independent schools council

Digital Strategy Group

GROWTH HEADSET?

Exploring the use of Virtual Reality and Augmented Reality in Schools

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Re thinking education

evidence-informed school improvement and impact evaluation

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James is an education researcher and consultant who worked as a Science teacher for 12 years, and spent 8 years in school leadership roles. He is a founding Director of Rethinking Education, specialists in research-informed school improvement, professional development and impact evaluation.

James works as a Bespoke Programmes Leader at the London Centre for Leadership in Learning at the University College London Institute of Education. In this role, he works with teachers and schools throughout the UK to promote research-informed approaches to professional development and school improvement. James is also an Associate of Oracy Cambridge, a study centre dedicated to promoting effective speaking and listening in schools and the wider society.

James holds an MA in Person-centred Education from the University of Sussex, and a PhD in Learning to Learn from the University of Cambridge. James's doctoral thesis is an evaluation of *Learning Skills*, a whole-school approach to teaching and learning centred around metacognition, self-regulation and oracy. This 8-year mixed methods case study found that *Learning Skills* led to significant gains in subject learning, with accelerated gains among students from disadvantaged backgrounds. James can be contacted at james@rethinking-ed.org.

Rethinking Education (@Rethinking_Ed)

Rethinking Education are specialists in research-informed school improvement, professional development and impact evaluation. Their annual school improvement programmes include

- ***Learning Skills***: a whole-school, research-informed approach to teaching and learning, rooted in metacognition, self-regulation and oracy;
- ***Research into Action***: a systematic approach to professional development through engaging *with* and *in* research;
- ***Implementing School Improvement:*** a common-sense framework for improving school outcomes, rooted in the principles of implementation science.

Rethinking Education also carry out independent research reports and impact evaluations, such as this one-year study exploring the use of Virtual Reality and Augmented Reality in schools. For more information, visit rethinking-ed.org or email enquiries@rethinking-ed.org.

ISC Digital (@ISC_Digital)

The Independent Schools Council (ISC) Digital Strategy Group was set up in 2007, and is composed of experts and representatives drawn from various ISC member associations and schools. ISC Digital provides independent advice to Senior Leadership Teams

on a range of technology-related issues, through the publication of briefing papers and through its annual winter conference. For more information, visit iscdigital.co.uk.

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Foreword, by Mark Steed (@independenthead)

Each time a new technology has been launched, it seems that it is only a matter of days before teachers have found ways to harness its power in the service of education. Over the past twenty years, videos, DVDs, classroom projectors, interactive whiteboards, 3D projectors and computer games have been recruited to further improve the learning experience of their pupils. Now teachers can add Virtual/Augmented Reality (VR/AR) technologies to their armoury.

VR/AR technologies are still in their infancy but there are already signs that this is a much more powerful technology than their more passive predecessors. The lessons from the pioneers are that VR/AR are not just another way of conveying information, but there is something distinctively powerful about the fact that the viewer is in control. This makes the experience active and so immersive that they evoke an emotional as well as a rational response.

We know that each invention that is deployed in schools requires the development of an effective pedagogy which enables teachers to get the most out of the new technology. This, in turn, poses several important questions about the value and effectiveness of the new technology in promoting learning, understanding, empathy and in improving learning outcomes. With the luxury of hindsight, too many schools deployed new technologies without really knowing what they were doing or why they were doing it. History teaches us that effective implementation is facilitated by twin drivers of collaboration and research. This project launched by the Independent Schools Council Digital Strategy Group needs to be seen in this context.

I am in no doubt there is great potential for the use of AR and VR to enrich learning, to deepen understanding and, perhaps above all, to develop empathy. In order to harness the power of any new technology, schools need to go through four stages of adoption. Firstly, we might simply play, to get a sense of how the technology works and what it can do. Then, we start to experiment in educational contexts to find out how VR/AR might enhance learning. It's only once we've been through these initial phases of investigation, experimentation and research that we can move to the innovation stage where we start to design new learning experiences that can truly harness the power of the technology.

Finally, there I believe that AR/VR has the potential to be a disruptor of education by being a vehicle for new model for schooling
One thing is clear: in 2018, the time has come for more schools to start experimenting with VR/AR, conducting research and gathering evidence to help us understand how to develop the pedagogy to make the best use the

technology. Furthermore, we need to develop policies and protocols to disseminate best practice to other schools. Thus, the Growth Headset report is timely. It provides some initial insight into how VR/AR might be deployed in schools and seeks to answer some of the important questions about the place that Virtual Reality and Augmented Reality might play in schools over the coming years.

Mark S Steed is the Director of JESS, Dubai, and has been appointed the Principal and CEO of Kellett, Hong Kong, from September 2019. He chaired the ISC Digital Strategy Group from 2008-15. @JESS_Director and @Kellett_CEO

Executive summary

In November 2017, a research project was launched at the annual conference of the Independent Schools Council (ISC) Digital Strategy Group, to explore the use of Virtual Reality (VR) and Augmented Reality (AR) technology in schools. VR and AR headsets were loaned to seven schools during the Spring term 2018. Students and teachers competed a pre and post-intervention survey, and a sample of students and teachers from each school were interviewed. In total, the data collection comprised 132 student surveys, 32 student interviews, 18 teacher surveys and 9 teacher interviews. This report summarises the key findings of this case study. Much of the value of this report lies in reading the comments of students and teachers in the thematic analysis of interview data. However, the key findings of the study were as follows:

- Taking part in the study increased the amount of interest in using VR/AR in schools among both students and teachers. Prior to the study, 86% of students were 'very' or 'somewhat' interested in using VR/AR in schools, compared with 95% after the study. Similarly, 66.7% of teachers were 'very' or 'somewhat' interested in using VR/AR in schools prior to the study, compared with 83.3% after the study.

- Students' attitudes toward using VR/AR as a tool for learning also changed following the study period. When asked which words best describe their attitude towards using VR/AR in school, prior to the study 85.5% of students replied that they were either enthusiastic or curious, and 12% replied that they were sceptical. After the study period, 97.7% of students replied that they were either enthusiastic or curious, and only 2.2% replied that they remained sceptical.

- Students overwhelmingly found using VR/AR to be a positive experience; when asked to share their positive and negative experiences of using VR/AR in school, 77.8% of the comments were positive.

- Prior to the study, when asked 'how useful do you think VR/AR might be in terms of helping you with your learning?', 91.3% of students responded 'very' or 'somewhat'. The majority of reasons given were that VR/AR enables students to visualise things, or to see them in 3-D.

- The most common theme to emerge from both the student and teacher interviews was how VR/AR technology can be used to facilitate learning. Within this theme, the most common comments related to the role of visualisation in learning; the link between seeing things in 3-D and understanding; immersive learning and the nature of immersive learning environments; the ability to interact with one's learning environment; and the interplay between these ideas (visualisation, 3-D, immersion, interactivity) and memory. There was a common belief that immersive and interactive learning environments are more memorable, compared with using textbooks.

- Students and teachers also identified the value of VR/AR technology in terms of non-cognitive outcomes such as empathy, careers, and seeing the world or going on virtual field trips.

- When asked how VR/AR technology can be used to facilitate learning, students and teachers often cited subjects deemed to be 'more visual' such as the Geography, History, Science and Art. There was a common belief that VR/AR could not be used to facilitate learning in other subjects such as English and Maths.

- Several students and teachers expressed a sense of "healthy scepticism" with regard to the use of VR/AR as a tool for learning. Concerns included logistical issues with regard to using current VR/AR technology in the classroom; the cost of equipment; a sense that VR/AR technology has a limited lifespan, and soon becomes obsolete; and health and safety concerns about feeling dizzy, or the need to physically supervise someone who is immersed in a virtual environment. Several teachers expressed the idea that pedagogy and relationships are of critical importance to the success of any use of technology in the classroom.

- There was a clear sense that at this point in time, it is difficult for schools to determine the extent to which VR/AR impacts on learning using quantitative data such as exam results as the outcome variable. However, the majority of students and teachers were able to share examples practice where they felt using VR/AR had had a positive impact on learning, or where can have a positive impact on learning in the future.

- Students and teachers expressed a range of views on the relative merits of AR and VR. On the one hand, there was a sense that AR might lend itself more to the classroom because it allows students and teachers to interact and collaborate. However, a majority of respondents felt that VR holds more potential as a tool for learning because it is immersive, and because it enables the user to experience things on a large scale.

- There was a strong belief among students and teachers that VR/AR technology is still in an early stage of development, and that the technology holds the potential to become a powerful educational tool in future. However, there was an equally strong belief that much more needs to be done in terms of developing software that is relevant to the curriculum.

- Several teachers highlighted the need for tech companies to consult more with teachers, and for software to be designed with the curriculum in mind rather than retro-fitting existing applications to the classroom. To improve communication between tech companies and the teaching profession, one teacher highlighted the need for "training industry in how to deal with schools and training teachers in how to deal with industry".

Introduction

In November 2017, a research project was launched at the annual conference of the Independent Schools Council (ISC) Digital Strategy Group, to explore the use of Virtual Reality (VR) and Augmented Reality (AR) technology in schools. VR and AR headsets were loaned to seven schools during the Spring term 2018. Students and teachers competed a pre and post-intervention survey, and a sample of students and teachers from each school were interviewed. Two teachers with experience of using VR/AR in schools, but whose schools were not involved in the study, were also interviewed. This report summarises the key findings of this one-year case study.

Defining VR and AR

The term Virtual Reality was coined in 1987 by Jaron Lanier, the US computer scientist. VR has been described as "an artificial, computer-generated simulation or recreation of a real-life environment or situation. It immerses the user by making them feel like they are experiencing the simulated reality first-hand, primarily by stimulating their vision and hearing". [1]

The term Augmented Reality was coined by the former Boeing researcher Thomas Caudell in 1990. [2] Unlike VR, where the user is immersed in an artificial environment, AR technology "offers a real-time view of one's immediate surroundings altered or enhanced by computer generated information. When users examine their environment through AR devices, they see information superimposed on the objects around them". [3] AR "blends digital components into the real world in such a way that they enhance one another, but can also be told apart easily". [4]

Participating schools and interviewees

In total, seven schools took part in this study from throughout the UK. These were: Bedales School, Hampshire; Godolphin and Latymer School, London; Haberdashers' Aske's Boys' School, London; Rendcomb College, Gloucestershire; Royal Grammar School, Newcastle upon Tyne; Sevenoaks Prep School, Kent; St. Helen and St. Katharine, Oxfordshire. The extent to which each school completed surveys and interviews is summarised in Table 1. To preserve the anonymity of respondents, the schools are referred to by the letters A to G.

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[1] augment.com/blog/virtual-reality-vs-augmented-reality/
[2] Lee, K. (2012) Augmented Reality in Education and Training. *TechTrends*, 56 (2), p13.
[3] http://lexicon.ft.com/Term?term=augmented-reality
[4] https://www.augment.com/blog/virtual-reality-vs-augmented-reality/

Table 1. Participating schools: survey and interview completion

School	Survey pre		Survey post		Interviews post	
	Student	Teacher	Student	Teacher	Student	Teacher
A	4	1	5	3	0	0
B	0	0	0	0	12	0
C	12	8	9	3	6	3
D	0	1	0	0	0	0
E	57	0	0	0	4	1
F	0	0	23	0	6	2
G	19	2	3	0	4	3
Total	92	12	40	6	32	9

The vast majority of the students and teachers who took part in this study had limited experience with using VR and AR technology, and the surveys and interviews were primarily designed to capture their initial responses upon the equipment for the first time. To add greater depth to the study, two teachers with experience in the use of VR and AR in other schools were also interviewed; Graeme Lawrie, Director of Outreach and Innovation at Sevenoaks School in Kent, and Steve Bambury, Head of Digital Learning and Innovation at JESS Dubai.

Participant demographics are summarised in Table 2. Of the 132 students who completed the survey, 36% were female and 64% were male, since one of the participating schools with a high return rate was a boys' school. Of the 32 student interviewees, 47% were female and 53% were male. Of the 27 teachers who either completed the survey, took part in an interview or both, 59% were female and 41% were male. Six of the seven schools were secondary, and one was a prep school; two of the nine teachers to be interviewed were from the prep school.

Table 2. Participant demographics

n (%)		Surveys		Interviews	
		Student	Teacher	Student	Teacher
Female		47 (35.6)	12 (66.7)	15 (46.9)	4 (44.5)
Male		85 (64.4)	6 (33.3)	17 (53.1)	5 (55.5)
Year group	**7**	35 (26.5)	-	12 (37.5)	-
	8	0 (0.0)	-	0 (0.0)	-
	9	26 (19.7)	-	16 (0.5)	-
	10	53 (40.1)	-	3 (9.4)	-
	11	5 (3.8)	-	0 (0.0)	-
	12	12 (9.1)	-	0 (0.0)	-
	13	1 (0.8)	-	1 (3.1)	-
Total		132	18	32	9

The teachers who took part in this study had been teaching for between 4 and 31 years. The average length of time for which a teacher had been in the profession was 12.4 years.

Methodology

At the annual conference of the ISC Digital Strategy Group in November 2017, attending schools were invited to take part in a study to explore the use of VR and AR in educational settings, to be carried out during the Spring and Summer terms in 2018. Following the conference, seven schools volunteered to be part of the study. Two of the schools already had VR or AR headsets that they were able to use for the purposes of the study; for the remaining five schools, equipment was loaned on a short-term basis, at no charge to the schools.

In early Spring 2018, a pre-intervention student and teacher survey was administered online. Following this, schools experimented with the VR or AR technology. The hardware used varied from school to school: some used the HP Mixed Reality headset, others used the HTC Vive. The software used also varied from school to school: programmes used included Google Tilt Brush (a 3-D art studio), [5] Google Expeditions, [6] Google Earth, [7] a tour of the International Space Station, [8] BBC Home – A VR Spacewalk, [9] YOU by Sharecare (a simulation of the inside of the human body), [10] and Richie's Plank Experience. [11] As a consequence of this variation in hardware and software, the nature of how the technology was used also varied from school to school. While some schools used it in timetabled lessons, others ran sessions with small groups of "digital leaders" outside of lessons, at lunchtime or after school.

Following a period of trialling the technology over several weeks, in the Summer term 2018 a post-intervention student and teacher survey was administered online. School visits were also arranged for the student and teacher interviews, all of which were conducted face-to-face. The majority of student interviews were individual, with a small number in groups of two, three or four. The interviews with Graeme Lawrie and Steve Bambury were each conducted over the phone in the Summer 2018. Because the nature of the experimentation varied from school to school, and because the VR experience of participants varied significantly, all interviews were semi-structured, to enable any interesting lines of conversation to be pursued. Copies of the survey and interview schedules are available upon request.

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[5] tiltbrush.com
[6] edu.google.com/expeditions
[7] earth.google.com
[8] store.steampowered.com/app/797200/International_Space_Station_Tour_VR/
[9] bbc.co.uk/taster/pilots/home-a-vr-spacewalk
[10] sharecare.com/static/YOU
[11] https://store.steampowered.com/app/517160/Richies_Plank_Experience/

Data analysis

Interviews

Student and teacher interviews were transcribed in full and combined into a single text corpus. In total, the teacher text corpus comprised 46,061 words and the student text corpus comprised 17,743 words. Each text corpus was then subjected to inductive thematic analysis, following the six-step procedure set out by Braun and Clarke (2006): 1) familiarisation with the data; 2) coding; 3) searching for themes; 4) reviewing themes; 5) defining and naming themes; and 6) writing up. [12]

Although there was some overlap in the content of the student and teacher interviews, the findings from the student and teacher interviews are presented separately, since there were also key differences between the two data sets. In each case, the themes are presented in order of frequency, from the most common theme to the least; within each theme, the codes are again presented in order from the most common to the least. For each code, excerpts from the interviews are provided to give a sense of the range of views expressed, while seeking to minimise repetition.

Surveys

The surveys comprised a combination of multiple-choice and long-answer questions. Where questions were repeated in the pre and post-intervention surveys, a comparison of the data is provided. To analyse the long-answer questions, responses were grouped into key themes using the inductive thematic analysis approach. These are presented as a percentage of total responses to the question. In total, the text corpus of long-answer questions from the student and teacher surveys comprised over 10,000 words.

Limitations

There are a number of limitations that should be borne in mind when considering the findings of a small case study. This study involved a relatively small number of students from seven fee-paying independent schools. As such, the schools in this study are unlikely to be representative of the wider school population.

[12] Braun, V., Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*. 3 (2): 28. doi:10.1191/1478088706qp063oa.

In each school, the students chosen to take part in the trial were selected by their teachers, having previously expressed an interest in technology. For example, in two of the schools, the students interviewed were "digital leaders" who have an existing role in exploring uses of technology in educational settings. As a consequence, the views of students involved in the study may not be representative of their wider school population. In addition, because the post-intervention survey was administered at a busy time of year, the return rate was only around half of the pre-intervention survey, limiting the validity of any pre and post-intervention comparisons.

There are a number of limitations associated with the use of semi-structured interviews as a method of data collection, since this approach introduces some variation in the way the questions were phrased from one interview to the next, and in the content of the questions. While this approach helps maintain an element of spontaneity in the discussions and enables interesting lines of inquiry to be pursued, it also limits the comparability of the students' responses and opens up the potential for researcher bias.

There are a number of limitations associated with the use of thematic analysis as a method of data analysis. Braun and Clarke (2013) emphasise that in thematic analysis, coding textual data and searching for themes is an active process: "themes are not hidden in the data waiting to be discovered by the intrepid explorer, rather the researcher constructs themes" (p. 122). [13] As Mabry (2008) points out, "The inherent subjectivity of [*methods such as TA*] leaves researchers susceptible to challenge regarding *validity* by those who equate subjectivity more with bias than sensitivity" (p. 219; original emphasis). [14] To guard against such criticisms, and to minimise the potential for researcher bias to influence the selection of codes and identification of themes, Braun and Clarke (2013) emphasise the need for researchers to reflect upon and acknowledge their assumptions, values and experiences before using the approach (p. 122).

Ethics

This study was carried out in accordance with BERA Ethical Guidelines for Educational Research (2018). [15] Prior to completing the surveys and interviews,

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[13] Braun, V., Clarke, V. (2013). Teaching thematic analysis. *Psychologist*, 26, 120–123.

[14] Mabry, L. (2008). Case Study in Social Research.. In Alasuutari P., Bickman L., Brannen J. (Eds), *The SAGE handbook of social research methods* (pp. 214-227). Thousand Oaks, CA: Sage. http://dx.doi.org/10.4135/9781446212165.n13.

[15] https://www.bera.ac.uk/researchers-resources/publications/ethical-guidelines-for-educational-research-2018

all participants were informed that their contributions would be treated confidentially and anonymously, and that they had the right to withdraw from the study at any time. No participants opted out or requested to be withdrawn from the study.

Disclosure

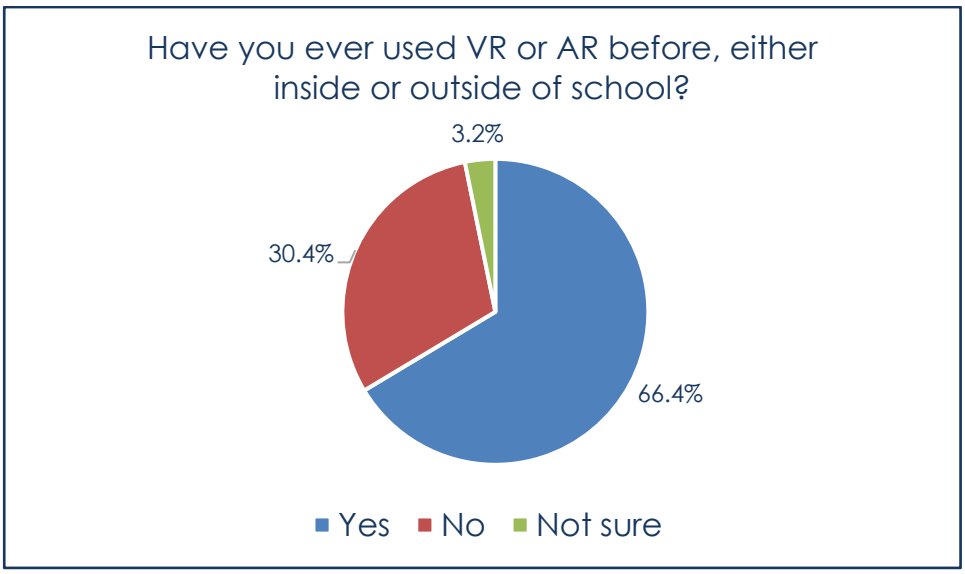
This study was commissioned and funded by the Independent Schools Council Digital Strategy Group. The equipment used in the study was loaned free of charge to schools on a short-term basis by SystemActive Ltd, with financial support from Microsoft, Intel and Hewlett Packard.

Survey findings: students

Student use of VR/AR

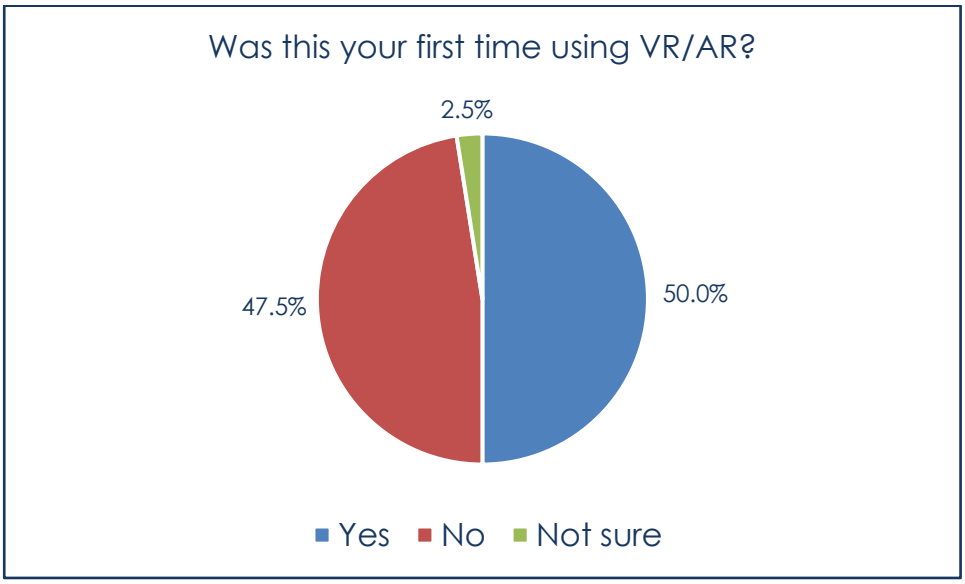
Before the study began, 66.3% of the students said that they had used VR or AR before, either inside or outside of school (Figure 1). The majority of this use was outside of school, either at home, at a friend's house or in a public place such as a museum, shop or exhibition.

Figure 1. Students' pre-intervention use of VR/AR.



In the post-intervention survey, 50% of the students said that this was their first time using VR/AR (Figure 2). The reason for this discrepancy was that a slightly different (and smaller) sample completed the post-intervention survey.

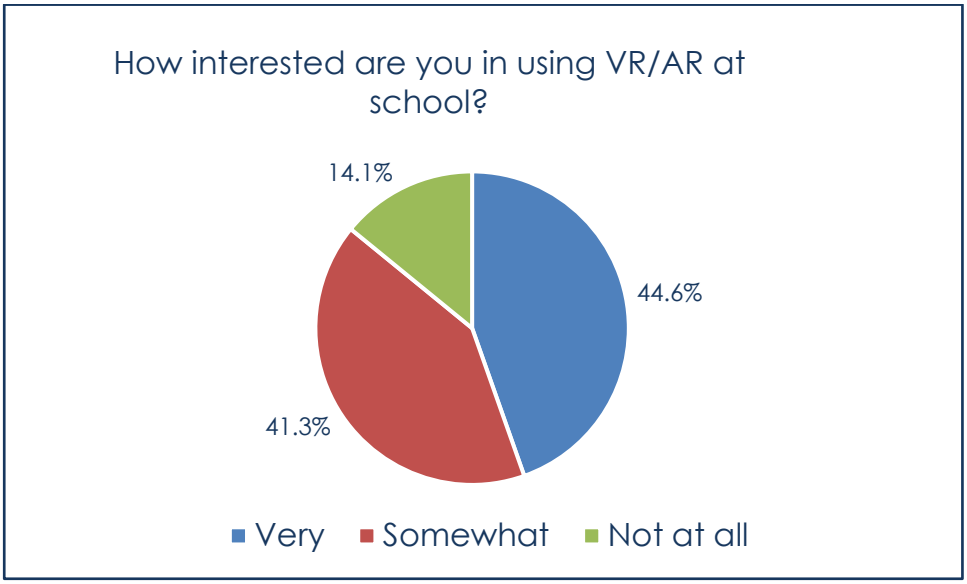
Figure 2. Students' post-intervention use of VR/AR.



Student interest in using VR/AR

Prior to the study, when asked 'How interested are you in using VR/AR at school?', approximately 86% of students replied either 'very' or 'somewhat' (Figure 3).

Figure 3. Student interest in using VR/AR at school: pre-intervention.



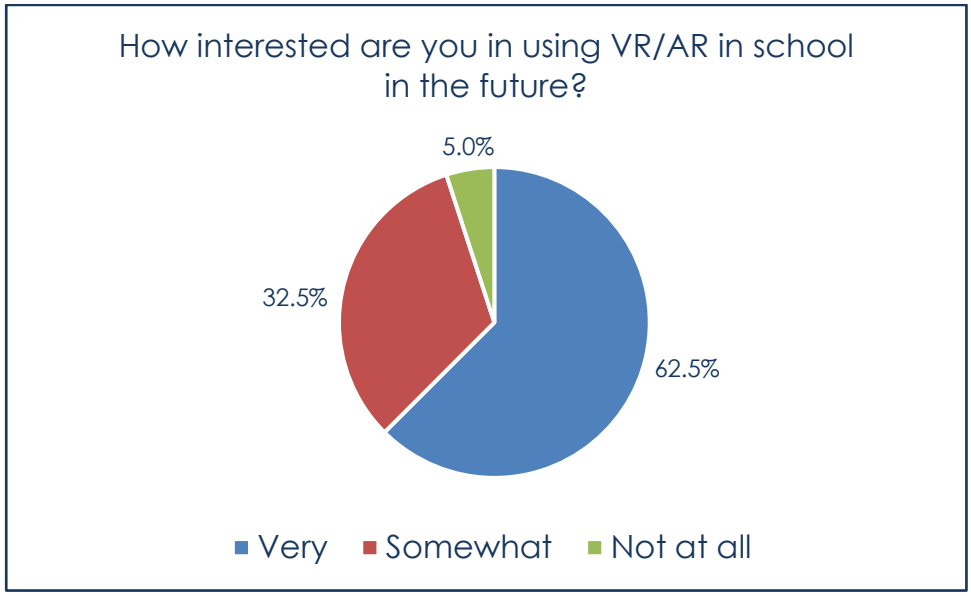
The 86% who replied either 'Very' or 'Somewhat' were then asked "what in particular you are interested in about using VR/AR at school?". The reasons given are summarised in Table 3.

Table 3. Students' interest in using VR/AR at school: pre-intervention.

Reason for interested in using VR/AR at school	% of comments
Learning / lessons / specific subjects	57.5
Fun / games / cool	20.5
Curious / want to try / general interest	6.8
See the world / experience things that are out of reach	6.8
Learn about VR	5.5
Feel more involved	2.7

In the post-intervention survey, when asked 'how interested are you in using VR/AR in school in the future?', 95% of students replied 'very' or 'somewhat', compared with 86% in the pre-intervention survey (Figure 4).

Figure 4. Student interest in using VR/AR at school: post-intervention.



The 95% who replied either 'very' or 'somewhat' were again asked "what in particular you are interested in about using VR/AR at school?". The reasons given are summarised in Table 4.

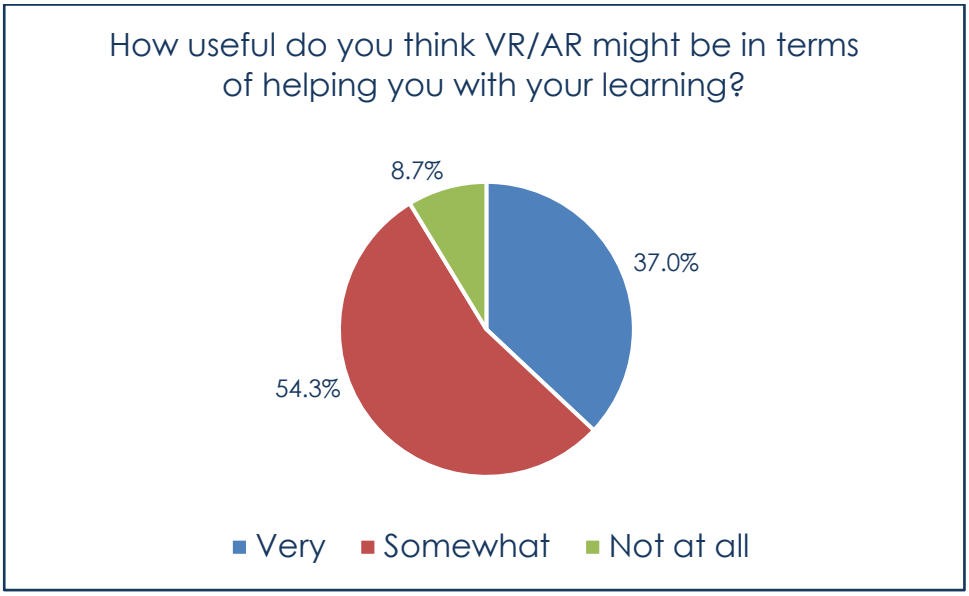
Table 4. Student interest in using VR/AR at school: post-intervention.

Reason for interested in using VR/AR at school	% of comments
Exciting / enjoyed it / cool / fun / interesting	29.5
Visit new places / go on virtual field trips	20.5
Different way of learning / future learning / effective learning	18.2
Named subject (mainly art, science, geography)	15.9
Memorable / visualisation / immersive / interactive	9.1

Student beliefs about VR/AR as an aid to learning

Prior to the study, when asked 'how useful do you think VR/AR might be in terms of helping you with your learning?', 91.3% of students responded 'Very' or 'Somewhat', and 8.7% of students replied 'not at all useful' (Figure 5).

Figure 5. Student beliefs about VR/AR and learning: pre-intervention.



Students were then asked why they gave the answers summarised in Figure 5. As can be seen in Table 5, the vast majority of students were able to provide plausible reasons as to how VR/AR might be useful in terms of facilitating learning. However, a minority of students expressed concerns that using VR/AR might be distracting or have a "backwards effect" on learning.

Table 5. Student beliefs about VR/AR and learning: pre-intervention.

Reason given	% of comments
Increased ability to visualise / see things in 3-D	20.8
Distracting / "backwards effect" on learning / dizzy	14.8
More memorable / learn things in greater depth	13.9
Interactive / immersive / exciting	12.9
Interesting / new experiences / visit different places, times	11.2
Different way of learning	11.2
Many potential benefits / the possibilities are endless	4.0
Unclear / don't know enough yet	4.0
Creativity / imagination / help with creative writing	3.0
Prior experience / belief that VR can help with learning	3.0

In the post-intervention survey, students were asked 'what was your experience of using VR/AR in school? Positives/negatives?' Their responses are summarised in Table 6. Negative comments comprised 22.2% of the total responses; the remaining 77.8% of comments were positive.

Table 6. Students' experiences of using VR/AR in the study.

Positive and negative experiences / responses	% of comments
Positive: Fun / cool / amazing / enjoyable / exciting	30.1
Positive: Immersive / realistic / high quality experience	18.8
Positive: Interesting / useful for learning / easy to use	18.8
Negative: Disorienting / hard to use / glitchy / dizzy / uncomfortable / tangled in cables / bumping into things	14.1
Negative: Took a long time to set up / waited a long time to take a turn	7.1
Positive: Named subject (mainly art)	3.5
Positive: Visit new places	2.4

Negative: only one person can use it at a time	1.2

Student attitudes toward using VR/AR in schools

In both the pre and post-intervention survey, students were asked which words best describe their attitude towards using VR/AR in schools. Their responses can be seen in Figures 6 and 7, below.

Figure 6. Students' attitudes toward using VR/AR: pre-intervention.

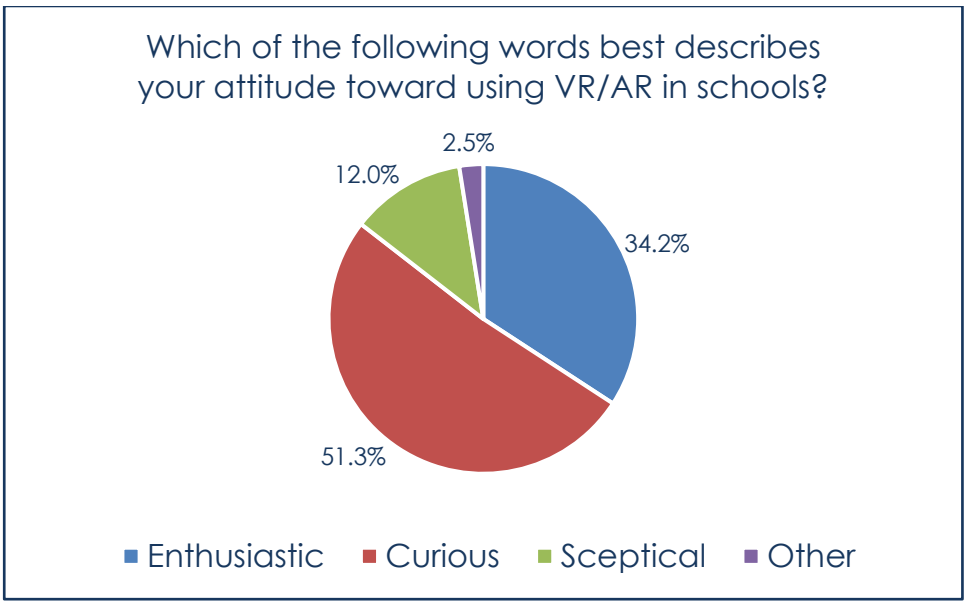
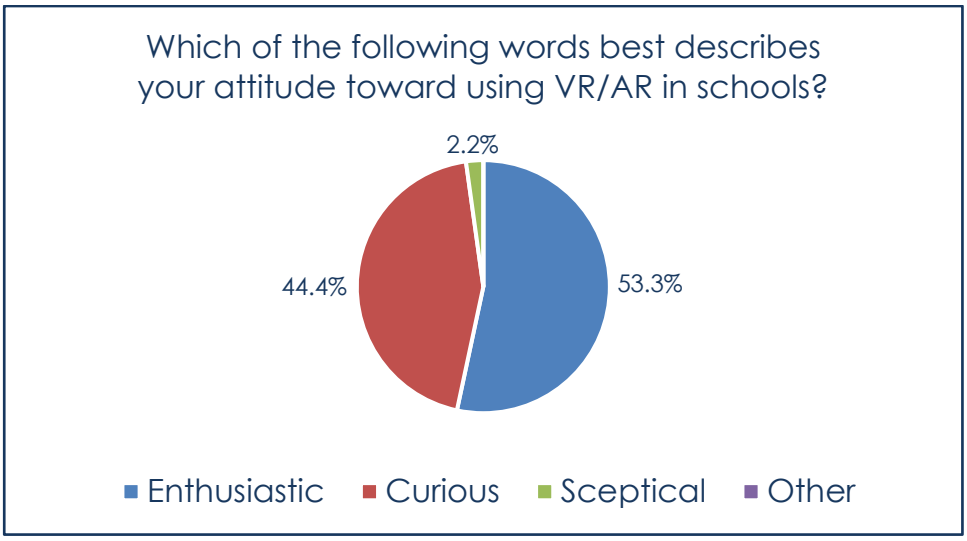


Figure 7. Students' attitudes toward using VR/AR: post-intervention.



In the pre-intervention survey (Figure 6), the 3 statements given for "other" were neutral, playful and excited. In the post-intervention survey (Figure 7), only one student responded that they remained sceptical having used the technology. This comparison of the pre and post-intervention attitudes of students suggests

that the experience of using VR/AR in this study shifted the attitudes of some students from feeling 'sceptical' to 'curious', and from feeling 'curious' to 'enthusiastic'.

Areas for improvement/thoughts on the future

In both the pre and post-intervention questionnaires, students were asked 'do you have any questions about VR/AR, or ideas for how we could use VR/AR in schools?'. Here, several students was a strong sense of the potential of VR/AR as an aid to learning, with clear suggestions for how they would like to see the technology develop in the future:

> "Perhaps interactive activities like the ones found on BBC bitesize, but in VR. For example, you could look over a recreation of the Battle of Hastings and point and click at a timescale to see the battle, or at a group of soldiers to find out their rank and role in the army. Or perhaps watching a simulated universe for learning about Astrophysics. The fact that this is in VR would make it much more immersive and students would enjoy learning much more, therefore be more keen to learn and so do better in exams and gain more knowledge."

> "I think VR/AR is a field of great potential, and I think it will have huge influence in the future in many parts of life such as bespoke orders of items. I am very excited to see this technology evolve with time and experiment with it."

> "For example, if you're studying Japan (like we just have in year 7) you could be transported to Mount Fuji using VR. Then you could have the freedom to look around and if you looked at a certain lake etc it would tell you a fact about it."

> "I would like to see it in sciences, History, geography as these subjects require a visual aid to help a child comprehend the topic/ subject."

> "I would suggest that it be used to recreate and visualise times/places that we could not possibly see in reality e.g. the surface of Mars, the Battle of Hastings, or even 65 million B.C."

Several students also expressed concerns about the use of VR/AR in schools, either relating to financial cost, or issues of health and safety, as can be seen in the following excerpts:

> "I think that they are very expensive for schools to afford. It requires a lot of space and could be quite dangerous. But I do think that it could be used well in schools."

> "Too expensive for most people and not used enough in school to merit cost."

> "I think it would be a good idea to test what students think of the idea and would like to know whether VR ruins your eyesight like in rumours."

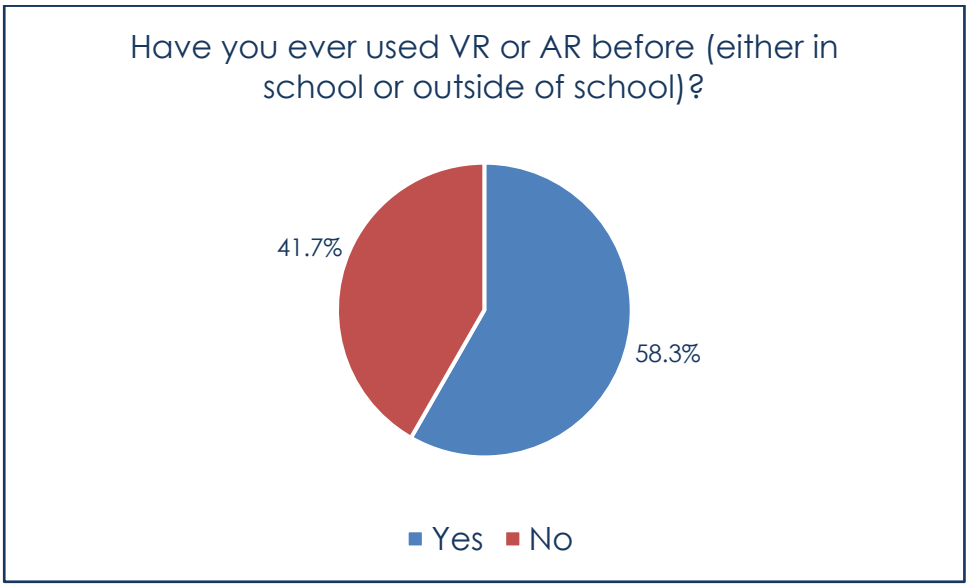
> "Don't use too much or you will have a headache or feel dizzy."

Survey findings: teachers

Teacher use of VR/AR

Before the study began, 58.3% of the teachers said that they had used VR or AR before, either inside or outside of school (Figure 8). In contrast with the students, for whom the majority of use was at home or at a friend's house, the majority of prior use among teachers was either in school, or at a professional event such as a trade show or conference.

Figure 8. Teachers' pre-intervention use of VR/AR.

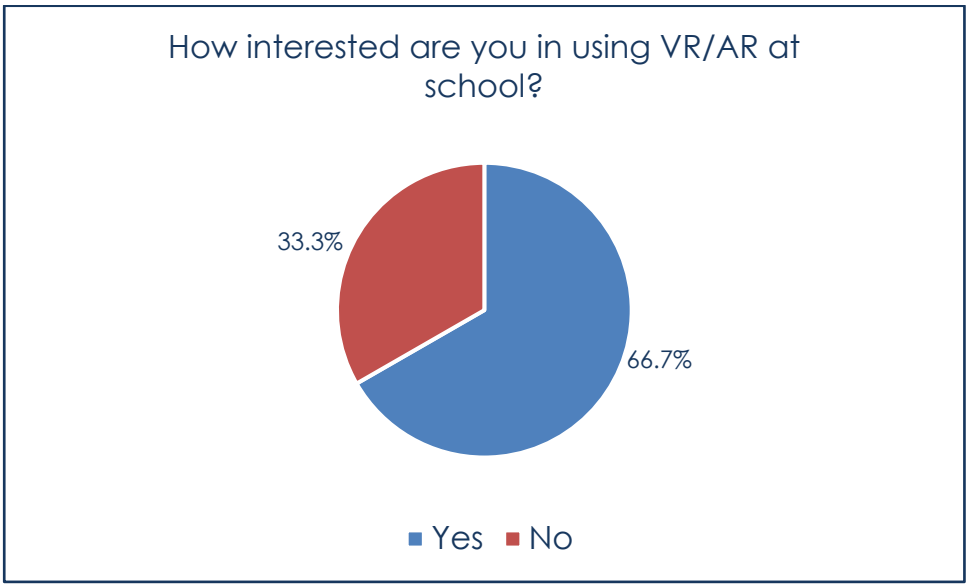


In the post-intervention survey, only 50% of the teachers said that this was their first time using VR/AR – the same proportion as for the students (Figure 2). The reason the figure was is that a slightly different (and smaller) sample of teachers completed the post-intervention survey.

Teacher interest in using VR/AR

Prior to the study, when asked 'How interested are you in using VR/AR at school?', 100% of teachers replied either 'very' or 'somewhat' (Figure 9).

Figure 9. Teacher interest in using VR/AR at school: pre-intervention.



Teachers were then asked "what in particular you are interested in about using VR/AR at school?". The majority of reasons given were subject specific, and several related to the idea of virtual field trips, as can be seen in the following excerpts:

> "Offering the students the opportunity to study the spatial relationship of landscapes (Geography teaching), for example showing them how a valley/gorge is actually the absence of rock on a mountain. Using VR/AR to conduct fieldwork/trips to places that are either too dangerous/too remote/too expensive to access e.g. volcanoes, ocean trenches, war zones. Providing students with better opportunities to experience situations that are very unlike their own lives and learn empathy from them for example refugees, slum residents and those suffering from hazards."

> "I would like to use it for visualisation of complex or difficult concepts across all subjects. It would be a great enabler for pupils who cannot travel, who cannot access areas of study (e.g. Marine Biology in the Cotswolds could go undersea exploring with VR) and also for disabled pupils to access situations they may not be physically capable of accessing."

> "I teach classics so getting students to empathise with the remote past is difficult. When using VR/AR you can be placed in the moment and it really helps students to understand the ancient world more. Even watching 360 YouTube videos gives them a good sense so I feel VR/AR would give them an even greater feeling and understanding."

Additional reasons given included to excite and engage students, to make teaching even more relevant to students, and to help students visualise difficult concepts.

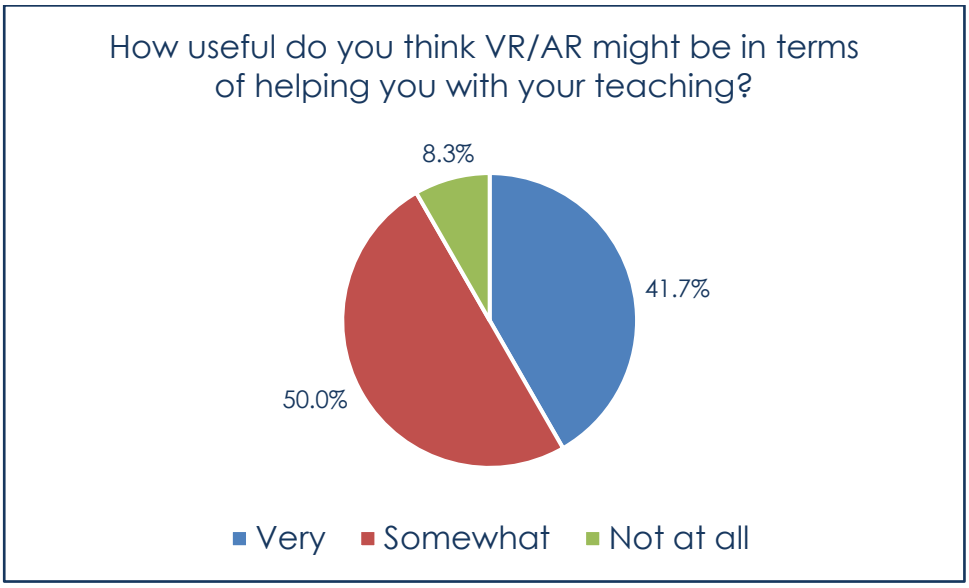
In the post-intervention survey, 83.3% of teachers said they were 'very' or 'somewhat' interested in using VR/AR at school in the future. When asked 'what in particular are you interested in about using VR/AR at school?', the teachers who answered 'very' or 'somewhat' responsed as follows:

> "Seeing how it can be used in different subjects."
>
> "Developing the idea of empathy."
>
> "Adds experience and depth to places studied."
>
> "Enabling experiences and insight for pupils that they simply wouldn't get with a 2D piece of footage / photo / book / audio."
>
> "It's an interesting, enjoyable experience and changes perceptions."

Teacher beliefs about VR/AR as an aid to learning

Prior to the study, when asked 'how useful do you think VR/AR might be in terms of helping you with your learning?', 91.7% of teachers responded 'Very' or 'Somewhat' (Figure 10), a figure very similar to that of the students (as seen in Figure 5).

Figure 10. Teacher beliefs about VR/AR and learning: pre-intervention.



Teachers were then asked why they gave the answers summarised in Figure 10. Again, some of the responses were subject-specific. Some of these comments anticipated positive outcomes for subject teaching, as can be seen in the following excerpts:

> "I teach Geography and the VR helps to transport students into environments that they may never be able to visit and can help them visualise better than an image in a book."

> "Geography is all about engaging students in the world around them and VR would give us the opportunity to expand students' understanding of landscapes, landforms and processes."

> "Molecular modelling (chemistry)"

Other teachers were not clear about VR/AR might help them teach their subject, but were hopeful that is might, as can be seen in the following excerpts:

> "I am a chemistry teacher and I haven't seen any resources, so far, that I can see helping with my subject in particular. I would be interested to see what is out there though."

> "I can't think of ways in which this will help maths teaching but I am open to suggestions."

Two teachers were more sceptical about the potential impact of VR/AR at this point in time beyond 'student enjoyment', when taking into account financial cost and the lack of software relevant to their subject:

> "The content just doesn't exist in sufficient quantity to meet the requirements of rather old-fashioned curricula. There is no direct benefit outside pupil enjoyment for using it as the specifications lack any reference to it! Also cost - building a PC capable of running a decent headset is > £1k minimum plus peripherals and VR devices. Mobile phone kits are all well and good but they are just glorified 3D video watchers at this stage."

> "I feel very hopeful that this offers an excellent complimentary tool to show the students more of the world. However, I retain a 'healthy scepticism' that the current equipment is too expensive (mostly the graphics card), too cumbersome and insufficiently resourced with software to integrate completely into the school environment. I think there still needs to be some work done before I feel it will be complementary to mainstream teaching, rather than just being a flashy toy to keep students interested (though this may also have its benefits)."

In the post-intervention survey, this question was repeated: 5 teachers (83.3%) responded that VR/AR might be 'somewhat useful' in terms of helping them with teaching, and one teacher replied that it would be 'not at all useful'. Once again, reasons for scepticism with regard to the use of VR/AR primarily related to the current lack of content that is relevant or specific to their subject area / curriculum.

Teacher attitudes toward using VR/AR in schools

In both the pre and post-intervention survey, teachers were asked which words best describe their attitude towards using VR/AR in schools (enthusiastic / curious / sceptical / other), and to provide a reason for their response. Their responses were predominantly 'curious', as can be seen here:

> Curious & sceptical: "Waiting for more research!"
>
> Curious: "My knowledge of what is out there is limited so I'd be interested in more ways."
>
> Other (disengaged): "Because I have other interests and concerns at the moment."
>
> Curious: "Need to be more confident and it needs to be relevant for the lesson and more accessible to everyone."
>
> Curious: "I am interested in the possibilities that VR presents in a learning environment."
>
> Enthusiastic: "If it provides a unique learning experience how could I be anything but?"

Areas for improvement/thoughts on the future

In both the pre and post-intervention questionnaires, teachers were asked 'do you have any questions about VR/AR, or ideas for how we could use VR/AR in schools?'. Here, several teachers suggested that the technology has further to go in terms of achieving its potential as an aid to teaching:

> "I'd like to see examples of how it could be used in art, craft and design teaching."
>
> "More things clearly linked to exam specs."
>
> "What are the short, medium and long-term plans of the major content producers with regard to VR/AR education?"
>
> "It would be good for companies creating software to look at GCSE and A Level syllabuses and create things which are relevant to them. Also, not to forget niche subjects like Latin/Classical Civilisation where VR/AR could have a good impact. For example, with the GCSE Classical Civilisation course, we have many prescribed temples and ancient buildings we have to study like the Parthenon, Colosseum etc. To be able to properly walk around and get a sense of scale would be amazing, particularly if we can't go and visit them. Also, in subjects like Art History when studying sculpture, if you can walk the whole way round a sculpture rather than view a flat image on a piece of paper, that will enhance student's understanding of the artwork."

> "I would really like a Geographical app to be developed to show the change of landscapes over time. The idea would be to stand on a hill and see the current day landscape and then use the VR/AR equipment to show what the same landscape was like during the last ice age. Ideally the students could then configure what they see to vary different factors such as increasing temperature to cause ice to melt and sea levels to rise. We see great potential on trips but obviously the flexibility and need for power/processing speed on the current units prevent this kind of work."

Some of the responses to this question raised concerns relating to logistical issues with using the technology in its current form, and expressed a feeling that AR might be more useful than VR as an aid to teaching:

> "You need to make it cheaper, easier and more reliable for schools. Taking a week or two to get a simple setup like this working just doesn't work for teachers short on time and tech support."

> "I am much more excited about AR as it offers the students the opportunity to interact with each other and the teacher as well as the virtual world rather than being completely immersed."

> "The high-end VR gear was pretty clunky to set up, navigate, access software etc. Needs to be much slicker. Rather have quick wins with low spec kit. AR far more interesting than VR as the idea of interacting with a modified here and now maintains the positive element of being in a classroom with human beings."

Interview findings: teachers

All teacher interviews were transcribed in full and combined into a single text corpus comprising 46,061 words. The text was then subjected to a thematic analysis. In this method, each section of the text is ascribed a code, and the codes are then grouped together into themes. The codes and themes to emerge from the teacher interviews can be seen in Table 7. As can be seen here, there were three main themes to emerge from the teacher interviews: comments relating to the ways in which VR/AR might impact on learning; concerns about the use of VR/AR in schools; and comments relating to VR/AR technology itself.

Table 7. Summary of key themes: teacher interviews

Theme	Theme tally	Code	Code tally
Learning	113	Visualisation / 3-D / memory / immersive / interactive	54
		How VR/AR can facilitate learning	46
		Non-cognitive – empathy	15
		Pedagogy / relationships / collaboration	13
		Non-cognitive – careers	3
Concerns	57	Doubts / scepticism / novelty factor	24
		Logistical issues / cost / obsolescence / novelty	20
		The lack of subject-specific content	13
VR/AR	27	Evolution of VR/AR	15
		Named software *	9
		Evidence of impact	3
		VR vs AR	3

* Mentions of subjects or software were only included if a substantive comment was made.

Learning

The most common theme to emerge from the teacher interviews related to the ways in which VR/AR can facilitate learning. Within this theme, the most common codes related to the role of visualisation in learning; the link between seeing things in 3-D and understanding; immersive learning and the nature of immersive learning environments; the ability to interact with one's learning environment; and the interplay between these ideas (visualisation, 3-D, immersion, interactivity) and memory. These codes are summarised below, from most frequent to least frequent.

Visualisation / 3-D / immersive / interactive / memory

Several teachers commented on the importance of being able to visualise concepts, as can be seen in the following excerpts:

> "Visualisation is such an important part of learning. we are always trying to find different visual ways of showing children how things work, you start off trying to draw things on the whiteboard and then you use images and you go to Google Earth and we're always desperately trying to find a better way of showing kids how the world works…"
>
> --
>
> "I've got some student who really do learn using video clips and that kind of learning rather than reading about it. Giving them a description of water channels is one thing, but when they saw it that really made an impact. What they remembered was what they learnt visually."
>
> --
>
> Researcher: Can you think of any ways in which students can learn things through VR that they wouldn't be able to learn in other ways, or that they wouldn't be able to learn as well in other ways?
>
> Teacher: Yes I think a good example is being able to view the lungs. Things where children find a concept tricky to visualise. By being immersed in those environments, they can get a sense and an understanding, they can grasp concepts that they couldn't grasp before. And I think those kinds of opportunities will be very useful for all learners.

Similarly, several teachers noted the advantage that VR/AR technology offers in helping students to visualise things specifically in 3-D, as can be seen in the following exchanges:

Teacher: I think [VR/AR] really helps because just looking at their iPads… they can't quite get that sense of where they would be standing and how everything relates to each other. So being able to fly over the top of the dam in Google Earth, and then sit in the base of the dam looking at it from street view gave them a sense of scale and perspective that I don't think that they'd had grasped before. And it's difficult because as a Geography teacher it's hard to understand why they don't understand, and so it helped me to show them the parts I was talking about him put names to things – these are the walls of the Dam and this is the reservoir behind it, and they can see everything in the right place.

Researcher: And so do you think it helps them conceptually?

Teacher: Very much so, particularly because we looked at different dams in their building construction… because at the moment Google Earth only has one snapshot, and it allowed them to see what the valley would look like before the Dam was put in, as the Dam was being built and then with the water filling up. So they got a sense of the stage process.

--

Teacher: We've used things like the AR T-shirt [Virtuali-Tee] that you use with an iPad and it will show you the beating heart in the right position, and the lungs and then you can click on the lungs and it will show you a picture of the alveoli with the blood running through and you can click it and get more details.

Researcher: Do you use the T-shirt often?

Teacher: Well I've just been teaching respiration so we used it then, and I used it when we were doing the heart with year 6.

Researcher: Do you find the T-shirt useful as a teaching tool?

Teacher: Yes I find it useful because a lot of the time, but particularly with the lungs, it's the 3-D-ness… they don't get to see them living. They get to see them dissected and they diagrams that they must label… but it's quite abstract. But when you go back afterwards and you see them moving and inflating and deflating and the heart beating, they just go "Oh I see!" and it just clicks for them. it's just gives them much more of a sense of what it's like in a living being and they get much more enthused about it then, because they can connect it straight back. because if you give them a diagram of the lungs and all the parts of the lungs they go oh it's just another science diagram whereas when they see it moving as it would be in our body, it ties it all in for them.

Researcher: Do you find it easy to use in the context of a lesson…?

Teacher: The T-shirt is very easy to use, we just pull it into the middle of the room and then they can see it on the iPad and we can do it as part of a circus and the students are quite good at using iPads now, so they can actually go up as a team and press buttons.

Researcher: So it doesn't eat into lots of lesson time?

Teacher: No it literally took about 3 minutes last time. So that doesn't eat into a huge amount of lesson time.

The relationship between immersive experiences and memory also emerged several times in the interviews, as can be seen in the following excerpts:

> "It's about having an experience and our brains are very good at remembering experiences compared to reading about something or intellectually appreciating something… it's not the same. It's about turning it into an experience that is very visceral, and you will remember it so much more because there is just that much more to the experience than there is in reading about it or watching a programme about it. I guess if you had a very good teacher that gave you a very animated lesson with lots of different things you might remember that, but you probably remember the lesson more than what they were talking about."
>
> --
>
> "I think this whole idea of memory… you know, there are experiences we have in our lives that we will always remember and that we can always recall. And one of the things I talk to my staff about is the fact that if you make a lesson memorable, then kids will remember it. And that sounds like a really stupid obvious thing… realising that if we make lessons memorable, and the kids do pay attention all the way through, then it will then burn into their deeper knowledge. And the virtual stuff can do that. I mean, if you've stood on top of the Hoover Dam and looked down both ways, you're going to get dams… and if you can drop down and see the hydro-electric part, you're going to get that… you're not going to have to bone that up the night before the exam, are you?"

However, some teachers expressed scepticism about the relationship between VR/AR and memory, as can be seen in the following excerpts:

> "I can see why you would think those memory palaces might work, and I see them on VR boards, somebody says "Oh I made a Memory Palace for learning Spanish" and I always I'm tempted to put on there, "Essentially what you've done is you've got the words then you've put them on slides and you've dotted them around a virtual space and I move around that space and I can see the words." But if you actually read up, as I have done in the past, about the concept of memory palaces, there's a lot more to it than simply putting some words in a space. It's

about how you catalogue ideas and how you link those ideas. It's about how you link one idea to the next so that you create that train of thought and can therefore recall huge amount of information. If you're interested in this, Derren Brown is a very good place to start. When he was at university he memorised the entire works of Shakespeare using the Memory Palace technique. He talks about it in his book Tricks of the Mind that he put out about 25 years ago. Whether or not what we're seeing now in VR is that form of Memory Palace I doubt it, but I can see why they would suggest that it was. So I'm a little bit sceptical there."

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"I'm a little bit sceptical if I'm honest… I see that having an experience helps them remember things better… and if they've had a memorable lesson it generally means that they will remember it. Whether they remember the right stuff is another question, but at least it creates that memory pathway. But I am not convinced yet and I have not seen any evidence yet, apart from the spatial side of it, that it creates knowledge."

How VR/AR can facilitate learning

The next most common code to emerge from the teacher interviews was the extent to which VR/AR can facilitate learning. The frequency with which this code appeared was not a surprise, since this question was asked explicitly of all interviewees. A number of teachers were able to give extended explanations of how they have used VR/AR technology to facilitate learning in lessons / specific subjects, as can be seen in the following excerpts:

"In January 2017 I bought the HTC Vive, and as I said I've always got my teacher head on and it became "How can I get this going in school?" So I looked for different ways of using it in the classroom. I got one of my 6th form IB students to create some artwork, which she actually submitted as part of her IB using Tilt Brush [a 3-D art studio]."

"One of the all-time favourite projects that I've ever done… we were working on a Vikings topic, and we were using an app called Epic Citadel. It was just a tech demo, and it was a 3D… it's almost like a computer game with no story or enemies or anything, it was just an empty castle that you could use on-screen controls to walk around, and we used that app as a stimulus for creative writing. They were writing Viking sagas, and it was some of the best work that we've ever seen out of kids. Boys especially were all over it, they were so inspired by using the technology to immerse themselves… I mean it wasn't exactly a Viking castle but it was medieval enough that we could get away with it. And what I instantly saw with VR, even that simple level of VR where it's just 360° images so you can look up and around was… the fact that you could take students back to Viking times and have them wander around and experience it as if they were actually there."

--

Researcher: So you used VR again recently?

Teacher: Yes. my job share and I both had a go to see what it was like and there was a really good lungs one, so we could go inside the body and look at the lungs and the alveoli. And I was like "That will be really helpful". With my class we connected it up so the rest of the class could see it on the whiteboard. I think four people wore the headset, but other students were getting involved also.

Researcher: And was in the context of a lung dissection lesson?

Teacher: Yes. I was quite determined not to shoe-horn anything in because of the technology. We have lots to cover and I don't have much time with them, so in that one-hour lesson I could do that and do the lung dissection. So I had the lungs, and they could really see what they look like and we inflated and deflated them and then they could see on the VR what it looks like at microscopic level.

Researcher: Do you think that it has something over and above an animation or a video? Does VR do something that video doesn't?

Teacher: It depends on the child. I think some get very excited by the fact that it's VR and then they'll have forgotten about any form of learning. So you have to pick your children well… I selected four of the children that you could… who would gain something out of it and the one who wouldn't could see it like a video on the big screen, like an interactive video. With the lung software I felt like you did, when I put it on I said "Oh my goodness, look down there at all the alveoli, and you can see them bulging as the air is coming in and you get so much more, it is so much more interactive… my mind was blown, and I've got a degree in it. But it just depends on what the VR is and what you're doing. I think that worked beautifully in context, so I think if it's in context and you've got the right sorts of students… I think they'd already used it in art as well so the novelty factor had worn off, so they were ready to take in what was in front of them.

Researcher: So you say that it worked beautifully within the context of that lesson, as a way to just another dimension to a very sort of hands on lesson about the lungs?

Teacher: Yes and it really tied in… they kept thinking about ventilation in a really basic way, like it was almost mechanical, but when they saw it all happening it was like "Oh OK, that's awesome".

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"One of the first projects I delivered was a World War 2 project with Y6 students. The topic was The Blitz and I had been given the TimeLooper app. TimeLooper's excellent because it contextualises history… it's essentially a 360° video and you're in modern day Trafalgar Square, and there are people around you. And then the world kind of bleeds into the past and it's suddenly 1940 and the Blitz is taking place, but you're stood on the exact same spot. And it uses… live actors, dressed like a recreation, mixed with CGI to create the effect of the past. And one of the teachers I spoke to, he said the lesson he delivered off the back of it… he delivered the exact same lesson… last year, and… they used photos and a little bit of video footage to give the students context for the writing. And he talked about the fact that the level of writing, and the authenticity was so much greater when we had used the VR experience with them, compared with the year before."

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"There's an app that we piloted this year called Kubity, it's a Design Technology (DT) application… We were working with year 10 students on designing a car showroom of the future. And they designed this car showroom of the future that actually included VR headsets inside the showroom. And the DT teacher mentioned it to me and I suggested we use this app. So this let the students take their model, drop it into Kubity, and then go inside it using the HTC Vive. So they were actually stood inside their model. And a model like that should be viewed. And as soon as one of the students was stood inside the model, he looked up and I said to him "what's the matter?" and he went "the doors are too small". And I said "what do you mean?" and he said "The doors are too small. The doors are here, and the average height of the person is here and people won't be able to get through that door. Plus we need them to be wider because we want more people coming in." And I saw this two or three times in other DT projects that we did after that. Using Kubity to visualise their model in one to one scale… especially when you're building a room or a house or something that's supposed to be human size, it's absolutely impossible with any other technology. He could not see that mistake on the screen. I had a girl, we did an open evening for parents a month before the end of term, and she built a clothes shop. And it looked absolutely amazing on the screen… you would have given it an A*. And then she realised she had scaled the entire thing incorrectly, and the clothes were like 10 feet in the air and you couldn't reach any of them. And she instantly pulled the headset off and she said "This is wrong, I need to go and change this, can I go and change this now I need to do it again?" and I was like "Yeah course you can". And she flew across, she was absolutely distraught that she had made this mistake, and she never would have realised it. Potentially a busy teacher who's walking around a busy room and trying to assess a whole bunch of projects might not have realised it either. I mean that's a good example of meaningful and purposeful VR."

Non-cognitive – empathy

Teachers were also asked about the potential of VR/AR technology to develop non-cognitive aspects of learning, such as empathy. This was in response to a 2015 TED talk by Chris Milk, called 'How virtual reality can create the ultimate

empathy machine'. [16] The response from teachers was quite mixed. Some teachers expressed scepticism about the idea that VR can develop empathy, as can be seen in the following extended exchange:

Teacher: I have actually heard a lot of positive things about the creation of empathy, and I am very sceptical about that.

Researcher: How do you mean?

Teacher: So they have said it's a wonderful experience to be able to teach students to be empathetic like what's it like to live in a slum. And I feel that that just can't be right because it's a bit like giving someone a seat and saying this is what it's like to not be able to use your legs, or this is what it feels like to not be able to hear. The students will never be able to know that because that's something that's really personal and I think that we dumb down the experience by suggesting that in any way we can replicate it. It might give an insight but it doesn't create empathy in and of itself, and nor do I think that we can really teach empathy. It doesn't work that way… ultimately the kids can take off the headset and turn away, and it will never actually… I mean it's an improvement… and I think that it's a good learning tool but I don't think you can claim that that creates empathy. I think there's an extra leap that we haven't fully considered.

Researcher: It's also not obvious to what extent it's a school's job to develop empathy. Where does that fit, PSHE?

Teacher: I feel like that is something that we should do in Geography, but we need to handle it quite carefully. It's not something that you can teach by rote, it's something that has to be almost learnt. So for me, it's more about creating the space for them to demonstrate empathy rather than saying this is what it means to be empathetic and know you must do it, and then you give them a grade and tick them off on a list and say well done you are 68% empathetic. And in some sense, even attempting to do that, whether with VR or not, will almost elicit the wrong response from students. They are very quick and bright on these things, and if they feel patronised or feel that we are dumbing down something, they will spot that instantly and it won't be successful. It won't be an authentic experience. In the same way, if you invited in someone who lived in a slum and asked him to speak about it, that's real, that's an actual person, but they would still never actually imagine it just because they've heard them speak for ten minutes. They wouldn't know what it's really like, and I feel that that's the divide that we're trying to bridge too much.

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16 https://www.ted.com/talks/chris_milk_how_virtual_reality_can_create_the_ultimate_empathy_machine

However, other teachers had more nuanced ideas about the relationship between VR/AR technology and empathy, as can be seen in the following excerpt:

> "Empathy doesn't have to be the outcome, empathy can be the agent of instruction so to speak… I can get Siri to tell me when World War 1 started; I can get her to tell me who was involved; I can get her to show me pictures and video clips. But virtual reality allows me to stand on Omaha Beach and watch thousands of soldiers get gunned down. It allows me to… I've done this one thing with history students where we use TimeLooper and D-Day… you know the classic photo of the sailor kissing the girl in Times Square? TimeLooper allows you to stand in Times Square in the modern day and then it bleeds into the past and you're stood at that exact moment as everyone is dancing and celebrating, and then the two characters come together and that moment freezes in time. It's actually allows you to feel like you were there, and get a sense of… obviously it's a re-enactment, it's not video footage but it allows you to get that sense of the emotion that was prevalent on that day. We did another one using the same app that takes you back to the exact day of the Wall Street crash, and you glide through almost like a ghost and you see people throwing themselves out of windows and they're frozen in time and then people are collapsed on the floor crying, and you really get the idea of the emotional content of that moment rather than just the statistical content of that moment. Not just how much money was lost on that day and how many people were affected and why it happened and all that… there's always more to any event, any place any time any person, there's always more going on than just the facts and the figures. So it's not empathy in itself, it's that the empathy dimension allows you to understand the consequences and the meaning of an event more fully."

Pedagogy / subject knowledge / relationships

Several teachers expressed the idea that pedagogy and relationships are of critical importance to the success of any use of technology in the classroom. This can be seen in the excerpt above where the science teacher carefully selected students who she felt would benefit from the experience. In the excerpt below, the same teacher expands on what she would like to see more of from tech companies in order to make VR/AR work in the context of a lesson:

> "I think it would be handy for tech companies to create experiences where it's just a little snippet… rather than spending an hour exploring the International Space Station, you just need to be able to go into VR for three minutes see what you need to see and then come out again. The lung software [YOU by ShareCare] works quite well for that… it took about two minutes to set each child up with it, and then about five minutes for them to have the experience. So it took up about 20 minutes of my lesson which is really easy to fit in. The rest of the group also worked well because they could see it on the big board they were asking questions and saying can you press on this or that. So they still did interact with it but only because it was on the big board, if it was just on the laptop I think they would have lost interest.

> and you need them to have interests so that you can manage all the behaviour at once otherwise you got someone with a headset on that you need to concentrate on at the same time as kids that are losing interest.

The importance of pedagogy can also be seen in the following excerpt from an interview with a teacher discussing the recent adoption of one-to-one iPads in her school:

> "We're a one-to-one iPad school. We started in 2015 and now from September 2017 every kid in the school has an iPad. We were very influenced by the one-to-one team from School X… It's about the pedagogy, it's not about the shiny thing. It's about asking "What can iPads do that help with teaching and learning?" One thing that has been really successful is using them for retrieval practice – quizzes, that sort of thing. That has helped a lot of our kids and our staff."

Non-cognitive – careers

Another example of non-cognitive learning that VR/AR technology might help facilitate relates to careers, as can be seen in the following excerpt:

> "Things where children find a concept tricky to visualise, by being immersed in those environments they can get a sense and an understanding, they can grasp concepts that they couldn't grasp before. And I think those kinds of opportunities will be very useful for all learners. Also, being able to participate in simulations. Higher up the school, if students are thinking about what career they would like to do… if they want to be a pilot for example, if they can experiment with that in a VR scenario, they might come out of that and say "No way do I want to be a pilot, I'm not going to spend several years of my life training to do that!"… You could potentially have students in lower secondary school performing virtual operations, and we could bridge the gap between learning all this theory and the real world of careers and skills. We could bring a lot of that lower down because it can be done virtually."

Concerns

Doubts / scepticism / novelty factor

As well as the scepticism about the role of VR/AR in developing empathy as seen above, a number of teachers expressed a sense of "healthy scepticism" with regard to the use of VR/AR in schools, as can be seen in the following excerpts:

> "I can't see it doing anything that you can't do with things that are already there. I guess I don't know what I don't know. To be honest I can see ways it can augment

and improve and make things that already exist seem exciting or more interesting better more immersive, but I think we as with all these things, it's the content creation that is really important and the vector is less important, the vehicle of how it is delivered. Because for instance, talking about creating an immersive video experience of a day in the life of someone, that's all very well but why does being immersive make it so much better relative to the resource implication of making it at that level? I'm not convinced that that is the biggest barrier to learning… certainly in my sector, I am in a very expensive public school and we are in a different setting and having visitors coming to speak and have students meet people and to go and visit these places in the flesh is much easier for us. I would say that using Google Earth to look around Iceland… well, most of the students are actually going to Iceland and I think that is, I don't think [VR] is going to be as good. It's a complement in some cases but it's fundamentally not a change."

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"Some of the organic chemistry… getting your head around a three-dimensional version of a molecule, yes I can see that actually and I am a big fan, I am trying to get my kids to do it and I use it a lot in my own work as well, this idea of dual coding. And I can see it but these images in my head, everything that fits together in my head but doesn't in theirs… I am coming to the conclusion that if you can't draw a picture of it you probably don't understand it properly. So I can see that VR might help to get people to see what I can see, particularly 3 dimensional structures of stuff. But again, there is a certain amount of that you can do by just making them draw a diagram. I did it the other day with year 8 I said right don't write pages and pages of notes let's just draw a picture and they are getting there. So I'm not sure that you need VR necessarily you just need to be aware of drawing some pictures."

Logistical issues / cost / obsolescence / novelty

Having taken part in the trial, a number of teachers pointed out issues they had experienced or thought about since. These issues related to a number of factors, ranging from classroom practicalities and concerns that the novelty of VR/AR technology would soon wear off, through to considerations of cost and obsolescence. Examples of these concerns can be seen in the following excerpts:

"It was OK… limited sort of usage I would have thought. You would have to think very carefully about how you would integrate it into a learning experience, rather than it just being a feeling of being somewhere. The novelty aspect is fine to begin with but I can see it would wear off – "here we go again, the teacher's got the goggles out" sort of thing, it's all a bit old hat after once or twice."

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Researcher: So do you just use this with one student at a time?

Teacher: Exactly. That's the huge limitation at present with where this is at. For that reason. It's still has a slightly gimmicky fat side to it because you can only offer it to 1 student. However it worked quite well in a recent science lesson where the teacher allowed a couple of students, and made it clear that only a couple were going to be able to use it, and the other students quite enjoyed watching it on the screen just to have a bit of a walk through. And that was interesting, whereas to get every student through would be quite challenging.

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"It is important to be philosophical in this because technology… we've got to find some justification. I mean, I've been doing this for 25 years and honestly, there has been such a waste of time and money. Such a waste. So much kit is left in cupboards that was bought with all the best intentions, and it's still sitting there. It's a disaster. And I think we just missed the student out in most of these. We didn't talk to the student, we didn't engage with them, we didn't get their feedback about what was successful, or what would work for them."

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"It's not particularly sensible for schools to invest too much in these technologies only for it to become out of date. The Vive was around for two years and now the new Vive Pro is out. And if you buy a Vive Pro now, then in two years you will want to buy the next thing. So, things are constantly moving, and it would be far better if there were companies that turn up at the school and lend equipment or show off different things for a while and then they kind of take it away again, rather than schools having to buy all this… There's nothing worse than having antiquated equipment lying around because they can't keep affording to buy new stuff. So any school that buys stuff needs to understand that within two years they will need to buy more stuff. Otherwise, don't bother in the first place."

The lack of subject-specific content

Perhaps the most common complaint from teachers was that the current available software is of limited use in schools. In particular, there is a common perception that much of the currently available software has not been created with the classroom in mind, as can be seen in the following excerpts:

"Maybe I just haven't seen anything and that's the problem, so if you know someone who's a VR specialist and a chemistry specialist then they might be able to make something work but they would need to be a really good chemist. And that's the problem with a lot of Ed tech, that the companies are just like "this is what people need" and actually if you don't have the subject knowledge… there are loads of multiple-choice things that you can just buy off the shelf, and actually, if the multiple-choice questions are rubbish, it doesn't matter how flashy the tech is, it's

not going to help. I can write better multiple choice questions because I know the misconceptions in my subject. And so I think that's the key."

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Researcher: If you could have the ear of tech developers, what would you ask for?

Teacher: If they looked at the curriculum first. What are people trying to teach? If they looked at how it is currently being towards as a starting point rather than saying all this could be quite cool. At the moment they seem to say "well we've got Expeditions, let's give it to Geography because that's the closest thing we've got to Expeditions. Rather than starting with Geography and going right let's look at what's on the syllabus for GCSE and A level. There's no point in doing an immersive interactive tour of JK Rowling's Edinburgh. because Harry Potter is not on the syllabus whereas Dickens's London could be really valid and useful. I think there is lots of stuff that could be useful but it just needs to be led by learning to start with. That's the key thing – how is this better than using pen and paper? The number of times I see people say things like "oh you can use this app and it selects the students randomly" and I just think. "well yes but I could just write their names on a piece of paper and pull them out of a hat".

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"I would really love to see where the developers are going to go in terms of integrating the fieldwork course work that we've got with the syllabus. Because my real worry for VR is that it's going to be a gimmick or a shiny toy that makes a lesson look flashy, and the kids enjoy the experience but don't actually learn any more from it. So I would do love to do more work with Company X or whoever is creating it to make sure that they are able to provide resources that are much more than Google Expeditions, where there is real subject content created by experts that actually matches the syllabus. It needs to be done in a way that makes it easier for teachers who are already having to deal with the class and ask questions, and it just becomes an additional tool for them to use rather than something that they have to be particularly expert in or something that is just a gimmick."

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"[Tech companies] don't really deeply understand the value that it can provide. they know there's a bandwagon they know it's probably going to be really big they know they're going to make a lot of money and they actually spoiling things a little bit creating crappy content that either people think is meaningless or it's very trivial and they're not connecting with the serious kind of value that it can provide."

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Researcher: To what extent do you think tech companies have effectively liaised with the teaching world, and in curriculum design as well, because there are pedagogical issues around it and then there is also, "does this fit with what the teachers need to cover?

Teacher: It does happen, but… if you go to talk to industry leaders or companies, teachers are not really taken that seriously… It's a jack of all trades, master of none situation, You are brought in as a token teacher to a lot of these things, because the companies… want a teacher involved so they can say they've had a teacher involved. They want a teacher because they really don't know anything about the curriculum, but then when the teacher gets there they don't listen. It's very, very common. They'll ring me up and say "oh we need your input, we've heard about you, why don't you come in, you can take part in this discussion". You go along, and you sit there in the corner of a room, and they just do what they were going to do anyway. You put forward your point of view and you tell them how it could be best used in different scenarios in the classroom, and you go through the various pedagogical ways you could harness the technology, but… on the whole they'll already have their route, and they want you there as the token teacher. I think it's partly our fault, as teachers. Because I do go to a lot of other things where teachers are involved, and the teachers that are involved are perhaps not as tech savvy as they claim to be… So you immediately fall into that category of "yes they're a teacher, they know the curriculum, but they're not really that technologically savvy". And I think that's the biggest problem. We are not experts in technology, and we shouldn't really have to be – we should be able to pick up, plug and play, drop it into the classroom and we should be doing the curriculum application, and then they should be using us to provide them with that information and then they provide the technological side. But then problem then is that when you get there, you're not deemed as a credible voice. So that's the problem. Teachers are trying to mould themselves into the environment, the commercial environment if you like, and we're not used to the sales environment, or to technological development environments. We just want to use the kit. And I think that's where there's a bit of a gap that needs filling in training industry in how to deal with schools and training teachers in how to deal with industry.

VR/AR

The final theme to emerge from the teacher interviews related to VR/AR technology itself. These related either to the evolution of VR/AR, evidence relating to the impact of VR/AR on learning or other outcomes; comments relating to particular software applications; and the relative advantages and disadvantages of VR and AR.

Evolution of VR/AR

The most common code to emerge from the teacher interviews related to the idea that VR/AR is a field undergoing a period of rapid development, and that in 2018 we are in the early stages of exploring the extent to which this technology might be used in educational settings:

Researcher: If you could fast forward 5 or 10 years down the line, do you think we're going to have class sets of VR headsets that are used like we use mini whiteboards now, that they just become part and parcel of the teacher's toolkit?

Teacher: That depends on how breakable they are. A few years ago we had laptops for every student, and they broke very quickly. So they need to be robust… if you have a set of 20 or 30 they have got to be pretty bulletproof. The issue in a classroom setting is obviously you need a space around you, so managing people not going into each other's spaces, they will have to learn how to do microscopic movements to achieve the same thing. Or you would have to be in a bigger space. I think AR might be the way to go rather than VR because you can still see the room that you're in and it's safer and you can collaborate. Because as a teacher, if a kid is in an immersive environment you can't always see what they're seeing. Well you can if it's on the whiteboard but you can only do that with one child at a time.

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Teacher: In my previous school we started using cardboard headsets, just some early apps that offered a VR experience and also some 360 videos. Then about two years ago we started to use the more powerful headsets like the HTC Vive, and that offered a much richer immersive experience.

Researcher: When you were using the cardboard headsets, could you see the potential for this as an educational tool or were you thinking at that time "I'm not really sure where this is going?

Teacher: A bit of both to be honest. It did offer a glimpse of what the technology could offer but compared to one of the more powerful headsets it wasn't as real as an experience so it kind of offered a 360 experience but it wasn't sort of tricking your brain if you like, it wasn't a real virtual experience but it did whet the appetite. Then we got the HTC Vive, and it was interesting to see with students how immersed they could be in a particular experience. That definitely gave me a glimpse of how students can learn in future very differently from today's textbook approach, to having something where they are part of the experience essentially. More recently, we've been using

an HP mixed reality headset, and that offers a similar experience. The advantage of this particular headset… is that you can set it up very quickly, so you just power up the laptop… and basically it's good to go because the headset has embedded sensors. So you don't need the light boxes and all that. The headset is not wireless, it still has a big chunky cable that you have to hold so that the person doesn't trip over, but the set-up is about 5 minutes compared to maybe 20 minutes with the HTC Vive.

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"Things are quite bulky at the moment, so after 15 minutes a child probably wouldn't enjoy wearing it any more. Not always… I took the Apollo 11 experience home and most of my family tried it even though it's an hour long… but they're sitting in a comfy chair… in lessons you wouldn't want to be spending too long when there are other things to do. But I guess because these are the first-generation things at the moment… the HTC Vive is the first iteration that is public, and the Rift which is probably a slightly more comfortable thing. So by waiting I guess you save yourself from the trouble of first-generation things, but you also don't have the learning… then you haven't understood what works and what doesn't work and you are just relying on what someone else is telling you and following along. But any school that wants to understand its value for themselves, they need to just get going but not spend too much money. The current headsets are just a stop gap where we have to put these things on our heads and they certainly will get slimmer and you will be wearing sunglasses that you can dim down to get VR or become transparent for AR and I would say that's five years out."

Named software

A number of teachers singled out examples of specific applications they had seen used to good effect. Primarily, these comments related two of the programmes used in the trial – Google Tilt Brush, and Google Expeditions – as can be seen in the following excerpts:

"Seeing people draw with Tilt Brush… stuff like that is amazing for people who don't even think they can draw. They like feeling like not everyone's watching them, even though they can be watching on a screen… they feel like they're in their own little world, they can draw what they like, they can experiment with drawing and it's very intuitive. And you can do collaborative drawing as well so you can work on something bigger together. There are sculpting programs as well now, because sculpting work slightly differently, laying down a kind of medium that you can deform.

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"Tilt Brush I would be really interested to investigate further. I had an art student come in and just have a go on it and so it was pretty much like giving her a

paintbrush and telling her to get on with it, but it was really interesting to see how she felt it could be used. She started off quite small and timid with it and doing little sketches, and by the end it was almost like a dance because she was using the whole room and the whole of the space and she really liked the sense of perspective. So she drew a replica of the Hokkaido wave, you know the famous Japanese Tsunami picture, and she really… got to grips with how the space worked so rather than it being a flat image she had created it so that you could sit underneath the wave and look up at it and see the perspective of Mount Fuji in the background, which was really lovely to see."

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"Google Expeditions is absolutely fantastic for primary schools. It's mainly photographs, still images. But that's OK for primary schools because you don't really want anyone under the age of 13 experiencing video VR because it makes them quite sick quite quickly… But Google Expeditions has a fantastic range of resources, and I think that when they brought out their classroom packs, that was a real turning point for this technology in classrooms. I think that… lots of people are going to be replicating that, because they've basically created one box that has a classroom set of 30 headsets in it that can be controlled by the teacher. And that was a real breaking point for me because I was… saying "well it's brilliant this technology, and I can see the use of it but actually in a classroom environment it's really difficult to get into your curriculum because if one kids on it…" But the Google Expeditions stuff I've been in schools, where they've been teaching kids about the Ebola virus and you take the kids to a marketplace where the Ebola virus apparently broke out, and the kids are able to look at the floor and see all the rubbish lying around… I've seen kids go on a tour of museums in Iraq and they go "Oh my God there's grass there!" If you put them in a situation where they are immersed in it, and when it's in the curriculum in the correct way and it's not just seen as technology that we have to use, it's the most appropriate tool to use for that scenario…"

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"Out of all our boxes and kits that we take out, the Google Expeditions box is… I sent it out 2 years ago in August, and I only see it when I pick it up and drop it off at the next school. It's never back at my school, it's always out. It's basically a massive plastic box and they've made up a box with 30 mobile devices that are effectively mobile phones without the mobile phone bit. There's an integral Wi-Fi router and there's a tablet that the teacher uses. And the tablet controls the experience. You download all the content onto the tablet not the headsets, and the teacher says "Right, now we're going on a tour of the space station" and they click a button, it brings up a picture of the inside of the space station on then on the right hand side it has everything the teacher needs to know. And the teacher can read through the content and as they go through the contents there are hyperlinks so you can say "Here's the viewing window so the astronauts can see Earth", and if you click on it there's a little flag on the viewing window and on all the headsets a little arrow appears so all the kids can look towards the viewing window. But on the tablet you see little happy smiling faces of every child and where they're looking, so you can

see where every child is looking in that virtual environment and you can say "Right, check this out over here you can see this." And it gives you a lesson plan. So it says "Over here is the Italian module of the space station and this is where they work" and it gives you loads of information. And in the Biology one, there's one on the lungs, and you can say "As you can see, here are the healthy lungs and here are the lungs of a smoker"… So it does the lesson for you as well. But the content… I mean literally I went to a school the other day and they're doing a trip to France next year, so they want to take the kids around various places in France so they typed in Eiffel Tower and up came 30 virtual tours of France. So it's the library of content in that alongside 30 headsets, the whole class can be involved at once and the teacher can control the entire experience themselves from the front of the class. And the associated lesson content that has been developed alongside it and is actually integral in it. That is incredibly powerful because it's been developed for the classroom, it's not been developed as a gaming thing that has been retrofitted to the classroom."

Evidence of impact

All teachers were asked whether they knew of any evidence relating to the impact of VR/AR on learning. As can be seen in the following extended excerpts, there was a sense that at this point in time, it is difficult for schools to determine the extent to which VR/AR impacts on learning using exam results as the outcome variable. However, several teachers were able to share examples from their practice where they felt using VR/AR had had a positive impact on learning:

Researcher: Can you think of any examples of how VR or AR can help kids to learn effectively?

Teacher: "It's interesting because I go through a lot of… impact reporting, and the issue surrounding impact reporting [is] the difference between qualitative and quantitative [data]… it's easy to get the qualitative, but it's very difficult to get the quantitative. Especially in my role… I go out to a school and use the kit, and there's no continuity, so I can't see whether what I've done with the children, or whether the kit I've given to those children has had an impact over time. But one of the things we're finding is that students… that struggle with concentration… students [with conditions such as] autism, ADHD [attention deficit hyperactivity disorder]… you know the children that struggle with sensory issues in a classroom of 30 kids, with lots of noises, lots of things going on around them… if you can immerse them in a virtual world that is educational: massive impact. Absolutely huge. To the degree where you'll… do something with them – say you'll do electronic theory, and you'll lose those children within about five or ten minutes. You know, they'll be doing something else, they'll be looking out the window, they'll be messing about. You immerse them and they'll stay in there for as long as they can. And of course

there's… nobody from their peer group distracting them, there's nothing else they can do… their entire perception is what you want to put in front of them. And I think because it's digital, it has a… I can't explain it really. It's like with [students with autistic spectrum conditions], if you do something on a computer… it might be the same mathematical sum, but because it's on a computer they enjoy doing it, it's just because they're using something digital. So I think the biggest impact I've seen is for special needs. It's quite phenomenal.

Researcher: What kinds of environments are you talking about?

Teacher: I'll give you an example with my kids. We don't have many children with severe special needs at my school, but we do have kids that have concentration issues. So for instance, I teach technology and our coursework involves six ideas… six concepts that are designs of their project. And a lot of students struggle with it because if you give them a blank sheet of paper… it's quite a big space, and they don't know how to fill it and it's quite ominous, and you can see them struggling before they've even put pen to paper. And then they end up doing, you know, a pretty rubbish drawing, not fantastic animation, and they end up submitting something that's, you know, pretty awful. And then you have to sit with them, and they do it again, and you teach them drawing techniques, and then they get bored with that and it's really not a nice process to go through with certain children. So what we've started doing now is that we put them into things like Minecraft, in the VR headsets, or there's some really nice sculpture software where your hands become chisels effectively. I think it's called Sculpt VR or something like that. And they can actually go in and immerse themselves, and they can generate the same ideas but out of little blocks, like Minecraft. And they'll go in and they'll be immersed for 60 minutes, for the whole hour. They won't be talking to their friends, they'll be walking around this thing, putting blocks down, moving things around. And you'll find that within a couple of hours, they've got a fantastic digital drawing. But not only that, they've taken it home, they've gone onto their various pieces of software they've got at home, they've animated it, they've added captions to it, they've done 3 or 4 videos surrounding the idea, and they submit something that's just truly amazing… it shows their creativity without having the barrier of that blank A3 piece of paper. So you know, monitoring… kids showing their creative side is very difficult if they're very worried about the fact that they can't draw. But if you stick them in a virtual world where… it's not quite looking as they want they can just delete a bit of it and rebuild it… And of course in Minecraft, they'll quite happily take it home and spend 3 or 4 hours on it, because it's fun as well. So you've got the gamification approach. So that's one example. And then you've got things like Google Maps, Google Earth, you've got Tilt Brush… you've got all those big packages that people have spent a lot of time manufacturing. They are superb. So for artwork, for Geography we

did a tour of the Southern coastline of the UK before the kids went on a field trip. And then the kids, when they went to the coast line actually on the trip, they were able to visualise it because they flew over it like superman in a virtual environment. So I think for those… children that perhaps struggle in a standard everyday classroom, I think it's gold dust.

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Researcher: Are you aware of any work that's been published looking at either qualitative or quantitative impact of VR and AR?

Teacher: I think time is one thing that you can save. So if you're trying to teach the kids about electronic principles or biological principles, if you can put them in an environment where they can see it… it's instantaneous learning. So there are things that I would normally do in two lessons that with VR I can do in about 20 minutes. Electronics Theory, the movement of atoms and electrons… if you try and explain that and you talk about atomic structure and electron clouds and voltages and bits and pieces like that, that's really hard and what I've done in the past is… different classes will pick it up at different speeds. So if you've got a high ability cohort you can do it in a single lesson. If you've got kids who struggle a bit more it takes longer. I have actually taken kids into the theatre and had the move one by one 1 seat at a time pretending to be electrons moving through. And you've got kids at one end being the battery and you got some spare chairs at the other end which is the other half of the battery. So you go through all these different teaching techniques to get that point across to different groups and different individuals. I've tried YouTube, I've tried making actual physical aids, all sorts of things… but if you can take a child and put them into an environment where they see things moving, well it's just instant, they go "Oh that's how it works"… I'm sure there are hundreds and hundreds of things like that that would save time in a curriculum, and that's a big problem for schools at the moment fitting everything in that you got to fit in. And of course if you can fit more things into your curriculum in and teach it in an easier way then you can make it more broad and give the kids a better learning experience. The other thing is… if you want to properly evaluate something like that, you have to have a control group that's not using the technology and do you have to have the group that's using the technology and the groups have to be of equal ability. and you need to run those two side by side and at the end of the year gather the data… how much time have you overrun with one group, what were the exam grades and so on. But I have not seen any research along those lines. And that hasn't been done because the technology hasn't been there yet.

VR vs AR

Teachers were quite divided on the relative merits of VR and AR, as can be seen in the following excerpts:

> "I think AR might be more suited to the classroom, because obviously you are still there in the same physical space and you can interact and collaborate in real time as well as virtually."
>
> --
>
> "I think once we get more towards mixed reality and augmented reality, I think that's when we're going to see a significant change, because it melds the two worlds."
>
> --
>
> "Talking about the difference between VR and AR… I think VR is more powerful because it contextualises the learning. To use the ancient Egypt example, I can use an AR app and pull Tutankhamun tomb onto the desk in my classroom, and I can look at it from all angles and I can inspect it and if it's good AR then… I might have labels or sound that's telling me all about it. And that's great, but ultimately Tutankhamun's tomb wasn't 6 inches long and sitting in my classroom, whereas if I walk inside a full recreation of his tomb, I get the idea of the scale of the thing… I get the idea of the layout of the thing I start to develop an understanding of the importance of different things and how they relate to each other. Now all of that surely elevates… as a learning experience, it automatically elevates it above remembering facts about Ancient Egypt."
>
> --
>
> "I think AR is certainly useful if it's for objects that can float in space, or in the space in front of you, something that you are learning about like an engine or a building or whatever. It doesn't work so well when you want to completely go to somewhere else like ancient Egypt or ancient Rome. It isn't so good for that so it's important to understand what each platform offers and wrestle one against the other because they're so different in what they do."

Interview findings: students

All student interviews were transcribed in full and combined into a single text corpus comprising 17,743 words. The text data was then subjected to a thematic analysis, using the 6-tep method outlined by Braun and Clarke (2006).[17] In this method, each relevant section of the text is given a code, and the codes are then grouped together into themes. The codes and themes to emerge from the student interviews can be seen in Table 8. As can be seen here, the themes that emerged from the student interviews were quite similar to the teacher interviews, with three identical broad themes (learning, concerns and comments relating to VR/AR technology itself) and one additional theme (enjoyment).

[17] Braun, V., Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*. 3 (2): 28. doi:10.1191/1478088706qp063oa.

Table 8. Summary of key themes: student interviews

Theme	Theme tally	Code	Code Tally
Learning	84	How VR can facilitate learning	30
		Named subject *	18
		Visualisation / memory / immersion / interactivity	18
		Non-cognitive – careers	8
		Non-cognitive – empathy	7
		Non-cognitive – seeing the world	3
Enjoyment	54	Cool / fun / amazing / enjoyable / exciting	19
		Gaming	10
		Comparison with textbooks	7
VR/AR	32	VR vs AR	12
		Named software *	12
		Evolution / future / importance of VR/AR	8
Concerns	27	Logistical issues / health and safety	17
		Content not relevant / novelty	10

* Mentions of subjects or software were only included if a substantive comment was made.

Learning

As with the teacher interviews, the most common theme to emerge from the student interviews was 'learning'. Within this theme, the most common codes related to how VR/AR can facilitate learning; visualisation, memory, immersion or interactivity; and non-cognitive learning such as that relating to careers,

empathy and seeing the world or going on field trips. These codes are summarised below, from most frequent to least frequent.

How VR can facilitate learning

Within the 'learning' theme, the most frequent group of comments in the student interviews related to how VR/AR can facilitate learning, as can be seen in the following excerpts:

Researcher: Do you think VR/AR helps children learn better?

Student: I'd say yes it does help a lot. Like recently… in Science, we're learning about space in Physics and then in Biology we're learning about gas exchange, and we were able to look inside the lungs with VR so we could see everything. We also did a dissection, but when you're looking [in VR/AR] you can see it as though it's alive, so it's more… of course you could see that it's not real, but it's very detailed and you could see everything… and I thought that was really good for the topic.

Researcher: And this was in the context of a lesson where you were doing a lung dissection?

Student: Yes and she asked one of the students to come up and she put the headset on and she put it on the screen, so we could see what they could see… he was looking at the lungs and we were able to look around as well, and you could see the alveoli and the bronchioles… that really stuck in my mind, which is good because it also keeps you interested.

Researcher: So what is it about VR that you think helps people learn better than they otherwise could?

Student: Because it's something which people enjoy a lot, because it's interesting especially if you're using it. We've all had a go and it sticks in your mind. Like when people do activities… For instance, when you leave School X, you will remember the exciting things you did. But if you did something exciting whilst learning then it will stick with us forever.

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Student: Also, for some people who have a more photographic memory, it might help them a bit more because they actually get to see everything for themselves. And then using the facts that we learn in class, they can start to deduce stuff, so it might be easier for when exams come around because they can remember the information just by looking at a picture.

Researcher: So you think that visualising things helps you to remember better?

Student: Yes. I think also, other than the fact that it's a fun experience and it makes education and learning fun when it's in that atmosphere, it's also good when it comes to picturing different things and piecing it together to learn information about exams… I think also if you're planning a trip you could scan places where you would go, or where you would want to go… so you could visit it before you visit it.

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"I think a lot of what schools can and can't do is often to do with safety and budget, but you can do anything online or in a different world. For instance, a lot of chemistry is theoretical, and a lot of it is stuff you can't really see, you just have to know it's going on… although in biology you can just look at the body, in chemistry you can't really do many things to see what's going on and often the more exciting things are dangerous… radioactive elements and all that. That could be really expanded, so you could see a lot more… people would get more interested and excited. The same would go for history for example. Obviously we can't go back in time, but being able to see events unfold in front of your eyes is really moving and it's extremely interesting and at the same time you would pick up different aspects."

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Researcher: Can you think of any ways in which this VR experience helped you understand science?

Student: Well, with the AR experience it helped me understand quite a lot because they had little captions and you could read all the facts and information. And also with the VR in the space station, it had facts and stuff like that. And the space walking wasn't really very educational but it was still fun, it gave you an insight about what the astronauts would do on a daily basis when they're up in space.

Researcher: Have you used any other apps that you think have helped you learn?

Student: Yes, quite recently in science we did one about the heart and lungs and the respiratory system and looking up smoking and how it affects your lungs… so we had a look at the lungs and we looked at alveoli and gas exchange… we had been doing the topic for quite a while, and this was the end of the topic to just give us an actual insight into how it really works because you can't really see it in a text book and you can't imagine it that well but when you get the VR… you can see it properly you get a clear insight into it.

Researcher: So do you feel that you understand alveoli and gas exchange better now as a consequence of using VR?

Student: Yes because… it helps you more than it doesn't help you. It helps you because you can develop the bigger picture… whereas in a text book it just tells you the facts, sentences that you need to know for the exams… when you have a look at it in VR, it actually gives you the experience… so you can know what's going on inside the body.

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"I wasn't too sure at first because I thought everyone would get too distracted and when it's not your turn, you wouldn't be able to get on with work as much. But then you can't have super short goes on the VR headset because then it wouldn't be as beneficial, you would have to have a fair amount of time on it to be able to take something away from that and have a sort of learning experience from it. But then when we actually started it, it was actually very surprising… obviously the first time everyone was just watching and it was all exciting but… further towards the end everyone was just getting on with work. I mean, it was still very exciting and it's a nice prospect thinking about it, but… you can still get on with work while someone is still in the room doing VR."

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Some of the comments in this theme related to the idea that students can learn at their own pace through VR:

"There are so many uses for it that will improve what we have now to make learning more immersive and make things easier to learn, and more inclusive to all sorts of people. it's not like we all have to look at this for this amount of time and then we will move on, you can just look at something until you understand it and then move on at your own pace. So it gives you a degree of flexibility rather than everybody just going at the pace of the teacher."

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Researcher: Do any of the apps that you have used, could they be used to help students with their academic learning?

Student: Yes I think so… because with a static presentation by a teacher, you have to look at that one thing. you know "we are learning this at the moment" and if you already know it you just have to sit and wait. Whereas with VR, it's easier… you put a headset on and there are multiple topics you can do, and you can do the all the topics at your own pace.

Named subjects

As seen in 'The importance of specific subjects' section above, students were far more likely than teachers to cite specific subjects in which they felt VR/AR either might be beneficial, where they had already experienced it as being

beneficial to their learning, or where they felt VR/AR would not be suitable. Some examples of this can be seen in the following excerpts:

Student: Well for some subjects, you don't need to do VR… like in maths, you just do sums. But for English say, if you're doing creative writing and you just put the VR headset on and you actually get to walk around the scene that you're describing and you can look around and you can see the birds and the flowers and the trees… it helps you. But in some subjects it just doesn't help you at all.

Researcher: Which subjects do you think it lends itself to?

Student: Science… English… Geography, because you can explore all the continents… a bit like Google Earth, if you had a globe where you could just go somewhere. History might be quite good because you could explore medieval places, and you could see what it would have been like 200 or 300 years ago. But yeah not all subjects need VR.

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Researcher: Do you think VR can be used to help people learn better?

Student: There's a lot more information input that you can receive in classroom… you usually have the teacher writing on a board and then you copy it down, and that's like a couple of sentences within a minute. But with [VR/AR] you have multiple fields of view which you could look at, and have multiple information streams. And in things like Geography, you could have coral reef and you could go into that without flying to Australia… And in Art lessons, people were replicating what they were doing already in their projects, which was good but I don't think anyone realised that we could have done a lot more than what we were currently doing. We kind of did it on a 2-D platform, but nobody really did anything in 3-D which is a possibility that would be better to explore.

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Researcher: Can you think of any ways in which VR could help people to learn within those academic disciplines?

Student: I think I will use Biology as an example. There's a thing called YOU by ShareCare, it's the body and inside a cell. Normally you watch a small GIF on the whiteboard, it's just following a cell… it goes round and round the body and it's the life cycle of the cell. Whereas with these things, you can watch it as it goes through each vein, as it goes through the cycle. It feels like you're in the vessel, inside the blood vessel. So it's more immersive. Much more immersive.

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"I see a lot more application in sciences in terms of what it can actually be used for. Especially in computer science and coding, because there's a difference between you creating a coding or scratch thing with coding knowledge you've learnt, and then building a virtual world that you can then walk around in and edit different things and see it change in VR. So in terms of ICT, computer science, that sort of thing, I feel like it's got an application there. Sciences… when I was having a previous discussion about this, we thought about running simulations. So a similar way to how NASA would run a simulation to see how a rocket would perform under this situation, you could view what's going on during that simulation or during a more dangerous chemistry experiment which you wouldn't be able to do in school, you could do virtually because you could have all the equipment laid out and everything could work reasonably seamlessly like that. As far as Maths and English are concerned… I see less of an application for English. Obviously, you could see a play in VR or something like that, but I don't think it's as useful as something like IT. But Maths, in the earlier years not so much, more when you get into higher up the school when you start to do differentiation / integration type things, when you can see how things are physically… And obviously maths combines well with the Physics aspect… at the moment we're limited by what technology has created for us, because obviously you've got to make the platform and then make everything which you then put on top. But I can see there being potential for it, even if it's not there currently."

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Researcher: What was the context in which you used it, did this link to Geography?

Student 1: Yes because we were learning about Mumbai and how it's a city of contrast, and it was really cool to see how it actually is, and how there are some really tall buildings and things like that but then there are also some really poor areas. But she didn't really have any pictures to show us, so we didn't really know what it was like.

Student 2: At first we all went to our houses, and then we saw what it was like walking home every day, comparing real life to virtual reality, and then after that we could go to a place we've been studying in Geography, and we've studied Japan so I went to see Tokyo.

Student 3: I went to Mount Fuji.

Researcher: And did you find it helpful?

Student 3: Yeah because like sometimes you can't really picture it if it's just a flat picture, but you can go overhead and get a birds eye view, so if you're learning about Mount Fuji you can see it as though you're flying there.

Visualisation / memory / immersion / interactivity

As seen in the teacher interviews, when students were asked why they thought VR/AR might help facilitate learning, they often made comments relating to the ability to visualise concepts, or to the idea that immersive and interactive environment is more memorable:

> "I am a visual learner because I have a photographic memory, so when I was in there I had a look around and I can remember the experience quite well, quite visually… and I can remember… what was there so that helps me… if we're doing a test on it I can just get that back up in my mind, remember what I did in the VR headset and answer those questions based on what I did in that immersive world that has been created for me."
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> "I didn't personally do it, but some other people did and I could see what they were doing, where they went inside the lungs… they could see the alveoli and it was very visual and quite real, it was like expanding and you could see all blood flow. I wasn't personally in [the VR experience], but some of my friends were and it was on the big screen so we could see what was happening, which was cool because I could still understand what was happening inside the headset. And that day with the lung dissection, it really helped us understand what we were about to go and do in the lesson, and what actually really happens in the lungs."
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> "You could visualise what was happening in the lungs on a microscopic level. Because in a lung dissection you can see the tubes getting smaller but you can't really see alveoli, you can't see the blood flow because the alveoli are microscopic, so it was quite nice to be able to see that in detail."
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> "In VR you can really get a sense of what's happening inside you. When you are revising, sometimes it's pretty boring because you don't have any fun. Some people like to visualise things and other people like to do it, just read textbooks to learn the facts. But if you visualise what's going on, it's really helped you understand so that when you're in the exam, your mind has more to think about than just the textbooks because you can think "I remember that because I have that experience as a memory…"
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> Student: When you do a text book, you're going to forget about that because personally from my experience I find textbooks quite boring, and I find VR much more fun and interesting so that's probably much more memorable. I can remember what happened in that VR experience

more than in a diagram, and so I think that's probably better because it's more memorable.

Researcher: Why do you think it's more memorable?

Student: Simply because it's really immersive, and you feel like you're there and you can start to understand how it works, whereas in a text book it's on a piece of paper and you have to read it all and you have to do all of that note taking. And you have to do it for a while. Textbooks are still good, if you look at them for a while you can start to understand the parts. But when you come away from it you weren't immersed in that world of what's actually happening. Where is when you are in VR you are immersed.

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"I think there's a lot of potential in the academic side of virtual reality, talking about the different games and experiences you can try. ENGAGE is one we had been trying to get working, I think we've cracked it now, where you can really engage with other people and interact with them, and I think it is that interactivity that will drive it forward because ENGAGE is really simple. It's a meeting, but it's in virtual reality and as well as it being a meeting you can go to different places, you can take your group to different places to experience the same thing… you know you are all experiencing the same thing, you can speak to each other and I think it is that that is one of the most important things. School will never become all virtual reality because interactivity is one of the main reasons you come to school, and it's one of the main reasons people play games or go out with friends, to do things because you are with other people… you can enjoy it together you can talk together be interested together and so I think it is that interactivity that will hold together and it's what needs to really be thought about.

Non-cognitive – careers

One notable difference between the student and teacher interviews, as well as in the surveys, was that students were more likely to consider the ways in which VR/AR technology might help them access information about future career paths, as can be seen in the following excerpts:

Researcher: Can you think of any other ways VR might be useful?

Student: Workplaces - it can be used to sell flats. In Dubai, they sold all the flats very quickly. Also design, architecture…

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"I guess with VR it's all about the immersive experience… maybe if they made extra things, more multi-sensory inputs… especially with cooking, that would be amazing you could smell what it's supposed to smell like if it's cooked correctly… or maybe if

they got a chef to do a really good meal, people could look through their eyes and then imagine doing the same thing, so you could see how rare the meat has to be cooked or whatever."

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Researcher: Do you think that VR is more suited to recreation and playing games, or do you think it does lend itself to learning?

Student: There's lots of uses. I wrote about this a few weeks ago, you can use it for all sorts of things… it's being used for young doctors to learn to practice without actually putting anyone's lives at risk. It can be used to help with mental trauma like PTSD, you can be put in a scenario similar to the ones you were in before… to try and conquer that as you face your fears one by one in a controlled environment.

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"I suppose the way it creates an actual virtual reality, that leads to so many things that we can do that we can't do here. Looking at places in more detail, looking at houses, even building your house and then getting that evaluated by estate agents and architects… the same with cars, you can look at cars from inside, you can look at a wider range of cars because you're not limited to the dealership space."

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Researcher: Can you think of any other ways VR might be useful?

Student: Medicine. At BETT [an education technology conference], I used the HoloLens, and I saw a patient and I diagnosed them and I saw how it worked. And I see them being used now in the NHS to train up nurses I believe… you can walk around and have a look at the injuries without having to look at the patient. And in the future you might have a University interview where you go and put a VR headset on and take almost like a small aptitude test of checking over a patient, since now you have basically a test subject where you walk in and you say "do you mind if I, would you like to take your top off so I can check something, is that OK, is that painful" etc. Whereas in the future you might have immersive VR where you might touch them and have them go "ow", something like that.

Non-cognitive – empathy

As with the teacher interviews, students were asked about the potential role VR/AR might play in developing empathy. Although some students expressed scepticism at the idea, others were open to the possibility:

Researcher: Some people have described VR as an empathy machine, do you understand what they might mean by that?

Student: It's because you can use it to feel things.

Researcher: In your experience of using this technology, have you felt like you have had a truly immersive experience where you felt things that you wouldn't have otherwise felt?

Student: Well there is Richie's Plank which truly does give you vertigo… it makes you feel like you're high up, which just shows that VR at a high resolution high quality is just like real life. In Richie's Plank you put the headset on and you're in a lift with multiple floors. and there's a plank button so you hit the plank button and you'll go up in an elevator at the actual speed that you would in real life, and then the doors open and there's a plank sticking out the side of a skyscraper. When you look down below, you can see cars and a normal road very far below you, and you don't realise that you are standing on the floor, you think that you are standing on the plank. And then you need to jump off. but even when you're falling you feel scared that you are going to crash and then when you do land you feel scared that you have just landed and what's going to happen.

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Researcher: Some people have described VR as an empathy machine, do you understand what they might mean by that?

Student: Yes I think that's quite true you can put yourself in other people's shoes. but you could never feel exactly how they felt. So you could never completely understand what they were going through. you could partially understand but you wouldn't fully understand what was happening in their mind because everybody is different.

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Researcher: Some people have described VR as an empathy machine, do you understand what they might mean by that?

Student 1: Yeah because we've just been doing about earthquakes, and we watched tonnes of videos from Haiti but they were all sort of blurry, and they were really old videos. But if they were in a headset, they'd probably be a lot more real.

Student 2: You can't really relate to them or what it was like, but if it was in VR we'd all understand it a lot more.

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Researcher: Some people have described VR as an empathy machine, do you understand what they might mean by that?

Student: I see how it might help people develop empathy. Are we getting close to it? Honestly it's still a long shot. It's still early stages I believe. Even though it's coming along at such a fast rate, we're still in the infancy…. If I was in VR… say there was a dog, I could give him a cuddle and he sits down. Would I have empathy if I saw that dog in pain? Yes I'd have empathy. But we're still a long shot away from full empathy through VR.

Non-cognitive – seeing the world

Several students also discussed the opportunities VR offers for going on virtual field trips, for exploring parts of the world/Universe that they might not otherwise be able to visit:

> "I think if you are discovering things for yourself, often you retain a lot more information. That's why school trips are a thing. You go out and you'll see the world around you, and although they might point out different bits, all students pick up on different parts of life and different parts of the different scenes they see. And so [in VR/AR] you can really get the knowledge your way and go at your own pace, so you're not being pushed on or pulled back when you really want to explore in more detail."

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Student: A couple of weeks ago we started looking around the International Space Station and then you could go outside and do a spacewalk, and that's quite cool. And some of them were in sketch up and they were making a house.

Researcher: This space station experience, did you learn about science or was it more of a fun experience?

Student: It was quite fun but it was also interesting, and I think VR and AR could be used a lot more in the future for education. I think it would really benefit students in schools. VR would help, as in you wouldn't have to go on school trips to learn, you could just stay in school. If you're learning about history, you could get up an image that has been created, like for instance… using it to look at dinosaurs, which would be quite cool and it could show you all the information about them as well. It's a fun way to learn and it would benefit children because it's not just textbooks and writing down and copying answers, it's more like a way that you can get involved more.

Enjoyment

Cool / fun / amazing / enjoyable / exciting

The main difference between the student and teacher interviews was the extent to which students talked about VR/AR being enjoyable to use. As can be seen in the following excerpts, some students thought that having fun helps them learn things by making it more memorable; however, others were more circumspect, and thought that having fun might get in the way of learning:

Researcher: Can VR help us to learn? Is it worth the investment in terms of helping children to learn better?

Student: I think it is, because when a person is in it they can project the image onto a whiteboard so everyone can see it, and then they can switch turns so everyone can have a go at some point.

Researcher: OK, and so you can still learn in a visual way, but then you could argue that that's just the same as watching a video. You could you just project that image onto the screen anyway, and you wouldn't need the VR.

Student: Yes I guess that is an argument. But it's more fun to bring VR into the classroom.

Researcher: Yes and do you think fun helps people learn?

Student: Yes I think it does.

Researcher: Why?

Student: Because they're enjoying it more so they aren't just bored, and your brain is more active when you're having fun than when you're bored.

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"Sometimes when you have too much fun it's stops you from learning. If you have just a bit of fun it helps you concentrate because you're trying to have a good time but you're still trying to revise. But if you're having too much fun you think I can just give up revising now I can just do this. So it could over control the revising so that you don't get the revision that you're supposed to do.

Gaming

Another key difference between the student and teacher interviews was the extent to which students talked about the relationship between education and gaming, as can be seen in the following excerpts:

Researcher: Of the VR that you've tried so far in school, would you say that it's mainly a learning thing or mainly a play thing?

Student: They're trying to push it as an education thing. I went to BETT [an education technology conference] this year and everywhere it was VR, VR, VR… Do I think it will excel in education? To an extent. I think it's going to take years before you have a Biology lesson where you can go in and look around a cell in VR. That'll be years away. But what we're close to, I believe, is VR for computer science and game making. The sooner that's brought into the classroom, students will be more engaged. So yes it's an education thing, but it's come from games. Like the Vive is on STEAM - it's a gaming network.

Researcher: I see. So you see a role for coding… as in learning to code through VR?

Student: Yes - as in learning to code VR games. For example, Student X, who you spoke to earlier on. He did one with Student Y, they made a VR game and it actually worked in STEAM VR, which is quite cool.

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"Whenever you get a new technology like this, obviously you're going to experiment and I'm a gamer, and so I kind of applied that to VR already… obviously when there's something that's new and interesting you want to have a play, see what it can do about things that you already know. Because obviously it's a brand-new technology, and obviously you want to experiment with what you can do. I still think that there's an educational use for it, it's just that it's got gaming applications as well… Obviously with things like Google Earth and Super Hot, you can see the contrast between you playing it in VR or experiencing it in in VR and then going into the body and seeing how different cells work, to see the different levels that VR can be used on."

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"VR has lots of potential, like a computer… it's a completely different way of thinking about things, in terms of how you can apply it… In an educational contest, if you can get people so that they're playing around with it, they know what's going on, they'll be more educated as to what it is and then they'll be able to go "why hasn't someone done that?" And then someone who's very keen on IT comes along and says "how about we make this?" and then they go through with a teacher or someone and they start to develop it more and more. And as time

passes, more students come by, especially students that started coding in year 7, and they've had the experiences to try this that and the other, they will go "well why isn't this a thing? Maybe this could work" and then they can go ahead and develop it because they have the capability to do that. So right now it's in a very gaming-oriented spot, and that's part of what's driving the industry as well. It's just going to be the way it is, education is not going to purely invest in this so it's going to come from the gaming side of it. So it's got a lot of tweaks to make it oriented towards education. But in the future I see it having potential, and I think that's where we need to take it."

Comparison with textbooks

Several students expressed a preference to learning through VR/AR to learning through textbooks, as can be seen in the following excerpts:

"We also got to do a spacewalk, the ISS space station. It was more immersive because you got to do space walking and stuff. It was more fun than learning but you got to learn about gravity and about life on space stations up in space. It was like you're actually there, and there are little videos in the Oculus Rift telling you more about the space station, so it's better because it's people that are actually there at the moment telling you about it. So it would be more accurate than a textbook I guess."

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Student: It's a better experience than just sitting in the classroom with a textbook.

Researcher: Why?

Student: Because you're doing something physical rather than just writing it down. I'm more of a physical learner, so you can get more stuff in because you can touch information, it tells you all about it as you're looking at it so you get a better idea of what it actually is compared with a textbook.

Student: When you [use] a text book, you're going to forget about that because personally from my experience I find textbooks quite boring, and I find VR much more fun and interesting so that's probably much more memorable. I can remember what happened in that VR experience more than in a diagram, and so I think that's probably better because it's more memorable.

Researcher: Why do you think it's more memorable?

Student: Simply because it's really immersive and you feel like you're there and you can start to understand how it works, whereas in a text book it's on a piece of paper and you have to read it all and you have to do all of that note taking. And you have to do it for a while. Textbooks are still good, if you look at them for a while you can start to understand the parts. But when you come away from it you weren't immersed in that world of what's actually happening. Where is when you are in VR you are immersed.

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Student: [With VR/AR] it's fun and you're learning. In Science we went in the lungs to see all the different components in the lungs and the heart and stuff.

Researcher: How was that?

Student: Yeah, fun and learning. It's a better experience than just sitting in the classroom with a textbook.

Researcher: Why?

Student: Because you're doing something physical rather than just writing it down. I'm more of a physical learner, so you can get more stuff in because you can touch information, it tells you all about it as you're looking at it so you get a better idea of what it actually is compared with a textbook.

VR/AR

As in the teacher interviews, a number of students made comments about VR/AR technology itself. This theme incorporates comments comparing VR to AR, comments about particular software applications, and comments about the evolution, future or importance of VR/AR.

VR vs AR

Students expressed a range of views on the relative advantages and disadvantages of AR vs VR. As can be seen in the following excerpts, there was a general sense that VR will be more relevant to the classroom than AR:

> "I think VR is more useful than AR because it's easier to transform your surroundings and to to put yourself into a situation that you wouldn't be able to put yourself in in real life. And obviously when you're using AR, you can't really picture somewhere

else because you're just adding to the scene around you, but with VR you could be changing between scenes and really going places… like in simulations where you're training to do a job, if you were training to be a pilot so you could really be flying that plane. But… when you're in AR, unless you have extremely well-funded and well put together environment, you can't properly immerse yourself, so it doesn't get the same reaction and the same usefulness out of it.

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"AR and VR very different... mixing reality with virtual reality would be interesting because you could see how things could be, and how things could happen… and it makes you think "well what if this did happen what would I do in that situation?" And it would make your mind work on how to react to that situation which I think is quite interesting."

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Researcher: Which [AR or VR] do you think has the most potential and why? For school?

Student: I think AR… there's not a lot you could do with it… VR is where you will have more of the lesson planning I believe. But it's also the more costly and resource heavy.

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"I feel that AR hasn't got as many uses… I don't feel like it has as much potential as VR. That's because obviously VR puts you in a completely different situation where you're truly immersed in the world that you're in. Possibly going down the physics and maths route - engineering as well, artists. That's already there with things like Google Tiltbrush. But with Physics and Maths, you could make more simulations, running through scenarios. Also CCF [combined cadet force] running simulations for them - RAF, army, navy - flying a plane and so on. In terms of the technology we currently have, you're kind of limited to keyboard mouse or joystick. You haven't got as many options there. And then in the army you've got more simulation-based training. There is potential for all subjects to benefit from this technology because of the way that people learn - visual learning can help you in any number of fields, and obviously if you're in that situation you're going to remember it more because it's almost like an iconic experience."

Named software

A number of students made comments about particular VR/AR applications they had used:

"With Tilt Brush, it might just be my artistic talent but you can't really make things you see in the real world but you can make nice more abstract pieces. It may be more suited to abstract art than fine art."

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Student: We had a look at the International Space Station… you could read facts and there were videos that you could press on and stuff. that was the educational bit and then after that there was also a fun activity where you were in astronauts and you were moon walking in a way. And it was quite technical because you had to pull and twist the knobs to open hatches and stuff like that.

Researcher: And so that was done in the context of a science lesson?

Student: Yes because we were learning about the solar system and days and nights and seasons and how it works and how the Earth orbits the sun and stuff like that.

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"Tilt Brush is almost like a new art form where you can paint in 3D… you can't do that in any other way."

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"I only used Tilt Brush for 5 minutes. I was trying to recreate a piece that I've been doing in art on marbling. I was trying to do it near to my face and then far away from my face, and I found it really interactive it was really good. And you can teleport around in that space so you can look at it from different angles."

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"Body journey inside a cell. That's when I started thinking about applications in education, because I felt that that was an interesting way to learn about it. Because I did Biology up to GCSE level, but I feel like it's completely different when you're immersed in the situation… that was one of the main ones that stood out for me."

Evolution / future / importance of VR/AR

Many of the students made comments relating to how VR/AR has developed in recent years or how they see it developing in the years to come, or expressed the view that VR/AR is an important development, as can be seen in the following excerpts:

Researcher: If you were in charge of the school budget, would you invest in VR/AR based on what you've seen?

Student: I would buy a few headsets… one for each class so everybody could use it. But I wouldn't go and investigate that much into it because the technology is constantly changing. Not that long ago we didn't even have computers, so… if we have this now imagine what we will have 10 years in the future it will be a lot bigger and better. So I'd wait and see.

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"I think the Vive Pro is increasing its refresh rate isn't it? Sometimes it feels unnatural. You might put a headset on, it feels real but it doesn't feel real. It's got a sense of realism, but a) you know it's not real… you can almost not change that; and b) it's… sometimes, even if there's a bit of lag, it just breaks the immersion. And it just doesn't feel like it's all it's cracked up to be at times. So I'd just say "make it look more realistic". Let's try and do something like a Google Earth but make it feel like you're on the streets… make it feel like you're walking around in central London rather than looking around in somewhere that doesn't look that real."

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"I think new technologies should be looked at and always considered. I think a lot more should be done for the older generations as well as the younger generations to be able to try things out, to be able to try things that are new… history has shown us that's staying the same isn't always good. Change is useful and it is what drives things forward. So I think if more people were to see it and were able to try it, there will be a lot more drive and a lot more interest in it. So I think it's going to be really important and if I was the bursar I would want to try it and see for myself and I would then make my decision. Because you can't see everything from a piece of paper that someone has sent you saying I really enjoyed this, or this was a waste of my lesson time. so I think it's important for people to try it and then you can make your own decision not listening to the news or anything else."

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"The strongest argument for spending the money is that it has potential, loads of people are interested in it [and] it could do so many different things. For example, if you spent £1200 on some fancy equipment for Physics for example, it can only be used for Physics. If you buy [a VR or AR headset], it can be used in English, Biology, Chemistry, Physics, the Humanities… everyone is looking to try something with it. Let's say it would benefit 10 subjects. £1200, if you divide it out equally it's £120 investment for each subject, which is hardly a lot for that sort of equipment."

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Concerns

The final theme to emerge from the student interviews was a group of comments that expressed concerns around the use of VR/AR in schools.

Logistical issues / health and safety

The first code within the theme of concerns is comprised of comments relating to logistical problems with running VR/AR technology in classrooms and related health and safety concerns, as can be seen in the following excerpts:

Researcher: Tilt Brush first of all - what was your experience of that?

Student 1: It was quite hard to use, I kept pressing down. But once you got the hang of it, it was fine.

Student 2: We only used it for 5-10 mins. I kept on hitting people… bumping into people in the real world.

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"On Google expeditions I got very motion sick. It was a mixture of the low resolution… FOV [field of view] was OK but it was a low resolution and low frame rate. So it felt quite jittery on a still image… it didn't feel natural, whereas [with] the Vive - even though you know it's not real, it feels real."

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"In a lesson it wouldn't be very practical because you'd have to clear all the desks to the side, and you'd probably only have a few headsets and lots of pupils, so it's… fun if you do it for one day as a treat, but it's not something that you could probably realistically do on a regular basis just because… it takes effort to set up."

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"It was kind of blurry it wasn't the best definition, but I wouldn't expect it because it's the whole earth. And not all of the places could be seen, like we tried going to Stonehenge and the pyramids and that actually wasn't 3-D, so we couldn't see the pyramids or the places around it properly. I guess people haven't taken the photos there or they haven't programmed it properly in 3-D, or maybe people don't have permission to take pictures there."

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Student 1: With health and safety, if there are three people in a small room and there's one teacher, they could collide because obviously you can't see and also it could be quite expensive to have all of this kit, and it

would take a long time to get all the kit ready and also they might not understand how to do it.

Student 2: You have to teach everyone how to do it and then you might not have enough time to do it anyway. And also people have to wait around while other people are doing it.

Student 1: Yeah like there was only 10 of us and we only just had enough time in one period to do it.

Content not relevant / novelty

The final category of concerns related either to frustrations about the lack of relevant content currently available, or concerns about the 'novelty factor' wearing off after a short period of time, as can be seen in the following excerpts:

> "The way that the world is going, being more mechanical, based a lot more around computers, with people in the lowest part of the school doing coding a lot more, it could potentially enhance their learning quite a lot, especially if this happens to be the way that the world leads toward… we've got all these technological advances where you don't really know where they're going to end up, you didn't know that the internet was going to end up like this only a few years ago. There are so many different potentials for all these technologies. If you invest in it now, you could potentially give your kids quite a lot of a head start. I feel like that would be one of the main points, appealing to IT more than other subjects… I don't feel that the platform is ready for other subjects yet. It's more just waiting for people to come in and put their software on this platform. As of right now, it would be a lot more difficult to make the case for schools that don't just have the money."
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> "Whenever there's a VR event, everyone always walks out buzzing, saying "ooh that was really good". So you always have people talking about it. Will the novelty wear off? Possibly, if and when it becomes mainstream."

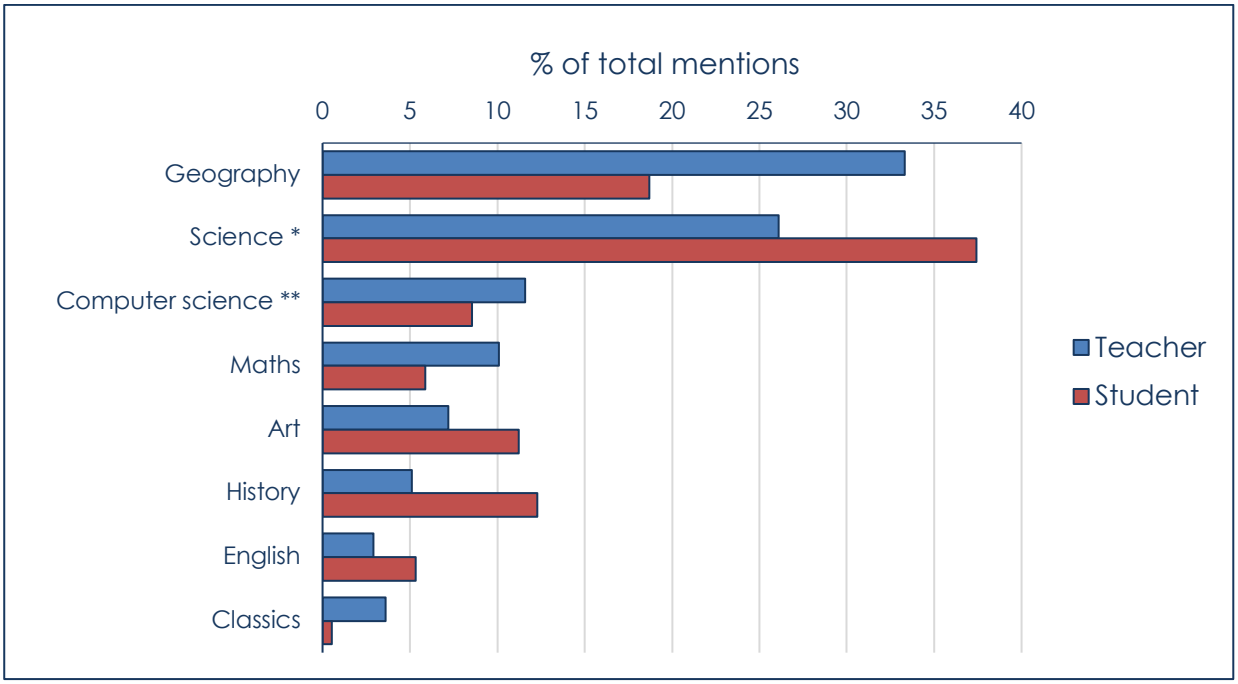
The importance of subject-specific content

Although this study sampled many more students than teachers, the combined text data from the surveys and interviews totalled 49,178 words for the teachers and 29,929 words for the students. The main reason for this difference is that teachers typically gave much longer responses to survey and interview questions; many of the teacher interviews lasted an hour or more, whereas student interviews lasted for an average of 13 minutes.

Despite the fact that teachers spoke or wrote almost twice as many words as students, students mentioned specific subjects 187 times, compared with only 138 times for teachers. A likely interpretation of this finding is that secondary school teachers tend to think primarily within their subject domain, whereas students are more likely to think about how something might affect all the subjects they learn.

The extent to which students and teachers referred to different subjects can be seen in Figure 11. This figure shows the proportion of total mentions that referred to each subject, for both students and teachers. Here, we can see that teachers mentioned Geography the most, followed by Science and computer Science. For students however, Science was mentioned twice as often as Geography (37.4% of mentions related to Science, compared with 18.7% for Geography).

Figure 11. Student and teacher references to specific subjects.



* Science includes references to Biology (4.3% teachers, 8% students), Chemistry (8% teachers, 2.1% students) and Physics (2.2% teachers, 7% students)
** Computer science includes references to programming and coding.

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