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Smartphone-based augmented reality avatars to improve secondary students course engagement

Conor Macklin, Esperanza Johnson

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Abstract
Education has suffered an unprecedented disruption due to the COVID-19 pandemic, impacting the provision of in-person education at all levels worldwide with temporary suspension or limited in-person sessions and the increased use of remote classes. These atypical learning conditions can have potentially harmful effects on students who require more guidance and benefit more from in-person interaction with teachers and other students. This paper presents the design of a solution that uses smartphone-based Augmented Reality (AR) avatars of teachers to improve students' engagement. The approach presented has been designed considering the feedback from teachers and students of Secondary level in Northern Ireland. As most students in developed and developing countries own and regularly use smartphones, we consider that the proposed solution would benefit students in Mexico and other countries.

Keywords:
Augmented Reality; Avatars; Education Technology; Co-Design; User Involvement.

1 Introduction
The World Health Organisation (WHO) declared the COVID-19 coronavirus outbreak to be a global pandemic on the 12th of March 2020, labelling it as "*Public enemy number one*" [1]. Within one-week, national school closures had been enforced in over 107 countries worldwide, including those in Northern Ireland (UK) [2]. This severe and unprecedented decision was deemed necessary to protect people's health and curb the spread of the virus. Governments and education authorities were tasked with the urgent decision on maintaining a certain level of education using online services. Many teachers had to adapt their resource work and deliver their syllabus using virtual methods leading to the increased use of remote classes using video conferencing technologies. Exams have been cancelled and predicted grades calculated. Interaction between classmates and teachers has been limited or non-existent for long periods. It has led not only to the deterioration of what may have been a pivotal year in an adolescent's life but also the stagnation of many teenagers' motivation, self-esteem, confidence, and social development [3]. Due to the unpredictability of COVID-19, it is difficult to say that issues such as spells of absences, disparity in keeping up with work and other issues will not happen again [4]. The need for innovative creation towards student/teacher collaboration is paramount for alignment to be achieved.

Remote classes have some advantages, such as not having to commute to school, providing an alternative way of learning, and making the most of the current technology available (Internet, laptops, smartphones, etc.). However, these atypical learning conditions might have mostly negatively affected students that require more guidance and that benefit more from in-person interaction with teachers and with other students. In that sense, Higher education students are generally more proactive, and thus, have self-directed learning compared to Primary and Secondary students, requiring more guidance and regular interactions with their peers and teachers.

Remote learning has been typically carried out by using video conferencing technologies aimed at general purposes (e.g., Skype, Zoom) or dedicated to remote learning (e.g., Blackboard), with many of these technologies having updates during the COVID-19 pandemic to improve the user interactions and engagement during video calls [5]. However, these improvements have not translated into a better learning experience, with remote interactions and engagement reduced when students turn off their cameras during video calls, or do not actively answer questions posted by teachers in chats or polls within the remote learning platforms.

This paper focuses on the research question "How has remote learning impacted students' academic engagement from secondary education?". The proposal is driven by the User-Centric Design Framework [6] and presents the design of a solution that uses smartphone-based AR avatars of teachers to improve the engagement of students.

The remainder of the paper is organised as follows. Section 2 presents the related work on the use of augmented reality avatars in an educational context. Section 3 describes the participants that supported this study. Section 4 presents a design of the proposed solution based on the objectives and on the functional requirements identified by the participants. Section 5 describes an initial prototype of the proposed solution. Evaluation and results are presented in Section 6. Finally, Section 7 presents conclusions and future work.

Macklin, Conor, Johnson, Esperanza.
Ulster University
Jordanstown, United Kingdom.
macklin-c@ulster.ac.uk, Johnson_Ruiz-ME@ulster.ac.uk

2 Related Work

The use of technological means to improve the engagement of students in different levels of education has been widely investigated.

The Jill Watson virtual teaching assistant, launched in 2016, aimed to assist Massively Open Online Courses (MOOCs) to automate responses to questions posed by students with Goel and Polepeddi[7] concluding Jill Watson as a positive experiment in human-AI teaching collaboration.

Latest research in the context of education has focused on emerging technologies such as Virtual Reality (VR) [8] and AR [9], which have been typically used to present educational content in a more immersive way to students to enhance learning [10]. While VR can provide more immersive experiences than AR, it requires additional equipment (headset), whereas to use AR it is sufficient with just a smartphone.

In recent years, the widespread use of smartphones has allowed novel applications that have popularised the use of AR, such as the game phenomenon Pokémon Go [11]. Criollo-C *et al.* [12] investigated the use of a mobile application with AR to support a new learning experience in engineering education, with usability issues possibly impacting the effectiveness of learning and the students' motivation.

In [13] the impact, practices, and attitudes of 87 trainee primary teachers regarding the use of AR in higher education are evaluated. Reported results mention that students positively valued the use of AR for their training, as well as improvements in creativity, collaboration, communication, and motivation.

The use of avatars as more personal interaction with students has also been investigated in the literature. Fridhi and Bali [14] presented a study about the interaction of students with avatars modelled in AR within an educational context and concludes that the implementation of AR supports students in their learning, increases their motivation and facilitates the teacher's role.

From the related work investigated and to our best knowledge, the use of smartphone-based AR avatars to support the engagement of students has not been widely addressed, hence the novelty and relevance of the presented approach.

3 Participants

A total of six participants from different schools took part in this study. Four took part in the data gathering; two teachers, aged 45 and 47, both male and teaching for an average of 22 years, and two 16-year-old students, one male and one female who were due to partake in GCSE exams. Whilst another two 16-year-old students, one male, one female took part in the evaluation of the study. We aimed at selecting participants who were due to either sit exams, or prepare students for said exams, during the pandemic, in order to identify key concerns from teachers and students at this stage. Therefore, this study evaluates concerns when attempting to deliver the curriculum to students through remote, in-class, and hybrid-learning situations.

Participants took part in an individual semi-guided interview lasting around twenty minutes each via video call (skype, Microsoft teams) with the goal of understanding and overcoming key deficiencies that surround pandemic education. They were each asked to draw upon experiences faced throughout the pandemic and how teaching/learning has been affected, both remote and back in class post-lockdown. Questions focusing on areas such as grades and attendance, practical studies, and overall engagement prompted vast discussion and insight into how daily life has been impacted by COVID-19 for peak Secondary education.

Each interview was transcribed and verified by a member of the research team. Each interviewee read an information sheet explaining in detail the purpose of the study and how their data would be used. They understood that all information was to remain strictly anonymous before signing a consent form to take part in the research. The data from the transcripts was then gathered in an affinity diagram [15]. The diagram consisted of eight key-areas of concern with quotes raised by the participants supporting each observation. This allows for analysis to reflect upon which areas raised most concern amongst all participants for which focus can be prioritised for an innovative solution.

4 Design of Solution

After analysis gained from the participants' interviews, we focused on how a user-centred design may help combat the key areas of concern that were expressed across all parties.

Participants were asked approximately twelve questions each in a semi-structured interview that included topics such as: What the experience was like during teaching or studying remotely and how things have changed since returning to class. Also, we asked how practical subjects were affected because of COVID-19 and if they had perceived any limitation to the software and technological equipment needed to carry out work while teaching or studying from home. The main issues consisted of **communication** problems which gave rise to over **16%** of the overall issues raised and cited in the affinity diagram, followed by **motivation**, and **engagement** issues responsible for **11%** and **10%** of concerns raised respectively. This allowed for a targeted approach for a design solution based on user-led information.

4.1 Findings

The use of email system appeared to be a difficult concept for some students at that age who didn't appear to be comfortable with the lack of immediate feedback and the reassurance gained from verbal communication when it came to the explanation of topics, raising concerns such as:

S1: *"Trying to email them yeah. It would be better if you said to them in person so they could help you a bit more and explain it better."*

With over twenty students in each class, and class groups changing every 40 minutes, a teacher may have to cater for over one hundred and sixty students each day with the requirement to reply to emails to remote learning students, teach in-class, or both.

T2: *"Obviously, the difficulty with that was receiving feedback from pupils. You were receiving maybe four/five/six emails, the kids weren't always clear with the instructions"*
S1: *"They (teachers) didn't get back to you as quick or they didn't explain stuff as well as they could of when they were in the classroom. So yeah, it was a bit difficult."*
S2: *"You didn't really know how to do it as the teachers all have different classes. Trying to get a reply from teachers over the lockdown period was quite difficult."*

Communication issues, coupled with isolation due to prolonged absence may have provoked further issues regarding motivation and engagement, particularly among the student participants. One participant stated that:

T1: *"The curriculum was being delivered; it certainly wasn't being absorbed by the students to the same affect that it would be through in-house teaching"*

S1: *"Sometimes they didn't see the text that you wrote in if you had a question because they weren't really looking at it because they were trying to teach."*

All participants cited engagement and interaction as the main key issues that suffered a decline because of the pandemic. Teachers and students both found that questions and answers were best delivered in person.

S2: *"Not being in the classroom and having that one-to-one with the teacher was very difficult, it was hard to ask for help when you were stuck on a certain part of the work."*
S2: *"Yeah, communication over the two periods (remote learning) wasn't great. From both sides."*
T2: *"Their engagement level wasn't always great during lockdown, whether that was technological issues, whether it was just that they didn't want to engage."*
S2: *"Something that makes it easier to communicate with the teacher."*

Based on this analysis, the solution to address communication and engagement issues is aimed at designing a method for which a student and teacher can communicate better whilst remote learning. The design will be to create a mobile app that uses smartphone-based AR avatars that students can interact with and ask questions while also receiving immediate feedback while studying from home. The aim is to alleviate some of the anxiety and stress faced while reaching out to teachers via email and feel stuck waiting on a reply. Teachers can also benefit through less time spent repeating explanations on the same topics while also feeling content that students are staying up to date with the syllabus.

4.2 Desk Buddy: An AR-based Solution for Remote Learning

We aim to design a mobile application named Desk Buddy, an app that will help students to engage by communicating with in-app avatar characters that each specialises in topics covered in the syllabus. The proposed approach is in the form of a mobile app that students will use by pointing the camera to a surface to show the teacher avatar. The student will then verbally ask the problem in plain English speech, and the teacher avatar will provide an answer in speech and in-text retrieved from an existing knowledge base of commonly asked questions.

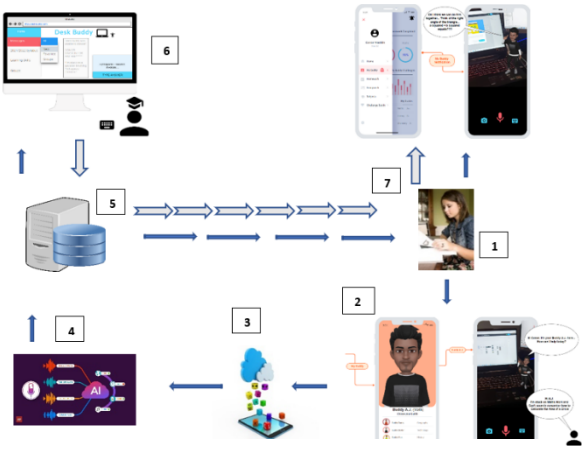

Figure 1 Architecture for User-Centered Design

Figure 1 demonstrates the system architecture for the user design, illustrating that while studying remotely, a student encounters a problem that they may need help ordinarily from a teacher (**1**). The user will point the app at any surface, and an avatar will appear on the screen and ask the user how it can help (**2**). Using technologies such as Natural Language Processing (NLP) and Machine Learning (ML), the app will retrieve the question from the student in plain English (**3**). The app will convert speech to text and retrieve answers to the questions along with hints and clues based on machine learning models trained on similar questions or information (**4**). The app will have a knowledge base stored on a Cloud-based server that will contain answers to wide-ranging topics covered on the students' syllabus (**5**). The student will then receive a notification once the answer has been updated and engagement with the avatar will recommence (**7**). If, however, the question asked is not yet stored in the knowledge base, an email is instantly generated and sent to the teacher (**6**). The teacher will then answer the question on the Desk Buddy web application at a time of convenience and will be stored on the knowledge base for reusable content. The student will receive a notification on the Desk Buddy mobile app once the question has been updated by the teacher and the avatar will appear again to discuss the answer (**7**). If the AI design knows the answer to the question posed by the student, it will aim to engage and motivate the student giving clues and encouragement rather than giving out the answer straight away.

5 Prototyping & Engagement with Deskbuddy

The Desk Buddy mobile app design principles will target the needs of Secondary school students, using recognisable icons and menu system that are commonly found in most mobile apps used today. The user sign-in screen will contain the Desk Buddy logo along with a username and password and a biometric sign-in option. After signing in, the user will operate from a home screen with a menu tab to the top left. From this menu the user will select the My Buddy section, where the user will be able to select an avatar based on their subject. The avatars used for this prototype were obtained from AR Zone mobile app found on the latest Samsung smartphones. Each character will have a name, and they will know the users name after sign-up. Once the avatar has been selected, the user then points their smartphone to a surface and communication between user and avatar can commence This process should address key engagement issues raised, encouraging students to interact with their favoured device in their smartphone, as opposed to emails and desktops.

The research gathered from the participants in this study found communicating verbally to be a more efficient and comfortable means for students, as opposed to typing. One scenario may be that a student is stuck on a math's question and asks the avatar for help. The student explains the issue verbally, and the (NLP) converts the speech to text which is then passed through an (ML) algorithm, and the solution is retrieved from a knowledgebase. If the AI knows the answer to the problem, it will retrieve clues and trigger-words related to the question to motivate and encourage self-thought in the student, challenging them to reflect on previous knowledge of the topic. It is hoped that this approach will help with motivation issues discussed, encouraging students to think for themselves, meaning higher morale and improved confidence levels.

On the side of the teacher, and in order to address issues caused by redundant or repetitive email responses, or explanations that were drawn-out compared to in-person, the Desk Buddy app aims to reduce this problem by producing reusable information for a student to access and that a teacher can update much less often than replying to multiple emails seeking an answer to a similar question.

At the beginning of each semester, a knowledge base will be created/updated based on the syllabus to be delivered in the year ahead that will include corresponding hints and clues to each topic.

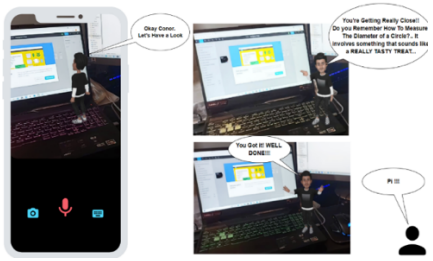

Figure 2 Avatar challenges student to use self-thought

6 Evaluation and Results

We evaluated the app using a Systematic Usability Scale (SUS) [16] with a focus group of two students aged 16, one male, one female. Using a scale of 1 for strongly disagree and 5 for strongly agree, we asked the user the following 10 questions: **1**.I think that I would like to use this system frequently. **2**.I found the system unnecessarily complex. **3**.I thought the system was easy to use. **4**.I think that I would need support of a technical person to be able to use this system. **5**.I found the various functions in this system were well integrated. **6**.I thought there was too much inconsistency in this system. **7**.I would imagine that most people would learn to use this system very quickly. **8**.I found the system very cumbersome to use. **9**.I felt very confident using the system. **10**.I needed to learn a lot of things before I could get going with this system. Group 1 scored the questions as follows: **4,1,4,2,5,1,5,1,5,2**, with Group 2 scoring **5,1,5,3,4,2,5,1,4,1**., and general positive feedback for most questions.

P1: *"I would use it instead of annoying my teacher."*
P2: *"It would be good if I was stuck instead of using Google."*
P1: *"I like the idea of talking. I think I can explain things better when I talk instead of writing."*

7 Conclusion

Technology has continually provided solutions to the needs of human-centred problems through innovative design based on data-led insight. The COVID-19 pandemic created unprecedented disruption to everyday human life. Immediate action was required to address the issues within the education sector to maintain an adequate learning platform for students of all ages. Many younger students struggled with the solution of remote learning via internet-based solutions. This study is aimed at addressing the user needs for students and teaching staff of Secondary school education, particularly those who were preparing for mandatory exams. The study found students who struggled with issues surrounding communication and engagement, and preferred verbal communication, whilst teaching staff encountered an exorbitant workload because of delivering online studies and replying to students via email with repetitive questions being asked. The user-designed app created from this study aims to address these key findings by reusing questions a teacher has already given and allowing students to interact verbally with a light-hearted and augmented reality application.

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