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A SERVICE DESIGN THINKING APPROACH: WHAT ARE THE BARRIERS AND OPPORTUNITIES OF USING AUGMENTED REALITY FOR PRIMARY SCIENCE EDUCATION?

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Abstract

It has previously been argued that Augmented Reality (AR) has the potential to provide relevant digital information to support pupils learning in real-time through engaging formats. However, the use of AR in the classroom remains uncommon for mainstream adoption. This study uses a service design methodology to focus on a more holistic approach toward AR as an educational service by investigating the challenges and conditions of integrating AR learning experiences into a primary curriculum. The research paper aims to provide an overview of how primary science (Key stage 2) in the UK is currently being delivered and where both barriers and opportunities occur for adoption to integrate more meaningful AR experiences that add real value to primary science education. An exploration stage (phase one) includes a questionnaire, contextual interviews, classroom observations, and focus groups. A thematic analysis was conducted on gathered data, identifying emerging patterns around teachers' needs. The discussion section empathises with teachers' needs and unearths key factors surrounding the implications of using augmented reality for primary science education.

Keywords – Primary education, Service design, Augmented reality.

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1. Introduction

The importance of teaching science remains widely acknowledged, within the context of the STEM agenda. However, research shows (Wellcome Trust, 2017) that primary teachers within the UK education system are now only managing to devote on average 1 hour and 24 minutes per week in teaching science. Moreover, primary science remains outside the dominant markers for accountability with no requirements placed on schools for the delivery of a specific number of hours of science teaching per week. This situation has the potential seriously impact upon the depth and breadth of science being understood and considered as a future career choice. The Aspires 2 project (Archer, Moote, MacLeod, Francis & DeWitt, 2020), highlight that addressing these challenges, and thereby building science capital, requires long-terms changes to core pedagogical practice starting as early as possible in primary schools and is the responsibility of policy makers to focus on 'building science capital' at an earlier stage of a child's education.

Novel developments in Augmented Reality (AR) technology – and the proliferating of mobile devices with built in cameras that can put these developments in the hands of children at a comparatively low cost – have been widely lauded as offering the potential for new content and teaching practices that may address these challenges. Huang, Chia and Wen (2016) argue that AR presents opportunities to move away from lecture-style teaching and use the medium in educational environments to create practical and highly interactive visual forms of learning. For example, Dede (2009) considers whether exploring forces, investigating materials, or analysing atomic structures, using use of Augmented reality offers the unique affordances to engage learners using text, videos, sounds, animations etc. to conduct investigations. Other studies argue (Billinghurst, 2002; Klopfer & Squire, 2007) AR has numerous benefits for the augmentation of teaching and learning environments, enabling learners to experience scientific phenomena that are not possible in the real world. Chen, Liu, Cheng and Huang (2017) reviews the use of augmented reality in education from 2011 to 2016 and conclude, from 55 studies published, that AR in educational settings leads to better learning performance and motivation. Other studies (Kerawalla, Luckin, Seljeflot & Woolard, 2006; Bistaman, Idrus & Rashid, 2018) specifically demonstrate AR provides a positive impact on a teaching and learning experience for primary science education.

Despite this growing body of previous research highlighting the rich potential of AR experiences in support of science teaching and learning, uptake in classrooms remains low. A study by Silva, Roberto, Radu, Teichrieb and Calvancante (2019) found that although educators did recognize the potential of AR, the adoption of such technologies within mainstream schools is rare. We hypothesise that one of the key reasons for this lack of uptake is the challenge of employing AR within the constraints imposed by the day-to-day delivery of learning in real classrooms (e.g., curricula, infrastructure), as well as the potential lack of alignment between the functionality of existing AR apps and user needs. Other studies (Akcayir, Akcayir, 2017; Wang, Callaghan, Bernhardt, White & Pena-Rios, 2017; Radu, 2014; Yuen, Yaoyuneyong & Johnson, 2011), suggest educators and designers need to collaborate in terms of creating sound pedagogy to develop AR applications that maximise on learning outcomes. Weerasinghe, Quigley and Ducasse (2019) examined educational AR applications and discovered the majority of those which increased in the marketplace over the years focused around natural science areas.

In this paper, we aim to inform the design of AR experiences for primary science education that will have a higher chance of classroom adoption. We do this by exploring how primary science (Key stage 2) is currently being delivered in the UK and where both barriers and opportunities occur for adoption to integrate more meaningful AR experiences that add real value to primary science education. We follow a 'Service Design Thinking' approach in our study. Stickdorn, Hormess, Lawrence and Schneider (2018) outline service design as an inherently holistic approach that considers an entire service through collaborating with key stakeholders as part of a co-creative process. In adopting this holistic approach –which is attuned to consider not only the potential functionality of AR applications, but the broader challenges and conditions that surround the use of AR in real classroom settings– we hope to uncover insight that will be genuinely useful for designers wishing to create experiences that can be usefully and practically integrated into the complexity of a primary science classroom and curriculum.

Our study focuses on the exploration stage of a service design approach (e.g., comprising questionnaires, contextual interviews, classroom observations, focus groups). By empathising with a target audience and conducting various exercises, this stage of the process has unearthed where barriers and new opportunities may lie for integrating augmented reality into primary science education. Further research investigations will follow the design methodology across both the creation and implementation stage, where these initial results will help to inform design decisions from a practical perspective. In the meantime, our current findings provide general value in establishing the parameters of understanding users' needs. This study begins with an exploration stage, (questionnaire, contextual interviews, classroom observations, focus groups). By empathising with a target audience and conducting various exercises, the study has unearthed where barriers and new opportunities may lie for integrating augmented reality into primary science education.

2. Study Method

2.1. Research Methodology: A Service Design Approach

In this paper, we present a study exploring teachers' opinions on using Augmented Reality to support primary science education, specifically focussing on i) identifying where challenges and opportunities occur for integrating augmented reality into primary science; and ii) understanding user needs to create a more meaningful AR learning experience.

Our aim was to gain a holistic insight into how AR experiences should be best integrated into contexts of primary school science teaching. Therefore, we chose to employ a Service Design approach for our investigation. Service design adopts a designer's approach towards tackling a problem where it initially investigates the need of an end user, transitioning onto rapidly experimenting and prototyping. When we are challenged to provide better services and end -to end customer experiences, 'service design' uses a pragmatic iterative approach towards developing whole new propositions particularly based on new technologies. Today, we can see AR is being used in many sectors to transform a customer journey through unique experiences. Brown (2009) acknowledges that an everyday device is already considered a service – a mobile phone that connects us to a network of telecommunications – and the lines between product and service have become blurred. Following the four iterative steps, this study focuses on the 'Exploration' stage: conducting an online questionnaire, empathy mappings, classroom observations, contextual interviews, and focus groups.

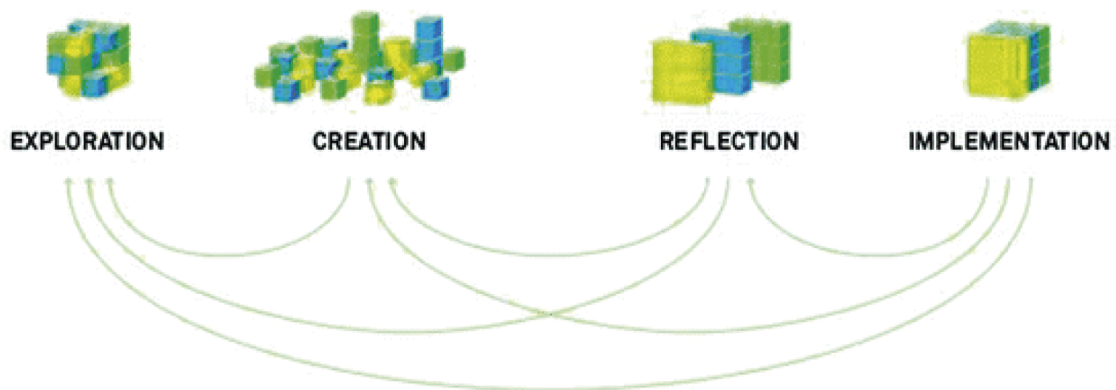

Figure 1. Service Design Thinking Process

2.2. Procedure and Participants

Considering a service design approach, data collection was undertaken through numerous methods such as desk research, self-ethnographic, participant, non- participant, and co-creative workshops. The combination of activities helps to improve the accuracy and richness of the research by using various methods, where different data output, (in this case field notes, interviews, observations, photos etc), provide a triangulation of data that enables this study to support findings with different underpinnings. A key partnership was formed with an Academy Trust based in Yorkshire, who support school hubs in York, Selby, Yorkshire Coast and in the East Riding and the Humber. All schools and teachers were selected by the Director of Communications and Development to ensure a diverse range of backgrounds. All participants who were involved in these activities were identified and recruited by the Communication and Development Director for the Academy Trust, considering experience, specialisms, age, and gender. The sequential order of investigation followed.

2.2.1. Questionnaire

An online questionnaire, 'A Research Survey based on using Augmented Reality to teach Sciences in Primary Schools', was circulated across England inviting primary school teachers to respond to a set of ten key questions around primary science and the use of augmented reality. An integrated video helped to explain Augmented reality for those teachers who were not so familiar. The purpose of this study was to understand more about how primary science is taught within schools and teacher's perceptions around using AR technology in the classroom.

The subjects of this study are schoolteachers who have experience in teaching primary science to key stage 2 pupils. Subjects were recruited by sending the questionnaire to primary schools across the Yorkshire region, and organisations such as Association for Science Education (ASC), Centre for Industry Education Collaboration (CEIC), Science Community Representing Education (SCORE), Digital Schoolhouse, Primary Science Trust, and North Yorkshire Business and Education Partnership (NYBEP), as well as, being distributed across social media platforms (Facebook, LinkedIn). Overall, 57 primary school teachers responded across a period of several months.

2.2.2. Design Sprint

A focus group studied more in-depth analysis of the 'exploration' process by engaging teachers over a two-day design sprint. The purpose of a focus group was to understand a group of primary teachers' perceptions, problems, ideas, and attitudes towards using augmented reality.

Day one (school campus) focused on defining the benefits and challenges of using Augmented Reality in school. Participants were introduced to several AR software and hardware platforms (Merge 3D, Zappar, Magic Leap) and asked to present ideas where AR may play a role in primary science teaching. Day two (online) was conducted using collaborative software (Mural), where several sets of data mapping were created (stakeholders, empathy, assumption), as well as, reflecting upon previous data findings from the questionnaire to identify commonalities and differences. Stakeholder mapping helps to understand any internal and external groups or persons who are involved in a project to build empathy; it allows a designer to reflect and identify key stakeholders, their expectations, and relationships between them to communicate more effectively. The empathy mappings dig deeper in understanding user needs and types of people we are designing for, whilst the assumption mapping allows a designer to step away from established assumptions, looking at a certain topic with a fresh approach.

The focus group involved engaging with six primary school teachers from an academy trust who teach in a range of socio-economic backgrounds from a wider Yorkshire region. Two participants were male and four were female.

2.2.3. In-Depth Interviews

We also held in-depth interviews to gather different perspectives of primary teachers' thoughts about the application of augmented reality for science learning. Interviews were conducted with ten primary school teachers associated to an Academy Trust based in Yorkshire. All interviews were conducted online using Google Hangout and video recorded having participants permission. Teachers were identified from a wider socio-economic background, age, and experience. Two participants were male and eight were female.

Several questions were preprepared in advance as a catalyst to stimulate non-leading questions, whilst examples of Augmented reality were shown to help participants on their understanding of AR. All interviews lasted approximately one hour for each session.

2.2.4. Non-Participant Observation

A total of three classroom observations were conducted to observe the teaching of primary science from a distance. The observations allowed to identify the types of activities introduced into the classroom and behaviour of both teachers and pupils. Key findings were recorded using photographs, field notes and sketches. Each session lasted around approximately three hours and was conducted across two primary schools based in Yorkshire.

Non-participant observations were conducted through observing both science and technology leaders (who participated in a focus group) in the classroom. The aim of this research activity was to level out any biases in other methods and to reveal any differences of what they said during the focus group in comparison to what they did. Furthermore, this included observing one more participant to note both teaching and activity styles.

2.2.5. Pre-Ideation

Stickdorn and Schneider (2018) explain ideas usually represent one or several points during an evolutionary process. Due to the service design model being an iterative procedure we can reshape a concept during any part of the four stages. At this stage, we simply look to generate a multitude of preliminary AR ideas that evolve back and forth, eventually arriving towards a point where a design solution can be approved by all stakeholders.

A focus group was asked to undertake a few exercises, 'part-sketching' and 'crazy 8s.' Knapp, Zeratsky and Kowitz (2016), designed the crazy 8's for participants to loosen their creativity by spontaneously drawing eight ideas on paper in eight minutes, allowing teachers to be free from their own inhibitions and to think more divergently about choices. Where empathy is not applied to understand what the user wants, design usually fails to perform a useful and meaningful function. Focus group sessions helped to perform several empathy mappings (stakeholder, empathy mappings, assumption grid). These various mappings produced noticeable themes around teachers' opinions on how AR can play an integral role in teaching primary science and where barriers exist for adoption in relation to an overall service.

3. Data Analysis and Findings

Both qualitative and quantitative data was collected during the research process. Qualitative data included responses from the questionnaire, collecting lesson plans, keynotes from observations, transcripts from contextual interviews, and recordings from focus groups. Qualitative data analysis computer software (NVivo) produced emerging patterns to steer the direction of the study. Data was analysed using a reflexive thematic analysis based upon Braun and Clarke (2006), to identify, analyse, and report patterns (themes). In the following sections, we discuss a selection of these themes that highlight where the barriers occur, and opportunities lie for using Augmented Reality for primary sciences.

3.1. Where do Barriers Occur for Using AR from a Service Perspective?

3.1.1. Affordability & Investment

School budgets and resources are a concern for teachers. The online questionnaire revealed (Table 1) one of the main challenges of primary science was funding for new resources (22%). These results reflect the dominance of maths and English subjects in England. The contextual interviews reaffirmed these findings, where several teachers expressed not all primary schools operate on the same 'level playing field'. There are discrepancies within how school budgets are being allocated and prioritised. Teacher's responses included, *'It's funding. Nobody has any money, so it's not ideal',* in some cases highlighting schools within deprived areas are having to share devices, in comparison to affluent ones who have the capacity to distribute a device to every pupil. This is a significant factor if schools are to adopt AR – whether key decision makers or senior leadership teams are prepared to invest in portable devices and provide adequate resources for teaching. During a design sprint, teachers ask, '*Is it worth the money?*' *'Is It just another fad?' 'How will this have an impact on my pupils?'* '*Is AR cost-effective?'* (Figure 2 & 3). There is a clear consensus amongst science leads, teachers, and Senior Leadership Team, to invest in AR requires visible benefits for teaching and learning primary science, where teachers ask, '*How will this have an impact on pupils?'*

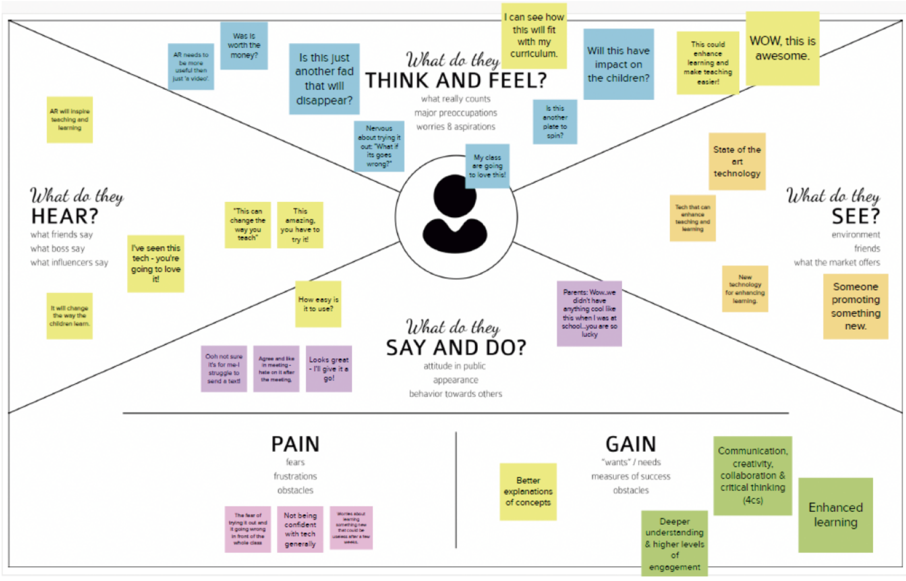

Figure 2. Empathy Map (Design Sprint)

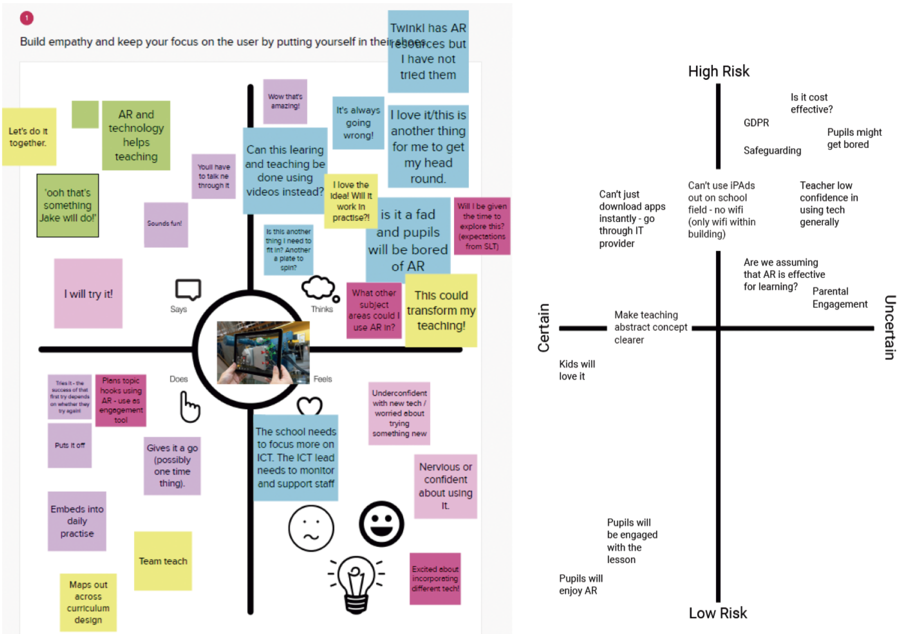

Figure 3. Empathy Canvas Map & Assumption Grid (Design Sprint)

3.1.2. Attitude & Confidence

Teachers reported (Table 1) on having low self-confidence in teaching sciences (10%), due to lack of time available teaching primary science, whilst contextual interviews (6%) of teachers referenced challenges of using augmented reality in a classroom environment (Table 16). Teachers expressed their anxieties, questioning whether AR can be an asset or hindrance to a teaching process, highlighting their fears and frustrations (Figure 2 & 3), '*not being confident with tech generally*', '*nervous about trying something new and what if it goes wrong?*' Contextual interviews reported further AR challenges of teacher's attitude and inadequate training (31%) being a barrier (Table 16), revealing there is resistance from colleagues towards using new technologies as opposed to traditional methods. '*Why change your delivery if it works?* Some interviewees reported on changing teachers' mindsets to think differently about new technologies, especially in the context of an older generation who are more accustomed to a traditional delivery. They highlight a need for (CPD) to enlighten and change the attitudes of staff members who may not be digitally literate or feel apprehensive using EdTech. Design sprints revealed one of unease. '*How will it work in practice?*' '*You will* *need to talk me through it.' 'What about skills training for teachers?'* These reactions emphasise teachers require further training and background knowledge in how augmented reality can support their own teaching, as well as, offering training to operate such applications with an element of competency. Teachers asked, '*What are the benefits of using AR in lessons?'* There appears to be a lack of understanding and limited background knowledge, suggesting teachers require better AR support and training for adoption.

3.1.3. IT Infrastructure

During the design sprint, teachers asked, *'Are schools AR ready*?' This study shows teachers are using iPad devices more readily (29%), followed by Chrome Books (15%) within primary schools (Table 11). However, the contextual interviews referenced a frequent use of Chrome Books due to accessing a cloud-based platform, where (32%) of teachers referenced using google classroom (Table 9) as a way of interacting with pupils. The information technology lead commented on, '*We invest in chrome books as we feel they are the most appropriate device in line with our vision and pedagogical approaches. I feel in the future we will hope to invest in chrome books that convert into tablets*.' Teachers viewed gaining access to devices (12%) as being a barrier to using AR (Table 16), where the contextual interviews highlighted the disparity between schools dealing with limited budgets may only have the capacity to offer shared devices, in comparison to more affluent ones who may distribute to individual pupils. One teacher reported, '*You see other schools doing fab lessons, and the kids with a device each. At the end of the day, you can't do what you've not got.'* Internal distribution of devices is a real problem, where this study reveals a higher proportion of teachers (64%) are managing class sizes of 30 above pupils (Table 6), that will impact on the development of an AR experience. Another aspect focused on the reliability of an internet service, revealing a small proportion (9%) of teachers reported on poor Wi-Fi connectivity (Table 16), and design sprints uncovered teachers viewing 'high risk' and 'uncertainty' of a Wi-Fi signal when undertaking science activities outside of the main school, '*We can't use devices outside on school fields.'*. Downloading content has barriers for AR where teachers have IT restrictions on instantaneously downloading content onto devices (Figure 3) due to safeguarding children. '*We can't just download apps – without the authority of our IT provider*.' Whilst this is understandable for safeguarding children, it does pose a barrier for time preparation when wishing to use an application.

3.1.4. Time Preparation

Time allocation for primary science (23%) was shown to be challenging for teachers (Table 1) where limited time has the potential to compromise on quality of delivery. A higher proportion of teachers (Table 7) are delivering science lessons for a duration of under 2 hours per week, to even ranging from only teaching 1 – 2 hours on average during half term time for some schools. Consequently, the contextual interviews evidenced time allocation was viewed as a barrier for AR adoption (9%) due to organising time to learn an AR application (Table 16). Furthermore, during the design sprints teachers questioned (Figure 3), '*Will we be given time to explore AR*?' They already feel under pressure to perform for the senior leadership team without implementing more technologies into the classroom. Given teachers have limited time preparation, they asked, '*How easy is AR to use?*' (Figure 2) – suggesting an AR experience needs to be intuitive to use and set up, where teachers are exploring quicker alternatives to help in their delivery by accessing educational online sites (Table 12) such as TWINKL, Explorify, YouTube, Association for Science Education, BBC Bitesize etc, downloading content to support their classroom delivery. One teacher described, '*I download resources as they are child friendly in the sense of eye-catching, matches the curriculum and vocabulary'. You can also edit any of the sheets and use it for a particular science unit*.' Another factor impacting on time preparation (Table 1) are health and safety restrictions, where teachers are required to assesses any practical activities that may involve storing or using equipment, observing chemicals, and arranging an outdoor expedition.

3.2. Where do Opportunities Occur for Using AR for Primary Science?

This section concentrates on how augmented reality can support a primary science curriculum. It was essential to understand what educational technologies they are currently using to benefit their own teaching and how they perceive AR as being of benefit to their existing curriculum delivery.

3.2.1. AR in the Classroom

Teachers do evidence introducing Virtual or Augmented experiences into the classroom using several applications (Google Expeditions, Virtuali-tee, Aurasma, Merge, WOW experiences). Design sprints revealed teachers considered AR as being state of the art technology to support science teaching.

Our study shows (Table 10) teachers have used AR in the classroom (28%), where (72%) had never used it. Moreover, these activities are commonly reported as being 'one-off' engagements and highlights AR is not considered a mainstream technology being used in classrooms. A general perception of teachers expressed (interviews, empathy mapping, questionnaire) AR technology being used as an enhancement tool, rather than a replacement for real practical experiments.

3.2.2. Curriculum Alignment

From analysing the data on curriculum frameworks (Table 2), it is evident most teachers (87%) are following a standardised National curriculum in England for science programmes, whilst others refer to using supplementary resources where schools provide additional funding streams. The consensus amongst teachers was that (design sprint, contextual interviews) any AR experience will generally not be adopted unless it's aligned to the National curriculum framework. Furthermore, teachers expressed the need for designing clear pedagogical goals, making it easier to assess pupil's progression and demonstrate where AR can be impactful during the process. In terms of subject topics, AR was seen (Table 15) as beneficial for explaining the human body (26%), habitats (22%) followed by (15%) solar system, (11%) animals, (10%) materials, (9%) plant systems, (5%) forces), (2%) light and sound and (1%) seasonal changes. Teachers imagined getting up close to animals, discovering dinosaurs, sea creatures and micro-organisms. Other areas included analysing materials, such as toxic substances, and rock formations where AR can help to three-dimensionally visualise structures without being dangerous to pupils. Furthermore, teachers described using AR to show inner workings of a plant system, effects of forces, pathways of sound and seasonal changes. Such topics highlight a diverse range of curriculum avenues to investigate, where one teacher raised, '*A science curriculum is broad, so how will AR react to any updates*?'

3.2.3. Cross Curricular

During a design sprint, teachers reported on delivering cross-curricular activities as a way of using limited time more effectively. Barnes (2015) defines cross-curricular learning as the experience, at a macro level, of using the skills, knowledge, and attitudes of several different disciplines to address a single experience, problem, question, theme, or idea – seamlessly aligning with science principles. Although the questionnaire showed a lower response rate for types of teaching using cross-curricular learning (Table 3), these responses demonstrate in some cases a shorter period is being allocated for explicit science teaching, plus an additional period for wider curriculum topics that link to other subjects. Contextual interviews reinforced these previous findings where teachers are exploring more ways of embedding science into wider curriculum topics. A teacher expressed, '*During the week, you do not have anytime – so, when possible, we are trying to work cross-curricular.'* Teachers referred to combining science with history, linking forces, literacy, and storytelling. STEM (Science, Technology, Engineering and Mathematics) was frequently raised in connecting science to other subject areas, where teachers are already downloading online STEM resources (Table 12). Teachers commented, *'STEM is something we are integrating into our teaching to combine science and design technology - we use STEM to analyse materials and the movement of transportation'*. Due to science subjects being less valued, more emphasis is placed on English and mathematics. Scientific vocabulary was another factor where contextual interviews raised linking literacy to science for cross-curricular purposes, a practice encountered whilst conducting classroom observations. Teachers highlighted (Figure 5) the possibility of having a shared resource accessible to all. Given cross-curricular embraces a variety of subjects, this provides an opportunity for increasing an uptake of AR applications where multiple strands of topics can engage a broader audience through collaboration and unite them.

3.2.4. Connecting Science to Real Life

A higher proportion of teachers (43%) viewed augmented reality as being a useful medium to connect science to pupils' everyday lives (Table 13). They expressed the importance of pupil's recognising how science links to the World around them as a form of engaging pupils (Table 5). One teacher commented, *'Pupils make the best links when they can relate science to their own lives.'* References were made to pupils being engaged by a hook – whether through a picture, question, story, film, or discussion of different perspectives to a problem; they like to discuss their views and question why. During a design sprint, teachers asked, (Figure 5) *'How might we connect AR science to everyday things?'* Key factors were raised around AR being able to visually demonstrate aspects of science on a microscopic level, describing '*to bring science to life where it can't usually be seen'*. Similarly, teachers viewed AR (Table 13) as being a powerful tool to visualise abstract concepts (33%) when trying to explain scientific phenomena. They expressed, '*AR helps children to step into their own learning'* and *'understand concepts around forces, changes of state.'* A design sprint reiterated these findings (Figure 3) where the assumption grid showed teachers are 'certain' AR will make abstract science concepts far clearer.

3.2.5. Science Capital

Science weeks and career fairs are seen as part of motivating pupils (Table 5). The contextual interviews, uncovered most teachers create science exhibitions or some form of displays towards the end of term, showcasing aspects of STEM related activities or using specific science themes. They expressed using augmented reality as an opportunity to create unique interactive experiences during science weeks to encourage pupil engagement. Furthermore, teachers viewed exhibitions as a way of promoting science capital describing, *'we sometimes try to get parents involved and for pupils to talk about their own work'*, especially for those disadvantaged pupils sharing their experiences to form stronger bonds. From beyond the classroom, a smaller proportion of teachers (Table 14) referred to using AR as a medium to be shared with parents for remote learning (8%) undertaking tasks and challenges that help to stimulate conversations around science. A teacher expressed, '*AR presents opportunities for collaboration and good school links*' where teaching methods such as a flipped classroom and project-based learning connects a science curriculum to real-life and classroom activities (Table 3). Project-based learning was a popular form of homework activity (26%), where teachers viewed AR as being a medium to share and engage with parents from home, helping pupils to link science to their everyday lives and share their findings during classroom periods (Table 8).

3.2.6. Learning Through AR

Practical activities (43%) were considered the highest motivating factors for pupils to learn science through 'learning by doing' (Table 5). Teachers viewed augmented reality (Table 14) as a medium that actively engages pupils (20%), as well as, enabling pupils to take ownership of their own independent learning (16%). During the contextual interviews, teachers highlighted an 'Ofsted Deep Dive (OFSTED stands for the Office for Standards in Education, Children's Services and Skills) with one teacher explaining '*Ofsted are looking at more interesting and creative ways to deliver curriculum*.' Therefore, senior leaderships are exploring new approaches to engage pupils and viewed AR as a unique medium through 3D learning. Given teachers are using videos (20%) as teaching aids (Table 4), they regarded AR as being an extension to enabling 3D models and animations to show abstract concepts. Teachers undertaking activities such as 'part-sketching' and 'crazy 8' (Figure 4) generated several loose AR concepts. These ranged from interactive floor maps, scanning objects to explain science, through to understanding circuits. Most commonly, all participants designed an instructional approach, depicting science topics around particles, forces, digestive system, plants, electrical connections, human body etc, serving as a stark reminder around a broad science curriculum when designing an AR experience. Emphasis was placed on using instructional methodologies including clear objectives; this method was equally supported for remote learning where teachers highlighted guidance is crucial, as software vulnerability may lead to a negative impact within and beyond the classroom. Teachers viewed AR being used remotely by pupils at their own pace whilst offering the opportunity to engage with parents. One significant factor raised by teachers was 'inclusive' where an educational AR application should embrace all types of learners; they felt it was important to consider students with Special Educational Needs and Disabilities (SEND).

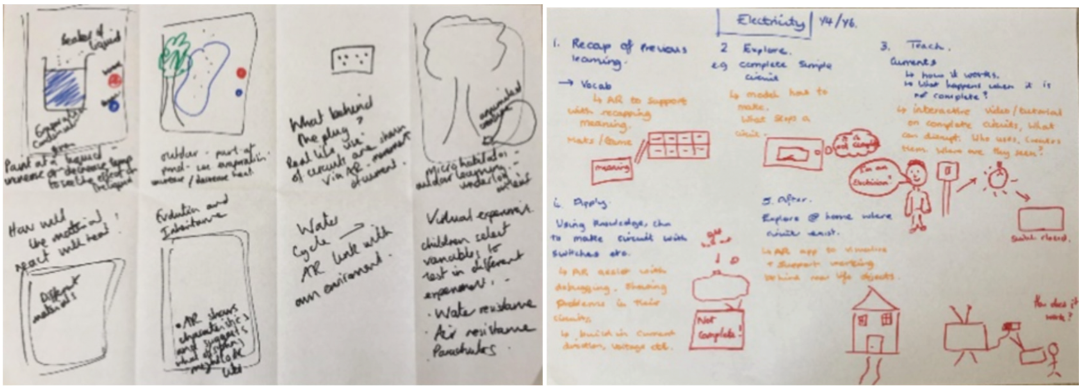

Figure 4. Examples of teachers Crazy 8 & Part Sketching (Design Sprint)

- Use AR for cross curricular activities?
- Link AR to curriculum delivery?
- Engage pupils and teachers through AR Creation?
- Connect AR to Science and everyday things?
- Create an AR shared resource?
- Create an inclusive AR experience?

Figure 5. How Might We (Design Sprint)

4. Discussion and Implications for AR

By undertaking a range of research exercises (contextual interviews, focus group, non-participants observations), we have gained a better understanding of primary science teaching and teachers' perceptions towards AR technology as a medium for science education. Our findings unearthed further detailed points by capturing the voices and opinions of teachers, revealing both opportunities and challenges for where primary science and AR can dovetail. From reviewing our overall results, emerging patterns have produced noticeable themes for where AR can play an integral role in teaching science and where the barriers exist for adoption in relation to an overall service. In this section we reflect on our findings to ask: what are the implications of AR as a service for primary science education?

4.1. How Can We Support Teachers using AR?

We should consider primary school teachers as educators and not formally as technologists. Although this study shows teachers respond positively to AR; in contrast both training and attitudes are most challenging for adopting AR (Figure 2 & 3), where the main thrust is around teachers feeling nervous and unconfident using new technologies. Melhuish and Falloon (2010) show schools should not assume teaching staff are ready to effectively use mobile devices from the outset. The Department for Education (2019) recognises for education to make good use of technology certain barriers such as empowering teachers to be confident users of EdTech are necessary. Contextual interviews raised a need in changing teachers' mindsets to be more flexible in new approaches, where some teachers suggested that an older generation were more reluctant to integrate AR technologies. This may be a sweeping generalisation where Bennett and Maton (2010); Bullen, Morgan and Qayyum (2011) demonstrate technology adoption in education is centred around exposure and experience rather than age, whilst Sirakaya. and Sirakaya (2020) show findings for teacher resistance to AR is a problem that needs to be overcome. Teachers revealed adapting to new processes whilst remotely working during lockdown. Consequently, this action led to those teachers hesitant of using technology to develop a more positive attitude and acceptance, realising the usefulness of engaging with new digital applications. Therefore, the willingness to adapt to using technology demonstrates potential appropriate contexts and systems to develop teacher confidence. For example, such concepts may take the form of an AR exhibition, display, interactive map, etc, that are highlighted during the research process.

This study shows teachers require further skills training, and CPD (Figure 2) on how AR can be integrated into their own practice to build on their confidence. These are similar findings of Silva et al. (2019) who suggest providing technical AR training will help teachers feel more confident and Silva et al. (2019), where teachers seem eager to learn about AR but need better guidance and support. According to Fernandez (2017) teachers need to be educated around AR technology. This study shows teachers are unaware of existing AR products available on the market, suggesting the need for collaboration between developers, or CPD training leaders to communicate the effectiveness of AR on teaching. Such factors may contribute towards a slower uptake of AR. Although our findings evidence teachers using AR, examples provided only demonstrate intermittent moments and not within a mainstream capacity. Silva et al. (2019) show similar results where the adoption of such technologies within mainstream schools remains very low. Participants of the focus group asked, 'How easy is AR to use?' Kangdon (2012) highlight that AR should focus on simplicity and ease of providing education and training experiences.

Teachers expressed (contextual interviews and focus group) using an AR application that is intuitive to understand, rather than being overcomplicated for both teachers and pupils to use. They also referred to sharing an online resource, (Figure 5) '*How might we engage pupils and teachers through AR creation?'* However, some teachers argued the ability to create their own content may have an adverse effect where it more available options are open to more errors. Given the limited time allocation for science lessons, teachers emphasised the need for applications that require little time to prepare beforehand. These concerns around inadequate time preparation align to others, Radu (2014); Silva, Radu and Schneider (2018), who emphasise the development of a user-friendly AR authoring tool that requires limited amount of preparation time. Given teachers raised a primary science being so broad, developers should consider an agile AR experience with longevity that adapts to curriculum changes.

4.2. Are Schools AR Ready?

Our findings suggest affordability is one of the key factors towards adoption. Given limited school budgets, augmented reality needs to demonstrate value to major stakeholders and be a cost-effective solution for teaching (Figure 2 & 3). Dede (2008); Singh and Singh (2013) suggest AR will become more affordable due to decrease in costs of digital devices, where a school IT lead confirmed specifications of a device (tablet) are becoming increasingly more powerful at similar or lower costs enabling AR applications to smoothly operate. (Table 1) evidence funding for science resources are a challenge, where contextual interviews (Table 16) show limited budgets can impact on AR adoption. Teachers reported on primary schools not all operating on the same 'level playing field' and discrepancies within allocation of budgets, leading to an inequality of distribution of devices between schools. A SLT representative commented on, '*school budgets are worked out through a central government formula that differs from area to area, and depends on factors such as per capita basis, SEN (additional funding) etc.*' Ultimately, headteachers are responsible for making decisions around school budgets. This study suggests their priorities may differ where deprived schools need to consider what is more essential, rather than portable devices being at the forefront of their list. This is in comparison to more affluent schools, where allocation of budgets may allow the freedom to purchase more devices for every pupil to access. Consequently, the availability of devices will predetermine the feasibility of what type of AR experience a teacher can provide. Light and Pierson (2013) offer similar findings, suggesting the distribution of ICT resources within schools, and accessibility of technology to pupils and teachers, will impact on what types of ICT-based activities teachers are able to do with their students.

Our findings show a higher proportion of class sizes being of 30 children and above, where teachers manage larger group sizes by separating into smaller ones to engage in-group activities. Questions do arise around the structure of an AR learning experience as to whether it is being designed for an individual, group or both activity? Sharing ideas and problem solving together in groups (Table 6) may suggest from a logistical and resourceful perspective an AR group activity is more feasible to manage in terms of class size, device distribution and shared learning.

Schools need a reliable Internet service, where in some cases teachers report on connectivity issues impacting their own teaching and classroom confidence when using technology – this could be challenging and an obstacle for AR, unless teachers are willing to spend preparation time downloading an application onto numerous devices. One alternative is the use of WebAR a solution. Qiao, Ren and Dustdar, (2019) show WebAR can alleviate downloading obstacles through triggering automatic AR experiences from a webpage rather than downloading an application. However, in the context of schools they need to be aware of safeguarding pupils having access to experiences without operating under a controlled environment.

Furthermore, our study shows teachers are using a variety of tablets (iPad and Android) for classroom activities; a significant factor is the influence of the IT lead guiding teachers towards google classroom for blended learning. Consequently, teachers are using chrome books as devices for better synchronisation and affordability. This raises questions around using AR given the rising popularity of chrome books and the mobility to learn on a laptop as premium devices become more affordable the school IT lead envisages providing flipbook devices to all pupils in the future. Depending on the device teachers are using, will inevitably affect the types of operating platform to be designing on – whether its Android, Apple, or both?

4.3. Where Can AR Intervene to Support Primary Science?

This study shows time allocation is a challenge for primary science teaching due to the emphasis on other subjects such as mathematics and English. Teachers are not only following a standardised curriculum framework focusing on the process of learning and teaching in conventional education systems, but they are also using supplementary education websites that exist outside of the formal education system to save on preparation time. Although worksheets and handouts were referred to as teaching aids for science (Table 4), teachers did not specifically refer to combining them into AR experiences for lessons. On reflection, this may relate to a lack of understanding around the creative capabilities of AR and where it can support lessons. These findings correlate with Kiryakova, Yordanova and Nadezhda (2018) who suggest teachers who are not so experienced in using mobile technologies may find integrating AR into lessons more challenging due to the time-consuming process of thinking innovatively around the approaches to interacting with an AR application. Given teachers are downloading online resources (worksheets) opportunities lie where existing educational providers may consider collaborating with AR developers to replicate new types of learning experiences. One teacher commented on, '*I would be interested to see what resources exist already and how successful they may be when using AR*.'

During the design sprint (Figure 5), teachers highlighted a preference towards an AR shared resource accessible for cross-curricular purposes. Teachers referred to cross-curricular delivery in several ways, but most significantly through connecting STEM related activities. Petrov and Atanasova (2020) reveal how using AR for STEM education in high schools has proved to be effective, making teaching a simpler process, more interesting and motivating. Therefore, perhaps similar activities can apply within a primary school setting where AR science covers a variety of subjects? Such examples can take the form around a linked theme (e.g., climate change) where the topic encapsulates several AR experiences, connecting science to the National curriculum. Outside of the classroom, if we consider a cloud system there are great opportunities to share AR resources between subjects and link classroom activities to homelife. Furthermore, teachers revealed organising a 'science week' or 'science fair' using cross curricular activities whilst encouraging parents to participate. Godec, King and Archer (2017) do offer teachers to consider how they may incorporate science media consumption into their own teaching, encouraging pupils to watch science documentaries on TV or online and discussed during science lessons. Given AR has capabilities of directing pupils through a variation of media channels perhaps this is an opportune moment for teachers who are looking for creative 'deep dive' solutions to implement an augmented experience for everyone to engage in.

This study shows another factor in motivating students is through 'learning by doing', drawing on parallels to Hamlyn, Hanson, Malam, Man, Smith, Williams et al. (2019) where practical work was considered the most motivating aspect of science lessons at school. Whilst real practical science is significant, SCORE (2009); Holman (2017) recognise that digital technologies such as virtual environments and simulated experiments can play a positive role, although both state ICT should only supplement and not replace a 'hands-on' experience in contrast to 'real and messy', a similar response to this study where teachers agreed, '*Technology should not substitute a hands-on experience for science experiment*s.' Although we should empathise with end users, their reaction may be due to a lack of understanding about immersive technologies where VR applications are using haptic senses with a potential to be translated into new AR experiences. However, our findings also show that the use of AR in the classroom introduces new safeguarding and health and safety concerns, meaning that time gains resulting from the application may be somewhat offset by new complexities.

Teachers refer to other factors in motivating pupils such as freedom to investigate and curiosity (Table 5), that relate to other studies Jesionkowska, Wild and Deval (2020), Farrell (2018); Muñoz (2014) where AR can benefit pupils through taking ownership of their own learning and awakening their curiosity. Fundamentally, this study shows whatever AR experience is being developed it essentially needs to align with the National Curriculum for adoption, as teachers expressed it is easier to assess a pupil's progression. Similarly, Fernandez (2017) reiterates where AR learning content needs to align to a curriculum rather than only offer experiences that interest pupils. Furthermore, teachers ask, *how will AR have an impact on children?* This raises an issue around providing pupils with clear objectives and meaningful learning outcomes, where Silva et al (2019) highlight pedagogical goals are essential to the process and Kerawalla et al. (2006) suggest AR needs to be less about what children can see and more about describing what they have learnt from their actions.

The contextual interviews revealed teachers feel AR is an appropriate medium to facilitate both parent and pupil interactions, due to the nature of 3D animations and interactions bringing science to life. Project based learning (PBL) was evidenced as being the most popular form of homework activity (Table 8). Bell (2010) describes PBL as an instructional method of curriculum design incorporating 21st century skills and an effective way to integrate cross-curricular subjects such as mathematics, reading and science. Therefore, given teachers are already engaging in remote activities with pupils, opportunities may arise for pupils to undertake AR challenges and investigations (PBL) from remote or home locations. Research by Godec et al. (2017) offers teachers to consider how they may incorporate science homework tasks by encouraging family and peers to talk about science in the context of everyday life aiming to normalise science outside of the classroom, where AR was potentially viewed a medium to engage parents and support science capital (Table 13 & 14). The challenges with PBL lie where it requires more time and effort to carefully plan each learning outcome; given preparation time is of concern for teachers (Table 1 & 16) PBL may be seen as a barrier rather than an asset unless adequate time is available to plan learning outcomes. In addition, contextual interviews refer to a flipped classroom approach where pupils can independently use AR outside of the classroom to build upon their existing knowledge acquired within school. Teachers expressed AR being used for different activities such as bear hunts, or following dragons; these are similar findings where Bergmann (2017) demonstrates that augmented technologies can be integrated into a flipped classroom using a variety of methods through art gallery walks, scavenger hunts, etc.

Where home learning becomes problematic is through the lack of Wi-Fi connectivity or in some cases where pupils have no access at all. Teachers reported on pupils encountering online problems due to sharing a network within a family household, whilst pupils from disadvantaged areas had no internet service to communicate with teachers. These are similar findings by Cullinane and Montacute (2020) where pupils from the poorest backgrounds are facing issues around internet availability. Consequently, a lack of unequal provision will be a barrier for AR adoption where a remote service will exacerbate a digital divide rather than unite users. During the design sprint, teachers refer to an AR shared resource for cross curricular purposes and accessibility. If we focus on cloud-based infrastructure, an AR cloud system will amplify the scalability of experiences through collaborative and ubiquitous processes for pupils to engage in science. Orlosky, Kiyokawa and Takemura (2017) describe how a 5G network will see a new generation of educational interfaces that likely revolutionise the way students interact with teachers from remote locations. Such interactions present new possibilities for pupils, parents, and teachers to engage in unique experiences within multitude of environments. Archer, Dawson, DeWitt, Seakins and Wong (2015) showed augmented reality has the functionality to free education from constrained conventional models. It is evidenced that engaging with science informally beyond the classroom can have a positive impact on student science performance and aspirations. It is not only about what we learn, but how and where we learn.

5. Design Implications

In summary, this study highlights several key points to where opportunities and barriers occur for AR adoption as an overall service and system.

Shared Values & Investment: Colleagues must share the same vision and embody it into their own working practices. Stakeholders such as SLT, and subject leaders need to be receptive towards embracing technologies (AR) and share common values for it to become mainstream. There appears to be no 'level playing field' for schools where disparities around accessibility to resources and investment are sporadic between schools which has implications on finding the right balance of a core delivery for a generic AR application. Schools need cost effective solutions to help democratise AR for adoption.

Curriculum & Pedagogical Goals: Teachers emphasised the need to align an AR experience to the English National Curriculum framework for adoption; adding relevance to the learning process and easier for teachers to provide clear objectives and assess pupil progression. Furthermore, pedagogical goals are important to the teaching and learning process, reinforcing what a pupil has learnt after using an AR activity. Teachers refer to an Ofsted Deep Dive to demonstrate creative ways of delivering curricular and its impact on pupils' progression; AR may a have a role to play in providing a unique platform. This poses questions around how can we measure or monitor AR as being effective medium during a learning process? Teachers highlighted the broad spectrum of primary science and challenges of how AR will adapt to any curriculum changes. They viewed AR as being a useful medium to explain scientific phenomena through using 3D graphics to show abstract concepts. Downloading resources from educational websites are popular with teachers for creative alternatives to alleviate preparation time; opportunities present themselves to explore partnerships with educational providers to integrate AR experiences using existing curriculum development.

Wireless Devices: Depending on the available number of devices, type of activity and class size, will determine what types of activities teachers can deliver and how pupils collaborate using an AR experience – whether this is on an individual or group basis. Classroom observations show pupils working in groups to solve scientific problems and are motivated through sharing ideas. Given some schools have limited devices and predominantly larger class sizes, this study suggest it is more productive and economical to design for group activities. A main factor is accessibility to wireless devices beyond the classroom, where this can potentially lead to an adverse effect of a digital divide if schools don't have equal provision. Teachers need to consider what type of handheld or portable device will be used outside of school. This study suggests a cloud-based learning management system (google classroom) can influence the types of operating system and device being used by schools for AR experiences.

Internet Connectivity: Internet connectivity is an issue internally for some schools, and teachers reported poor connectivity when using devices in the playground. Where internet connectivity is a problem, this can impact on teachers' confidence to deliver AR in the classroom. In addition, IT approval is an obstacle where teachers expressed planning around downloading applications onto devices due to safeguarding children. There seems to be a balance between control and flexibility – one solution being the possibility of WebAR. However, consideration needs to be taken where an AR experience is being deployed. Is it via an internal school infrastructure or outside of independent confined parameters? Who is regulating and safeguarding content? Who is the gatekeeper? The challenges for remote connectivity lie where households share a network, and in other cases, where disadvantaged pupils have no access to Wi-Fi connectivity. These issues need to be addressed for parity or schools will face barriers for AR adoption beyond a classroom environment.

Teacher Empowerment: Teachers attitudes towards AR is a challenge; they are hesitant to adopt new technologies (AR) due to their existing workload and in cases more comfortable to deliver a learning experience through traditional methods. Although teachers recognise the potential for using AR, they do require CPD and training to have confidence in delivering a unique experience; there is a clear lack of understanding around AR capabilities and where the benefits lie. The study suggests, we shouldn't impose technology onto teachers, as they are fundamentally educators not technologists. We should provide them with a robust foundational support (videos, training, developer talks) and tools to introduce a gentler 'drip-feed' approach having time to explore and understand what is possible. Therefore, this may suggest why AR is not a mainstream medium for now and being used as an enrichment tool for learning. As AR becomes normalised in society over the coming years, it may stimulate teachers to feel more confident in adopting AR into their own curriculum.

Cross Curricular Enrichment: Teachers refer to delivering cross-curricular activities to use their time more effectively by integrating science led subjects with others. Due to heavy workloads, and needing more preparation time, this study highlights science weeks and events are an opportune moment to implement an AR experience for an enrichment activity where teachers have time to plan and focus on learning outcomes. This study reveals STEM (Science, Technology, Engineering and Mathematics) is a popular choice for integrating subjects based on the use of online resources and contextual interviews where teachers felt AR can play a role to teach STEM related activities. Additionally, teachers viewed opportunities for AR being incorporated into a broader primary science curriculum through a variety of topics. Cross-curricular provides opportunities for more teachers to familiarise themselves with AR, where it may help to become more mainstream within schools.

Usability & Inclusion: AR applications need to be simple and intuitive to use for both teachers and pupils. Teachers expressed straightforward interactions will avoid minimal risks and help teachers' confidence when using augmented reality. Time allocation is limited, an AR application needs to avoid user complexities that may hinder delivery time for a lesson. Whilst teachers suggested exploring an AR authoring tool for flexibility, they did raise it may cause more obstacle if there are additional options. Furthermore, if pupils are engaging with remote learning without the supervision of a teacher an AR application needs to be easy to understand, as well as more of an instructional approach for direction. Teachers would benefit from developers providing adequate guidance and support for AR adoption; they expressed developers should consider aspects of usability from an inclusive approach for pupils with special needs and disabilities (SEND).

Remote Learning: AR Cloud and edge computing will bring about different opportunities to how information is processed, providing mobile augmented reality with greater opportunities for location-based experiences. An AR cloud can offer accessibility to teachers, pupils, and parents to share resources and promote science capital. Given teachers are already familiar with using online resources, AR has the potential to connect curriculum beyond the classroom through activities such as project based and flipped classroom learning, making science relevant to pupil's everyday lives, and encouraging science capital.

6. Conclusion

When reflecting upon the studies of Akcayir and Akcayir (2017); Wang et al. (2017); Radu (2014); Yuen et al. (2011), we see that they suggest educators and designers need to collaborate in terms of creating sound pedagogy to develop AR applications that are 'meaningful' and 'maximise on learning outcomes. By following a service design methodology, we have taken holistic approach to considering a broader spectrum of influences in relation to primary science teaching and using augmented experiences. The process has helped us to engage with users (teachers) through different levels and understand their needs far greater. Teachers have provided valuable feedback to identify core factors that entwine in delivering AR experiences and unpick what is important to them. Collaboration has demonstrated the significance of expertise and their input as a collective working together in defining ways of creating meaningful AR experiences. By looking at AR through the lens of a service we have highlighted where opportunities occur and equally where barriers prevent AR adoption (Figure 6). Consequently, this study identifies both patterns in differences and similarities to make more well-informed decisions based upon teacher needs, whilst eradicating any assumptions that pre-existed beforehand. These key findings are integral to the developmental choices throughout the 'creation' stage (Figure 1), as part of an iterative process.

Based on our research, it is evident primary school teachers are already accustomed to engaging with technology both inside and outside of the classroom; online interactions and collaborations are happening across many different platforms (Table 12). Teachers reported already using augmented and virtual reality, although AR is a medium not being regularly used to teach and more a way to engage pupils as a teaching aid. There is evidence to suggest it is filtering into science lessons but is yet to establish itself as a more prominent learning tool for primary schools. Whilst technology shouldn't be imposed onto teachers, it is evident they require more background, CPD and training to understand how AR can be purposely integrated into their curriculum. Whilst teachers acknowledge AR has potential to be a useful medium through 3D learning AR should not replace a practical 'hands-on' science experience but act as a supplement for teaching, where studies show Holman (2017) practical science is important but recognises digital technologies are rapidly evolving, so teachers should have access to evidence about what works and training in their use before implementing into lesson plans. Teacher's need confidence in a reliable IT infrastructure, where financial investment is necessary for adequate connectivity and accessibility to devices, similar findings to Alkhattabi (2017); Silva et al. (2019) who show a lack of appropriate ICT infrastructure can be a barrier for AR adoption.

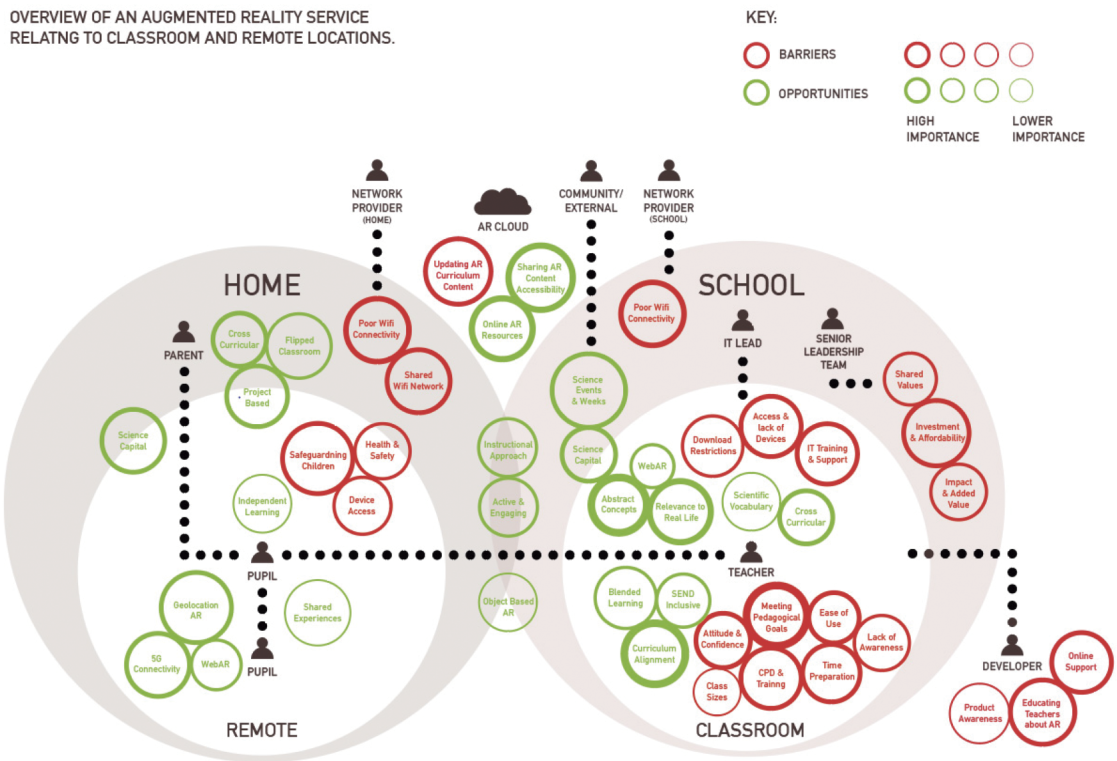

Figure 6. Diagram to show a service using Augmented reality from classroom and remote locations

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Appendix

Primary Science Challenges	Percentage (%)
Lack of Equipment	29
Time Allocation	23
Funding for Resources	22

Primary Science Challenges	Percentage (%)
Teacher Confidence	10
Value of Science	5
Health & Safety	5
Class Numbers	4
Student Confidence	2

Table 1. Percentage of responses from teachers towards science challenges (Questionnaire)

Curriculum Framework	Percentage (%)
National Curriculum	87
SNAP Science	7
Cornerstones – Love to Investigate	2
Learning Ladders	2
Solihull LA School and Department for Education	2

Table 2. Percentage of responses from teachers using a curriculum framework (Questionnaire)

Teaching Types	Percentage (%)
Practical Science	31
Investigations & Tasks	23
Experiments	10
Scientific Enquiry	4
Group Work	4
Project Based	4
Skills Based	4
Observation	3
Games	3
Storytelling	3
Active Learning	2
Problem Based	2
Flipped Classroom	2
Cross Curricular	2
Demonstration	2
Workshop	1

Table 3. Percentage of responses from teachers regarding teaching types (Questionnaire)

Teaching Aids	Percentage (%)
Practical	20
Videos	20
Worksheet	11
PowerPoint	11
Handouts	9
Interactive	6
Textbooks	5
Images	5
Concept Cartoons	4
Games	3
Quizzes	3
Storytelling	3

Table 4. Percentage of responses from teachers regarding teaching aids (Questionnaire)

Pupil Engagement	Percentage (%)
Practical Activities	43
Freedom to Investigate	12
Science relevant to real world	12
Sharing Ideas	9
Curiosity	7
Teacher Inspiration	6
Visiting Speakers	4
Science Events	4
Being Hooked	3

Table 5. Percentage of responses from teachers regarding motivating pupils (Questionnaire)

Class Sizes	Percentage (%)
30 above children per class	64
20 above children per class	27
10 above children per class	7
Below 10 children per class	2

Table 6. Percentage of teacher responses for class sizes. (Questionnaire)

Time Allocation	Percentage (%)
2 Hrs Per Week	30
1-2 Hrs Per Week	19
1 Hr – 1.5 Hrs Per Week	19
1.5 Hrs Per Week	16
Under 1 Hr Per Week	14
Half Term (6-8 Hrs Per week)	2

Table 7. Percentage of teacher responses for time allocation. (Questionnaire)

Home Learning	Percentage (%)
Project Based	26
Investigations	18
Vocabulary & Mathematics	18
Activities & Challenges	15
Experiments	7
Observations	4
Questions	4
Research	4
Quizzes	2
Competitions	2

Table 8. Percentage of responses from teachers regarding pupil homework (Questionnaire)

Remote Applications	Percentage (%)
Google Classroom	32
Seesaw	16
Dojo	14
Parenthub	11
Youtube	5
Scratch	5
QR	5
Zoom	3

Remote Applications	Percentage (%)
Facebook	3
Ed Puzzle	3
Dorling Kindersley	3

Table 9. Percentage of teachers' responses for remote applications (Questionnaire)

VR & AR Applications	Percentage (%)
YES	28
NO	72

Table 10. Percentage of teachers using AR or VR applications (Questionnaire)

Technological Devices	Percentage (%)
I-Pads	29
Chromebooks	15
Data Logger	13
Virtual and Augmented Reality	12
Smartboard	12
Applications	11
USB Microscopes	8

Table 11. Percentage of devices being used in the classroom (Questionnaire)

Online Resources	Percentage (%)
TWINKL	17
STEM	15
EXPLORIFY	15
YOUTUBE	11
ASE	6
BBC BITESIZE	5
SNAP SCIENCE	5
PSTT	5
HAMILTON	5
OGDENS TRUST	3
COLLINS CONNECT	3
PINTEREST	2
TES	2
CIEC	2
WOW SCIENCE	2
RSC	2

Table 12. Percentage of teachers' responses to online resources (Questionnaire)

Benefits of AR for Science Lessons	Percentage (%)
Relevance to real life	43
Abstract Concepts	33
Virtual Lab	6
Science Curriculum	6
Sharing with parents	3
Encouraging Scientists	3
Direct Experience	3
Data Recording	3

Table 13. Percentage of teacher responses to AR Benefits for Science (Questionnaire)

Benefits of AR for Science Lessons	Percentage (%)
Active & engaging	20
Independent Learning	16
Teaching Science	14
Remote Learning	8
Storytelling	7
Parental Support	7
Flipped Classroom	7
Project Based	7
Relevant to Life	7
Creative Learning	5
Blended Learning	2

Table 14. Percentage of teacher references to AR Benefits for Science (Contextual Interviews)

Primary Science Subjects	Percentage (%)
Human Body	26
Habitats	22
Solar System	15
Animals	10
Materials / Rocks & Soils	10
Plant Systems	9
Forces	5
Light & Sound	2
Seasonal Changes	1

Table 15. Percentage of teacher responses using AR for Primary Science Subjects (Questionnaire)

Challenges of AR	Percentage (%)
Training and Attitudes	31
Access to Devices	12
Internet Connectivity	9
Safeguarding Pupils	9
Benefits to lessons	9
Time Allocation	9
Parental Support (remote)	9
Funding of Resources	6
Staff Confidence	6

Table 16. Percentage of teacher references for AR challenges. (Contextual Interviews)

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