Integration of Extended Reality (XR) in non-native undergraduate programmes

Balaji Aresh, School of Computing Engineering and Physical Sciences, University of the West of Scotland, Paisley, UK, balaji.aresh@uws.ac.uk

Parag Vichare, School of Computing Engineering and Physical Sciences, University of the West of Scotland, Paisley, UK, parag.vichare@uws.ac.uk

Keshav Dahal, School of Computing Engineering and Physical Sciences, University of the West of Scotland,Paisley, UK, keshav.dahal@uws.ac.uk

Tony Leslie, School of Computing Engineering and Physical Sciences (CEPS),University of the West of Scotland,Paisley, UK, tony.leslie@uws.ac.uk

Marco Gilardi, School of Computing Engineering and Physical Sciences (CEPS),University of the West of Scotland,Paisley, UK, marco.gilardi@uws.ac.uk

Alyona Lovska, Department of Wagon Engineering And Product Quality, Ukrainian State University of Railway Transport, Kharkiv, Ukraine, alyonalovskaya@kart.edu.ua

Glib Vatulia, Department of Structural Mechanics and Hydraulics, Ukrainian State University of Railway Transport, Kharkiv, Ukraine, vatulya@kart.edu.ua

***Abstract*—This paper presents the use of XR technologies in teaching CAD. Immersive experience generated by XR technologies have traditionally found a quicker uptake in visualization industry especially in arts, entertainment and gaming. Current undergraduate (UG) modules in computer science and game development programme provide underpinning modules for learning XR technology. Other non-native UG Programmes such as architecture, engineering (mechanical, aerospace, automotive, Computer Aided Design (CAD)) and construction do not provide these modules as a part of the programme. However, use of XR technology has been widely exploited in such application areas as its use cases are exponentially growing. The proposed study explored the potential benefits of utilizing XR technology in the BSc CAD, BEng (Mechanical and Aircraft) program. The paper presents a review of the current state of the XR use in various industries and XR related pedagogy, followed by a pilot study of introducing Virtual Reality (VR) application to current programme modules at the University of the West of Scotland. This use case is particularly important to collaborative design review using XR technology. The study captures students' and staffs' perception on adapting to this new technology. This paper provides an academic feasibility scenario for integrating XR/VR subject area in non-native UG programmes. The paper also provides an use-case for implementing VR assisted collaborative product review for evaluating a product design and development progress.**

Keywords— extended reality, XR, virtual reality, computer aided design, CAD, higher education, pedagogy, collaboration

I. INTRODUCTION

'*Extended reality for extending education*' [1] the title of a Times Higher Education article could very well set the tone for this paper as it highlights the importance of future proofing student's career by embedding XR technology in their curriculum. The move towards Industry 4.0 also brings along with it a wave of integration along every level of the manufacturing process, thoroughly cemented by emerging technologies [2]. Though the United Kingdom ranks in the top five in the world and three in Europe in the Global Innovation Index [3], there is a looming skill gap in technology use and people skills [4]. A systematic analysis of literature based on Industry 4.0 has returned keywords such as digitalization, simulation, digital twin, augmented reality, technology, etc, to name just a few [5]. While Higher Education Institutions (HEI) currently cater to Millennials and Gen Z [6], upskilling and reskilling the current workforce [7] should also be prioritised within the curriculum.

Innovative technologies such as Artificial Intelligence (AI) and Extended Reality (XR) are native to programmes in Computer Science and Game development where students are exposed to relevant modules earlier in their learning years. Non-native UG programmes in Architecture, Engineering (mechanical, aerospace, automotive, CAD) and Construction (AEC) may have facets of AI embedded in CAD software packages (SolidWorks, Creo, Catia, etc) and XR as a visualization tool but may be looked upon by students as a novel curiosity rather than an essential tool or skill.

In a previous academic exercise, Vichare et al., [8], identified an approach to updating the current AEC modules to include XR technologies. Learning Outcomes (LO) were updated configuring 3D models in an immersive environment and to effectively use VR to conduct a collaborative product review. A framework was proposed to introduce students to collaborative design and development using Augmented Reality (AR) and Virtual Reality (VR) tools. Using the proposed methodology [8] and following an ethical review, authors of this paper conducted a pilot study with undergraduate students undertaking Computer aided Design module. The module covered student cohorts from BEng (Hons) Engineering Management (ENMS) Level 10, BSc

Computer Aided Design (CADS) Level 9, BEng (Hons) Aircraft Engineering Level 8, BEng (Hons) Mechanical Engineering Level 8 and BEng (Hons) Engineering Design & Manufacture Level 8. Students used AR and VR technologies as part of their coursework and at the end of the activity a survey was sent out.

The aim of this paper is to present the staffs' perspectives on integrating XR subject area in the module and the students' perspective on the use of AR and VR technologies in a collaborative environment. The paper presents a literature review on the current use of XR in higher educational settings (in native and non-native courses), XR based pedagogy, course currently offering XR and the current structure of CAD modules. It then describes the set-up of the pilot study and its outcomes: student and teacher perspectives.

II. Literature Review

A. XR/VR subject area and Engineering Design applications

Fuelled by the COVID-19 pandemic, and currently being propelled by the growth of Industry 4.0, XR technologies are finding more acceptance into varied domains beyond just visualization or entertainment. Domains such as healthcare, engineering, tourism, etc, are learning to adapt and use XR effectively.

Patrick et al., [9] examined the current literature to determine how extended reality (XR) and related technologies have been explored, evaluated, or used in educational and training activities. Using XR tools to aide student learning experience, improve their performance and getting them career ready were explored. The paper shows that XR applications are used albeit at a pilot-testing level in non-native undergraduate programs. It argues that learning from the pilot study level and applying to mainstream curriculum can facilitate experiential learning and improve student experience. It also states that hands-on use of XR technology ensures a greater likelihood of students remembering, retaining, and engaging with knowledge gained.

Vasarainen et al., [10] looked at the application of XR in three main areas: remote collaboration, knowledge exchange and work practices. It highlighted that though XR in its various forms were popular, VR did stand out as a most used option. Headsets were the accepted form of interaction but equally important were desktop and screen-based versions of XR.

The use of VR in early design phase was explored by Berni et al., [11]. While VR wholly supported the traditional design activities, the paper also highlighted that it propagated education in design. This aspect however has not been fully exploited according to the authors. It also supports the idea that some VR technologies may be favoured than others, but this will be based on different stages of the design process.

The useability of XR in specific to Architecture was studied by Abhari et al., [12]. The paper developed a framework to help XR technology developers specially for architectural use which featured around the interplay between concept, knowledge and environment. The framework can also be used in reverse such that architects can identify specific XR technology. This enhances collaboration between different project stakeholders.

XR has also been adapted into non-native domains such as Mathematics education. Lai et al. [13], recognised that a mismatch exists between XR technologies that are more suited for visualisation and mathematics education that requires cognitive functions. A case study involving undergraduate mathematics education highlighted that if XR is only used to remember, retain, and engage without 'dialogue' between student-student or student-staff then it is not an effective use of the technology. It once again highlights the need of critical thinking, collaboration, and creativity around the use of XR technologies. Yilmaz [14] studied the application of AR in university level teaching of chemistry and recorded a significant difference in student learning experience. Here students used their own phones to visualise already prepared 3D objects such as chemical compounds and structure of atoms while in a laboratory setting. While being in a laboratory itself lends a hands-on approach, the 3D visualization offered a different perspective to the laboratory work. Nechypurenko et al., [15] found similar success in using AR to support the teaching of chemistry; addressing the lack of Ukrainian language support materials and the need to implement AR in Ukrainian higher education institutions, the authors used HP Reveal and AR application to create a database of chemicals and their properties, laboratory apparatus, a virtual chemical laboratory with high-quality videos of chemical reactions and materials (videos, GIF and animations) for a Physical Chemistry course for students in distance education. Curran et al., [16] reviewed the use of XR in medical education. Different forms of XR have found uptake in surgical and anatomical education. The review found that XR technologies can be cost-effective way of teaching. Application of XR was the Point of View (POV) 3D videos which places the students as a doer rather than an observer.

The length and breadth of the application of XR in education and in various domains highlights the need to include XR in current undergraduate modules. XR inspired pedagogy have also been under constant development. Dengel et al., [17] looked at the use of AR and the instructor's ability to create AR content without needed for additional programming skills. Their extensive review of around 835 documents highlighted key words such as 'easy access' and 'GUI-based' for AR content creation. It also states that interactive content can be produced by still applying the six categories of the Bloom's Taxonomy. Though few applications were found suitable such as the Vuforia app, it highlights that extensive study by developers and educators of their use within an educational framework is missing.

'Smart Pedagogy' was explored through a survey by Doran and Uskov [18], where the 'smartness' or the use of innovative technology for teaching. The authors created a virtual classroom using Unity. The research yielded an overall positive outlook with one of the key highlights being that a smart pedagogy requires smart teachers, that is, teachers who possess both the skills and teaching qualifications. Meccawy [19] followed a qualitative approach to gain teacher's thoughts and experience in using XR within schools. The paper states that the teachers may themselves not have experience in using XR technologies but are aware of it's uses in teaching and the prime factor that gets them to use it to enhance student learning experiences but need to deal with hindrances such as their own coding skills, infrastructure and support from the educational institute. Though the research is limited to a school environment, it mirrors similar data gathered in Higher

Educational Institutes (HEI). The admission process to HEI in the United Kingdom is provided by Universities and Colleges Admissions Service (UCAS). A search for CAD programmes on their website produces courses offered in Computer Animation, Architecture, Games Development, Fashion, Product Design, Engineering to name a few [20]. Courses offered in programmes that are both native and non-native to XR technologies. VR which come under the umbrella term of XR is most popular topic offered.

A typical structure of the VR themed modules offered by various HEI are presented here. Common topics covered in these modules include 3D asset production, coding and game engines. Most of them offer these course or modules aimed at the gaming industry and the arts. The University of Kent offers a VR module with the assessment being a coursework with 150 hours of study hours. The module attributes towards courses in BSc in Digital Design and BEng in Biomedical Engineering. Topics covered are theory behind VR, designing of virtual environments and the programming aspect. A BSc in Virtual and Augmented Reality offered by the University of Portsmouth. VR and AR concepts, 3D modelling and coding for games are offered in year 1 with year 2 and 3 allowing for advanced offerings on AR and VR development and motion capture. University of Arts London offers a MA in Virtual Reality course of 1 year duration with principles of animation and games development explored from the start. This paper presents a pilot study of the introduction of XR technologies in a CAD module. This module is a part of BSc CAD, BEng (Mechanical, Aircraft) programmes. It is important to identify the level of integration that is offered by VR and AR technologies to include in non-native programmes listed above. Insertion of a CAD geometric model is completed using a commercial software such as Creo and Catia, into an XR environment. This involves a model preparation process and converting the model in a suitable file format. Even though this will enable importing the model into the XR environment, it usually leads to the loss of model features [21], [22] such as model complexity, animation and kinematic links.

Hunde and Woldeyohannes [23] reviewed the prospects of CAD and XR; it states that kinematics relationships are lost when being imported from CAD to a VR platform, but the 3D model can be animated by using Virtual Reality Modelling Language (VRML). To ensure that kinematic links are not lost, these usually need to be recreated using Digital Content Creation (DCC) systems as reported by Lorenz et al.,[24]. These are usually stand-alone applications or pre-packaged modules within CAD software with additional licenses that need to be purchased. Transferring CAD to VR environment is usually a top-down approach, that is, one way translation process but a study by Whyte et al., [25] shows a two-way data exchange is possible by using a central database which holds the information of the model and both CAD and VR is used as a interface thus changes in one application will effect a change in the other. Though possible, the database approach has not been implemented commercially. Lorenz et al., [24] proof-of-concept exercise in maintaining the animation and kinematics links from CAD to VR was successfully carried out via an object mapping interface set between the CAD and VR software; this interface would transfer any manipulation carried out by the VR to the CAD and the CAD would return the transformation matrices of the object and all related parts. Corseuil et al., [26] developed an application called ENVIRON (ENvironment for VIRtual Objects Navigation) for real-time visualisation and interaction of large 3D models in VR. The development of the application required extensive skills in programming. Hurtado et al., [22] took a similar approach to develop a method of visualisation by reducing the number of meshes, their effort to create in-house applications once again highlights the discord between CAD software and XR technology. Though STEP and IGES is an industry standard for carrying data between different CAD programmes, there however is no data standards for VR integration [27].

III. VR CONTENT CREATION PROCESS

A. Creation of AR and VR Environment

Fig 1 illustrates a process for creating an AR environment. Commercially available CAD software Creo was used in teaching the module. Creo has a built-in tool that converts the 3D model into a AR app readable format. Once the student creates a 3D model, it can be published into an AR environment using a static image reference method. Vuforia app was then used to open the 3D model and embed it in a virtual-physical environment. Fig 1 shows the example of a 3D model of the rocker-bogie mechanism which is then published as an AR readable model and opened in Vuforia. The example shows the use case of AR model, where digital Rocker-Bogie model positioned in the real-life (physical) door frame to evaluate its size and accessibility.

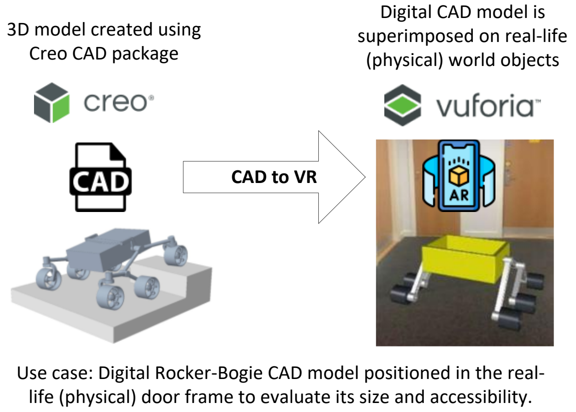

Fig. 1. Workflow of converting and embedding a 3D CAD model into an AR envoironment using Creo and Vuforia.

Fig 2 shows the flowchart for creating an VR environment. 3D model created using Creo was exported and saved as a .obj file format. Arkio desktop version was then used to create a virtual environment with already available 3D assets such as trees, vehicles and human figures. Students would then import their 3D model within the VR environment. This is followed by a creation of a virtual meeting room, which can be accessible from multiple platforms such as mobiles, tables and desktops using any browser system. Students can now wear the Oculus Rift 2.0 headsets and controllers and open Arkio within the headset environment as shown in Fig 3. Once the Arkio app is opened in the Oculus headset students would then log into the same meeting room. This would then welcome all users into the meeting room. Students can create ‘avatars’ to represent them in VR. They would then use the hand controllers to undertake basic manipulation of the 3D model such as move and scale. This meeting session provided the collaborative environment where students could discuss and present their designs.

IV. Introduction/Integration of VR in CAD module

The Creative Computing Technologies (CCT) group at UWS provided the expertise to teach AR and VR. As part of the programmes offered, CCT was already making use of VR headsets (Oculus Rift 2.0) and Arkio which provided the VR environment. To accommodate the delivery of all topics as included in the PSMD without changes, the schedule of the CCT staff and include the AR and VR components in teaching for the pilot study, the students in the CAD module were allocated with 4 hours (2 hours per session per week) of contact time on-campus during weeks 10 and 11. This provided students with ample time to learn about XR technologies and spend approximately 3 hours in using AR and VR technology.

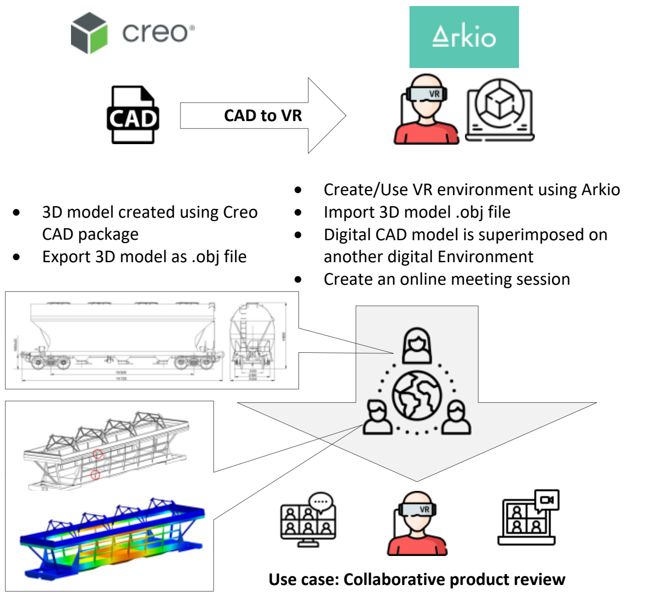

Fig. 2. Workflow of converting and embedding a 3D CAD model into a CR envornment using Creo, Arkio and Oculus Rift 2.0 VR headset.

Fig. 3. Examples of students interacting with the VR environmentusing Oculus headsets and hand controllers and Arkio app within the headset.

A. *Experiment set-up*

The assessment of CAD module consists of a class test and a coursework. It was in the coursework component that the use of XR technology was embedded leading to an experiential learning environment. A typical module duration is of fifteen weeks and students are expected to submit the coursework at the end of week 15.

The coursework involves the creation of a functional component, in this case, a rocker-bogie platform. Students were required to initially conduct a brief literature survey to understand the working of the rocker-bogie mechanism, then use that knowledge to create various design option but within given design parameters. A 3D product must be realised using Creo CAD package, and the rocker-bogie must be put through various motion, simulating flat, inclined and undulated surfaces. Once a fully operational 3D model was created, students will need to use AR to check that the model can roll-out through an access area which was a typical commercial door frame. These tasks were to be done individually. This was followed by the collaborative review of the rocker bogie model using XR technologies where students would get together in groups and perform a design review of the rocker-bogie platform. Given the number of students in the module and nature of the pilot-study to test the applicability of such technologies, it was decided to hold no control group and rather give all students access to VR technologies.

Common resources were relevant peer-reviewed literature, tutor created lecture videos and access to CAD packages such as PTC Creo 8.0. For the AR component of the course work, it was recommended that students download Vuforia View app into their smartphones or tablets. Creo lets you convert the model and to be exported to be viewed in the AR app. Resources in terms of teaching staff and VR headsets (Oculus Rift 2.0) were obtained from the Computer Games Development programme. A presentation was held by relevant staff and the headsets were distributed to students for a two-hour session to get them accustomed with VR headset, hand controllers and the VR environment creator called Arkio (already loaded on desktops as well as VR headset). When Arkio application is opened in the headset, it allows multiple users to join in a meeting with the users represented by avatars. This enabled the collaborative component of the coursework.

Arkio is a collaborative design platform which enables users to create simplistic geometries and allows the users to embed 3D models created in another software package. Arkio runs on desktops and on the headsets. Due to the limited time that students can use the headsets (4 hours split across 2 sessions), students were expected to use Arkio's desktop version to create a VR environment first and then during presentation, they were to wear the headset and present the collaborative product design review by accessing the already pre-configured VR environment.

VR assessment for collaborative product review was scheduled in week 15. Students were encouraged to present wearing the headsets but those who faced difficulties were required to join the Arkio meeting through the desktop or mobile version and still be able to present. Key points that students were expected to discuss were the critical appraisal of various design configuration.

The coursework thus would enable skills such as critical thinking, spatial navigation in VR environment, collaboration and the use of XR enabled technologies.

B. *Results: Instructors perception*

As the intention of the pilot study was to use VR and not create any new materials, presentation materials already developed for other modules was used in the teaching of XR technology. Videos on how to use Arkio using the VR headsets was already present in the Arkio webpage and links to them were embedded in module webpage on Aula, a Virtual Learning Environment (VLE) used by UWS. On the day of teaching there were 4 instructors (2 from CCT group) present reducing the student to staff ratio from 20:1 to 10:1. This ensured that student queries could be dealt with quickly. Instructions were provided on what XR is and its uses, how to export 3D CAD model into the virtual environment and how to manipulate the model in VR using the Oculus headsets and controllers.

Key observations during these sessions were:

- Majority of students had some knowledge of AR and VR but not necessarily used these technologies.
- Students learned to intuitively adapt to using the Oculus headsets and the controllers and manipulate virtual objects using the Arkio interface even though most had never used one.
- The current computing lab was spacious enough to use VR headsets as it had sufficient room between computers to allow students to wear headsets and move the controllers. Students were however cautioned to be aware of other participants.
- Only a handful of students out of 40 were not comfortable wearing the headsets.
- Since Arkio also provided the same interface on desktop version, students were able to use this version to refine their VR environment before using the headsets.
- Few students were frustrated at not being able to use AR or VR technology due to software or hardware issues. Issues included- AR apps not loading on smartphones, internet connectivity and battery running out on the headsets, to name a few.
- It was observed that students were excited to engaged with the a new technology.
- Students were collaborating in the VR environment during independent study time after university sessions.
- There were multiple instances of students teaching other students.

C. *Results: Students perception*

One of the research objectives of the pilot study was to gather student's perspectives on how XR assisted learning enabled CAD module's Learning Outcomes. The coursework provided to them, explored their ability to use AR using their smartphone and an application and VR through Oculus headgear and Arkio software.

AR overlays a digital object in the physical environment thus encouraging students to interact with their surroundings; this was achieved by the task on the coursework where they had to design the Rocker-Bogie mechanism with dimensions such that it would be able to roll-out through an access area equivalent to a standard/commercial door. This required the students to export their 3D model from Creo in a file format such as .OBJ or .FBX and opening them in a compatible smartphone application. It was recommended that they use 'Vuforia View', an app which runs on both Android and iOS. Of the 34 reports submitted, 25 of them successfully managed to complete the task and inserted screenshots of their work in their report; Fig.4 shows examples of the AR task. A general feedback from the students as reflected in their writing state that this task was interesting and helped them easily visualize their component in a real-world environment. Those, who did not complete the task, some have attributed them to software issues and the rest completely ignoring the task. This exercise did not require recording of data such as the type of smartphone or tablet used nor the mobile operating system version. Since AR does not provide for a completely immersive experience [28] and was limited to students' own device, this particular task may not have been digitally inclusive. This experience was reflected in an informal feedback session with students.

Next task was to conduct a collaborative design review in a VR environment as shown in Fig 3 and 5. Groups were formed, and students created their environment by embedding their 3D models in Arkio. Oculus headgear was used, and a virtual meeting space was created where all group members assembled along with tutors and reviewed their designs.

A survey was sent out to students at the end of VR assisted collaborative design review activity. It was designed to assess the impact of using XR technologies. Table 1 shows the results of the survey. Objectives statements and questions were included in the survey and assessed against a five-point Likert scale (definitely agree, agree, neutral, disagree and definitely disagree). 20 students responded to the survey, with the upper numbers on the table denoting the number of respondents and the bottom number, the corresponding percentage.

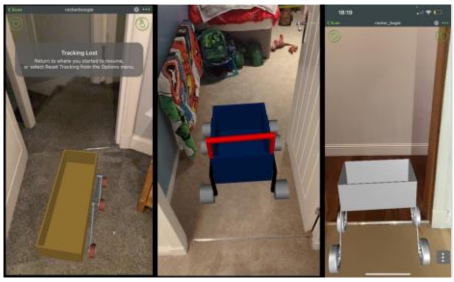

Fig. 4. Examples of students interacting with the AR app Vuforia shows their 3D CAD model viwed in a physical environment, a doorway.

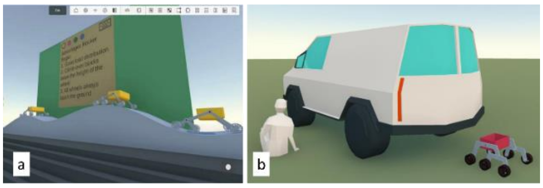

Fig. 5. Virtual environment created by students using Arkio by embedding their 3D rocker-bogie mechanism- a) shows different climbing states of the rocker-bogie, and b) represents the size and how a rocker-bogie can be transported.

S1 captures the student's perception of the structure of the assessment. 75% responded saying that they managed to use Arkio and Oculus to achieve their objective while 25% remained neutral. Statement S2 reflects the learning experience of students where 77.78% could appreciate the use of CAD packages and XR technologies to realise new product development. While 16.67% remained neutral and 5.56% disagreed. S3, S4 and S5 capture whether the students were able to learn and adapt to the use of XR technology for collaboration and most students agreed that their skills did improve, and it was a less stressful experience. Though in S4, it must be noted that 5.26% disagreed with this outcome while a seemingly significant 31.58% of students remained neutral. S6 presents a different view to that of S5 in that students felt that AR did not complement their learning experience with 20% staying neutral and 20% disagreeing. This is also reflected in the some of the reports ignoring this task.

V. Discussion and Conclusion

Following the framework previously designed, the pilot study proved the possibility of integrating XR technology in pre-existing AEC programme without affecting a major change to learning outcomes or changes to module structure. The pilot study offered a good insight to student perspectives on the use of XR technologies. Though the use of XR is not new as it is adopted for use in modules in Computing and Games Development, the translational use in teaching and learning of a module within BSc CAD and BEng programmes was welcomed positively by students.

A study conducted by Baxter and Hainey [29] conducted a survey among UG Games Development programme students regarding use of VR in higher education. When asked whether VR would enhance their learning experience, out of the 100 participants, 38 percent strongly agreed and 51 percent agreed that it has. This resonates with the current statement-S5, where 15.79% strongly agreed and 63.16% agreed. Though the 2018 study had large section of the students aware of VR and using it, the outcome generally reflects even when applied to a university-wide survey targeting both staff and students without XR integration, as conducted by the University of Newcastle [30]; despite staff and student having limited exposure to XR, the survey returned a positive outlook on the potential use in education. It reiterates the conclusion that the positive perception already exists, and this must be taken into consideration when refining the framework.

TABLE I. SURVEY OBJECTIVE STATEMENTS CAPTURING STUDENTS' LEARNING EXPERIENCES

Objective Statements	***Definitely Agree***	***Agree***	***Neutral***	***Disagree***	***Definitely disagree***
S1. As part of a group, I had the opportunity to use and implement VR technology for collaborative product review.	3 15%	12 60%	5 25%	0 0%	0 0%
S2. I now know the difference between CAD packages, AR, VR and MR and their use in product development.	4 22.22%	10 55.56%	3 16.67%	1 5.56%	0 0%
S3. With the completion of the XR tasks, my interest in the subject (CAD) has increased.	3 16.67%	8 44.44%	5 27.78%	1 5.56%	1 5.56%
S4. Do you think that XR technologies should be used in AEC programmes?	2 10.53%	10 52.63%	6 31.58%	1 5.26%	0 0%
S5. Do you think that VR environment can help you to engage more effectively with this module?	3 15.79%	12 63.16%	3 15.79%	1 5.26%	0 0%
S6. I managed to use AR for visualising CAD model over the physical world. It provided a different perspective than a traditional CAD software.	1 5%	10 50%	5 25%	4 20%	0 0%

AR has shown favourable views in other studies [14][31] and the experience reflected in this paper for statement S6 indicates 5% of the students strongly agreed and 50% agreed with the use of AR. But it also shows that 25% remained neutral and 20% who disagreed with the statement. As one student pointed out in their report – "*When it came to testing out the AR part, I was running into weird errors and decided not to pursue after a number of failed attempts choosing to deal with other problematic areas with the software, so I chose to focus on what parts I could salvage.*" An interesting perspective on emotions developed while using AR might offer an insight. An analysis of emotions evoked using AR [32] in education showed that it might generate a negative response usually caused by software or hardware issues; In the reported pilot study in this paper, students were asked to use their own devices. Most of them accessed them through their mobile phones. This task might have overlooked the digital divide [33], as it assumes that students have smartphones or tablets capable of AR applications. It could also be that students were not able to differentiate between the use of AR and VR as one student in their report stated – "*Once again, we are using the augmented reality (AR) Arkio to conduct a full review of the rocker bogie.*" Going forward, the task could be made digitally inclusive using hardware supplied to students during their time in the laboratory by the university.

Statement S1 describes the structure of the assessment; whether it provided the students with an opportunity to collaborate in a virtual environment. Collaboration is key to the implementation of XR in teaching and even in the workplace [6], [10]. It must however be noted that 25% of the students remained neutral. This can be attributed to the hardware and software issue that arose during the presentation including- headset running low on battery power, students susceptible to motion-sickness, headset wi-fi connectivity issues and Arkio environment unable to load. Though some of them can be controlled and avoided, other issues such as motion-sickness excludes the student from the learning experience this was recognised early on and it was vital that the VR environment creation tool such as Arkio was also available as a desktop and mobile version as highlighted by a previous study [10].

A key question in the survey points to whether students were able to differentiate the use of CAD packages, AR and VR applications. 22.22% definitely agreed and 55.56% agreed showing that students were clearly able to identify their respective uses. As we move towards further integration of technologies, there still exists a clear definition of capabilities of each component [23], this can be further highlighted in learning outcomes.

Previous literature support [6], [9], [10], [12]–[14], [16], [29] the inclusion of XR technologies in teaching and in various subjects. These invariable lend support to statements S3 and S4 but further thought must be given to the percentage of neutral responses. Study [30] has shown that 20.4% of students had put down XR as a 'passing phase' but did show an overall positive attitude towards XR in learning and teaching.

The key findings from the pilot study are presented below:

- CAD is traditionally taught as a hands-on approach, but XR technologies provided another layer of insight to this perspective.
- It increased student engagement with the subject and though initially considered a novelty, it did provide a good platform to further instil collaborative skills.
- Though the cost of XR technologies is lowering, it doesn't necessarily translate to a quick uptake of the technology at the student level as there still exists a digital divide. It

should be the onus of the education provider to ensure it is digitally inclusive, for example, providing access to such technologies in dedicated labs.

- training and development of current staff is required to deploy of XR technologies in non-native courses/programmes.

The pilot study has showed that inclusion of XR in non-native HEI programme will have a positive impact on staff and student experience. As the pilot study is based on the Paisley campus of UWS and on a particular program, the authors recognise that there will however be barriers to a university-wide adoption, such as digital inclusivity, staffing and availability of equipment. The pilot study set the example of introducing XR related activities into an Engineering course with negligible changes to overall learning outcomes. But further research is proposed, and any future pilot study must assess the effectiveness and the sustainability of such modules.

As the move towards Industry 4.0 gathers speed and the call for reskilling and upskilling current and future workforce grows, the need for XR technology awareness and use will increase, and the benefits of XR in HEI will be clearly established. This pilot-study provided an excellent frame of reference for further trials within UWS and HEIs as a whole.

Acknowledgment

The authors acknowledge funding from i) the Erasmus+ project eAccess, that is referred by "Project number: 610041-EPP-1-2019-1-PL-EPPKA2-CBHE-JP" funded with support from the European Commission, and ii) Project number: 11150 "Integrated rail freight optimisation in Ukraine: Railway sleepers, rolling stock and logistics", that is funded by Universities UK International (UUKi), UK-Ukraine R&I twinning grants scheme. This publication reflects the views only of the authors, and the Commission and funding body cannot be held responsible or any use which may be made of the information contained therein.

References

[1] M. W. Andrews and A. Di Raimo, 'Extended reality for extending education', Times Higher Education. Accessed: Sep. 27, 2023. [Online]. Available: https://www.timeshighereducation.com/campus/extended-reality-extending-education

[2] E. and I. S. Secretary of State for Business, 'Regulation for the Fourth Industrial Revolution', London, Jun. 2019. Accessed: Sep. 28, 2023. [Online]. Available: https://www.gov.uk/government/publications/regulation-for-the-fourth-industrial-revolution/regulation-for-the-fourth-industrial-revolution#fnref:1

[3] S. Dutta, B. Lanvin, L. Rivera León, and S. Wunsch-Vincent, 'Global Innovation Index 2022: What is the future of innovation-driven growth?', Geneva, 2022. Accessed: Sep. 28, 2023. [Online]. Available: https://www.globalinnovationindex.org/gii-2022-report#

[4] T. Allas, E. Foote, K. Gray, N. Salman, and S. Jones, 'UK Skills Mismatch in 2030', 2019. Accessed: Sep. 28, 2023. [Online]. Available: https://industrialstrategycouncil.org/index.php/uk-skills-mismatch-2030-research-paper

[5] Y. Lu, 'The Current Status and Developing Trends of Industry 4.0: a Review', *Information Systems Frontiers*, Nov. 2021, doi: 10.1007/s10796-021-10221-w.

[6] V. Kuleto *et al.*, 'Extended Reality in Higher Education, a Responsible Innovation Approach for Generation Y and Generation Z', *Sustainability*, vol. 13, no. 21, p. 11814, Oct. 2021, doi: 10.3390/su132111814.

[7] L. Li, 'Reskilling and Upskilling the Future-ready Workforce for Industry 4.0 and Beyond', *Information Systems Frontiers*, Jul. 2022, doi: 10.1007/s10796-022-10308-y.

[8] P. Vichare, M. Cano, K. Dahal, T. Siewierski, and M. Gilardi, 'Incorporating Extended Reality Technology for Delivering Computer Aided Design and Visualisation Modules', in *2022 14th International Conference on Software, Knowledge, Information Management and Applications (SKIMA)*, IEEE, Dec. 2022, pp. 114–119. doi: 10.1109/SKIMA57145.2022.10029398.

[9] P. Guilbaud, T. C. Guilbaud, and D. Jennings, 'Extended Reality, Pedagogy, and Career Readiness: A Review of Literature', 2021, pp. 595–613. doi: 10.1007/978-3-030-77599-5_41.

[10] M. Vasarainen, S. Paavola, and L. Vetoshkina, 'A Systematic Literature Review on Extended Reality: Virtual, Augmented and Mixed Reality in Working Life', *International Journal of Virtual Reality*, vol. 21, no. 2, pp. 1–28, Oct. 2021, doi: 10.20870/IJVR.2021.21.2.4620.

[11] A. Berni and Y. Borgianni, 'Applications of Virtual Reality in Engineering and Product Design: Why, What, How, When and Where', *Electronics (Basel)*, vol. 9, no. 7, p. 1064, Jun. 2020, doi: 10.3390/electronics9071064.

[12] M. Abhari, K. Abhari, M. Drinkwine, and J. Sloan, 'Extended Reality (XR) Applications in Architectural Practice: Towards a Development Framework', 2021, pp. 185–196. doi: 10.1007/978-3-030-90963-5_15.

[13] J. W. Lai and K. H. Cheong, 'Adoption of Virtual and Augmented Reality for Mathematics Education: A Scoping Review', *IEEE Access*, vol. 10, pp. 13693–13703, 2022, doi: 10.1109/ACCESS.2022.3145991.

[14] O. Yilmaz, 'Augmented Reality in Science Education: An Application in Higher Education', *Shanlax International Journal of Education*, vol. 9, no. 3, pp. 136–148, Jun. 2021, doi: 10.34293/education.v9i3.3907.

[15] P. P. Nechypurenko *et al.*, 'Development and implementation of educational resources in chemistry with elements of augmented reality', Kryvyi Rih, Feb. 2020. doi: 10.31812/123456789/3751.

[16] V. R. Curran, X. Xu, M. Y. Aydin, and O. Meruvia-Pastor, 'Use of Extended Reality in Medical Education: An Integrative Review', *Med Sci Educ*, vol. 33, no. 1, pp. 275–286, Dec. 2022, doi: 10.1007/s40670-022-01698-4.

[17] A. Dengel, M. Z. Iqbal, S. Grafe, and E. Mangina, 'A Review on Augmented Reality Authoring Toolkits for Education', *Front Virtual Real*, vol. 3, Apr. 2022, doi: 10.3389/frvir.2022.798032.

[18] J. P. Doran and V. L. Uskov, 'Smart Pedagogy: An Extended Reality (XR) Based Approach', 2022, pp. 40–51. doi: 10.1007/978-981-19-3112-3_4.

[19] M. Meccawy, 'Teachers' prospective attitudes towards the adoption of extended reality technologies in the classroom: interests and concerns', *Smart Learning Environments*, vol. 10, no. 1, p. 36, Jul. 2023, doi: 10.1186/s40561-023-00256-8.

[20] Universities and Colleges Admissions Service, 'UCAS'. Accessed: Oct. 06, 2023. [Online]. Available: https://www.ucas.com/

[21] M. Lorenz, M. Spranger, T. Riedel, F. Pürzel, V. Wittstock, and P. Klimant, 'CAD to VR – A Methodology for the Automated Conversion of Kinematic CAD Models to Virtual Reality', *Procedia CIRP*, vol. 41, pp. 358–363, 2016, doi: 10.1016/j.procir.2015.12.115.

[22] J. Hurtado, A. Montenegro, M. Gattass, F. Carvalho, and A. Raposo, 'Enveloping CAD models for visualization and interaction in XR applications', *Eng Comput*, vol. 38, no. 1, pp. 781–799, Feb. 2022, doi: 10.1007/s00366-020-01040-9.

[23] B. Regassa Hunde and A. Debebe Woldeyohannes, 'Future prospects of computer-aided design (CAD) – A review from the perspective of artificial intelligence (AI), extended reality, and 3D printing', *Results in Engineering*, vol. 14, p. 100478, Jun. 2022, doi: 10.1016/j.rineng.2022.100478.

[24] M. Lorenz, M. Spranger, T. Riedel, F. Pürzel, V. Wittstock, and P. Klimant, 'CAD to VR – A Methodology for the Automated Conversion of Kinematic CAD Models to Virtual Reality', *Procedia CIRP*, vol. 41, pp. 358–363, 2016, doi: 10.1016/j.procir.2015.12.115.

[25] J. Whyte, N. Bouchlaghem, A. Thorpe, and R. McCaffer, 'From CAD to virtual reality: modelling approaches, data exchange and interactive 3D building design tools', *Autom Constr*, vol. 10, no. 1, pp. 43–55, Nov. 2000, doi: 10.1016/S0926-5805(99)00012-6.

[26] E. T. L. Corseuil, A. B. Raposo, R. J. M. da Silva, M. H. G. Pinto, G. N. Wagner, and M. Gattass, 'ENVIRON: Visualization of CAD Models In a Virtual Reality Environment', in *Tenth Eurographics conference on Virtual Environments*, Jun. 2004.

[27] P. Vichare, X. Zhang, V. Dhokia, W. M. Cheung, W. Xiao, and L. Zheng, ‘Computer numerical control machine tool information reusability within virtual machining systems’, *Proc Inst Mech Eng B J Eng Manuf*, vol. 232, no. 4, pp. 593–604, Mar. 2018, doi: 10.1177/0954405417708219.

[28] Y. Xing, Z. Liang, J. Shell, C. Fahy, K. Guan, and B. Liu, ‘Historical Data Trend Analysis in Extended Reality Education Field’, in *2021 IEEE 7th International Conference on Virtual Reality (ICVR)*, IEEE, May 2021, pp. 434–440. doi: 10.1109/ICVR51878.2021.9483828.

[29] G. Baxter and T. Hainey, ‘Student perceptions of virtual reality use in higher education’, *Journal of Applied Research in Higher Education*, vol. 12, no. 3, pp. 413–424, Apr. 2019, doi: 10.1108/JARHE-06-2018-0106.

[30] M. G. Kluge, S. Maltby, A. Keynes, E. Nalivaiko, D. J. R. Evans, and F. R. Walker, ‘Current State and General Perceptions of the Use of Extended Reality (XR) Technology at the University of Newcastle: Interviews and Surveys From Staff and Students’, *Sage Open*, vol. 12, no. 2, p. 215824402210933, Apr. 2022, doi: 10.1177/21582440221093348.

[31] A. M. Al-Ansi, M. Jaboob, A. Garad, and A. Al-Ansi, ‘Analyzing augmented reality (AR) and virtual reality (VR) recent development in education’, *Social Sciences & Humanities Open*, vol. 8, no. 1, p. 100532, 2023, doi: 10.1016/j.ssaho.2023.100532.

[32] M. D. Gómez-Rios, M. Paredes-Velasco, R. D. Hernández-Beleño, and J. A. Fuentes-Pinargote, ‘Analysis of emotions in the use of augmented reality technologies in education: A systematic review’, *Computer Applications in Engineering Education*, vol. 31, no. 1, pp. 216–234, Jan. 2023, doi: 10.1002/cae.22593.

[33] P. Serafino, ‘Exploring the UK’s digital divide’, London, Mar. 2019.