online spaces

Area 4: Assessment

Immersive technologies can enhance existing assessment strategies and give new and better assessment methods. Additionally, educators can offer more targeted feedback and support by analysing the wealth of (digital) data available on individual students' (inter-)actions. Area 4 addresses this shift in assessment strategies.

Please choose the option that best reflects your current feedback practice: I use digital technologies to provide effective feedback.

- ☐ Feedback is not necessary for my work environment
- ☐ I provide feedback to students, but not in digital form
- ☐ Sometimes, I use digital ways of providing feedback, e.g. automatic scores in online quizzes, comments, or 'likes' in online environments

- ☐ I use a variety of ways to provide feedback. I systematically use digital visual methods to provide feedback or guidelines for students to provide feedback

Area 5: Empowering Learners

One of the key strengths of digital and immersive technologies in education is their potential to boost students' active involvement in learning and ownership. Digital technologies can also offer learning activities adapted to each student's level of competence, interests, and learning needs. At the same time, however, care must be taken not to exacerbate existing inequalities (e.g., access to digital technologies) and ensure accessibility for all students, including those with special learning needs. Area 5 tackles these issues.

Please choose the option that best reflects your current practice.

<u>Addressing digital problems</u>: I address potential digital issues and visual ethics when creating student assignments. E.g. equal access to digital devices and resources, interoperability and conversion problems, ethics, and lack of digital skills.

- ☐ I do create digital visual assignments
- ☐ My students do not have problems with using digital tools
- ☐ I adapt the task to minimize difficulties. I discuss possible obstacles with students and outline solutions
- ☐ I allow for variety, e.g. I adjust the task and discuss the solutions, ethical considerations or new tools and visual approaches to provide alternative ways for completing the tasks

<u>Personal Learning opportunities</u>: AR technologies offer students personalized learning opportunities. E.g. I give different students different digital tasks to address individual learning needs, preferences and interests.

- ☐ In my work environment, all students must do the same activities, irrespective of their level
- ☐ I do provide students with recommendations for additional resources, especially visual ones
- ☐ I offer optional digital activities for those who are advanced or lagging behind
- ☐ Whenever possible, I use digital technologies to offer differentiated learning opportunities
- ☐ I systematically adapt my teaching to link to students' individual learning needs, preferences and interests

<u>Active participation</u>: I use digital technology and AR for students to actively participate in class and online.

- ☐ It is impossible to involve students in class actively or online in my work environment
- ☐ I do involve students actively, but not with digital visual technologies
- ☐ When instructing, I use motivational stimuli, e.g. videos, animation, and cartoons, to link them to learning objectives
- ☐ My students engage with digital media in class and online. E.g. gaming, video conferences, and quizzes

- ☐ My students systematically use digital technologies to investigate, discuss, learn new tools and create knowledge

Area 6. Facilitating Learners' Digital Competence and Visual Literacies

Promoting students' digital competence and visual literacies is integral to educators'' digital competence at Area 6.

Please choose the option that best reflects your current practice.

Creation of digital visual content: I set up assignments that require students to create digitally visual content, e.g. videos, photos, Infogrames, and 3D models.

- ☐ This is not possible in my field of studies or work environment
- ☐ This is difficult to implement with my students
- ☐ Sometimes, as a fun activity
- ☐ This is an integral part of their learning, and I systematically increase the difficulty level to further develop visual content and digital skills
- ☐ I give them choices of tools and assignments that match different learning styles

Safe and responsible behaviour: I teach my students how to ethically create, use and share visual resources online and offline.

- ☐ This is not possible in my field of studies or work environment
- ☐ I inform them that they must be careful with visual copyrights and personal information online
- ☐ I explain the basic rules of using visual content critically and sharing it responsibly
- ☐ We discuss and agree on rules for the use of visuals
- ☐ I systematically develop my students' critical visual use of social practices in different digital environments we use
- ☐ I encourage discussions about digital tools' safe, social or ethical use to form a multidisciplinary perspective

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