



## ARETE – DELIVERABLE

### WP4 – D4.2: Analysis of User Requirements, Needs and Visionary User Cases for ARETE

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## Executive Summary

The deliverable D4.2 reports user needs and requirements from the ARETE target groups – primary and secondary school students and teachers. The methods employed were online surveys and interviews. The teacher and secondary school surveys share a similar structure. They start with demographic questions, followed by a set of questions on general AR usage to gather data on the overall perceptions and needs for deploying AR for teaching/learning. The last set of questions is to gather contextualised data by referring to a specific AR app that teachers/students have recently used, thereby eliciting their requirements for developing future AR apps for teaching/learning. For the primary school survey, the questions are mainly on experiences of using AR in general as well as for learning at school.

Despite our repeated attempts to disseminate the surveys through different channels, the response rates were discouragingly low. Altogether we have gathered complete survey responses from 65 teachers, 65 secondary school students and 130 primary school students. However, the numbers of visits to the three online surveys were 1746, 1157 and 1083, resulting in the completion rate of 3.7%, 5.6% and 12%, respectively. The high incompleteness rates of the surveys might be attributable to the low usage of AR educational applications for real-life teaching and learning. In addition, we were able to conduct interviews with five teachers with one deciding to withdraw. Similar to the surveys, recruiting participants for the online interview proved very challenging. Furthermore, the distribution of countries where the respondents resided was skewed. While these undesirable factors affected the quality of the data, we could still gain useful insights into the needs and requirements of the participating primary and secondary students and teachers for improving the uptake of AR for education.

We have identified 48 user requirements, which are divided into *functional requirements* (i.e. what the system should do), *non-functional requirements* (i.e. quality in use that the system should satisfy), and *organisational and pedagogical requirements* (i.e. teachers and students are enabled to use AR as educational resources). Each individual requirement is qualified with an importance rating (low [L], medium [M], high [H]) to signify the level of potential impact as a design feature of an AR educational application. There are 20 H, 26 M and 2 L.

| Requirement       | Functional |   |   | Non-functional |   |   | Pedagogical & Organisational |   |   | Total |
|-------------------|------------|---|---|----------------|---|---|------------------------------|---|---|-------|
|                   | H          | M | L | H              | M | L | H                            | M | L |       |
| Sources           |            |   |   |                |   |   |                              |   |   |       |
| Teacher Survey    | 0          | 3 | 2 | 4              | 3 | 0 | 2                            | 4 | 0 | 18    |
| Teacher Interview | 2          | 2 | 0 | 4              | 2 | 0 | 1                            | 1 | 0 | 12    |
| Secondary School  | 1          | 1 | 1 | 2              | 2 | 0 | 2                            | 2 | 0 | 11    |
| Primary School    | 0          | 2 | 0 | 2              | 0 | 0 | 0                            | 3 | 0 | 7     |

The requirements are communicated to WP3 and WP5 for consideration in the technical development of AR tools. The requirements, however, are not too specific, as respondents tended not to elaborate their qualitative responses. For visionary use scenarios, we planned to organise face-to-face workshops to have live demos of ARETE prototypes and other advanced AR technologies. Overall, despite the negative impacts of the coronavirus pandemic, thanks to the ongoing close collaborations among the partners, WP4 was able to achieve its objectives, albeit regrettably not to its full extent.



## 1 Introduction

The main goal of WP4 – User-centred Interactive Design – is to identify, update and integrate, user-based insights into designing and developing the ARETE digital artefacts, rendering them to be highly useful, usable, desirable and pleasurable. Methodologically, we draw on the User/Human-centred Design (UcD/HcD) approaches, including Participatory Design (PD), Usability and User Experience (UX) methods and tools. They are applied for formative and summative evaluations of ARETE digital artefacts with different fidelity levels.

D4.2 is the second deliverable of WP4, which aims to identify user requirements from the main target groups of ARETE, namely primary and secondary school students and their teachers, for the future development of AR educational applications in general. Methodologically, it would be ideal to deploy multiple methods, including workshops where synchronous observations and interviews can take place, and surveys (questionnaires) with which asynchronous responses can be collected. However, the pandemic has narrowed the options to surveys and interviews, which, unfortunately, also have reduced to much smaller sample sizes than normal.

In the following, we describe the methodology in Section 2, presenting data collection and analysis methods as well as design and dissemination of the surveys. Section 3 through Section 6 report the results of the Teacher Survey, Teacher Interview, Secondary School Student Survey, and Primary School Student Survey, respectively. Of particular relevance are the user requirements derived from the empirical data. It is then concluded in Section 7 with a plan for tracking the development of these requirements.

## 2 Methodology

### 2.1 Survey as Research Method

In the field of HCI, the common approaches for capturing user requirements include Participatory Design (PD) (Heintz & Law, 2018), Contextual Inquiry (CI) (Beyer & Holzblatt, 1998), and survey (questionnaire), interview and focus group (Lazar et al., 2017). Nonetheless, PD and CI entail real time interactive activities in situ, which proved impractical during the pandemic. Consequently, we employed survey as our main methodological approach, supplemented by interviews. In addition, we are going to conduct focus groups in June and November 2021; results of which will be reported in D4.3 (M30).

Surveys or questionnaires are a very powerful and widely used research method for collecting a relatively large volume of data within a short period of time (Lazar et al., 2017). Apart from efficiency, the other advantages of surveys include asynchronicity, ease of administration and low cost, especially when a survey is digitalised with a web-based tool. Furthermore, the structured question format can facilitate data analysis, especially the quantitative type. Nonetheless, some of the desirable attributes can lead to constraints, including the lack of opportunity to clarify questions or probe intriguing responses. While it is easy to construct a questionnaire, developing a questionnaire with high reliability and validity is challenging and requires a number of systematic steps.



The Leicester Human-Computer Interaction (HCI) team created the questionnaires for three main target groups of ARETE – teachers, secondary school students and primary school students – based on our expertise and experience in HCI and AR. The general structure of the questionnaire is to gather demographic data of respondents and their general as well as recent experiences with AR from which requirements for future AR educational applications can be derived. The draft surveys have been commented by the ARETE partners and then improved according to those comments. They have also been pilot tested with a handful of representative end-users (or proxies) to ensure that the questions are unambiguous and easy to understand and that the survey can be completed within a reasonable length of time.

In the subsequent sections, we describe the general structure of the three surveys. The complete surveys are listed in Appendix A, B and C, respectively. All three surveys have been translated into Dutch, German, Greece, Italian, and Spanish by the ARETE native speakers of the respective languages.

## 2.2 Teacher Survey and Interview

**Teacher Survey.** The survey consists of three sections (Appendix A). It starts with simple factual questions that are easy for respondents to answer. It is then followed by a set of questions on general AR usage to gather data on the overall perceptions and needs for deploying AR for teaching. The last set of questions is to gather contextualised data by referring to a specific AR app that teachers have recently used, thereby eliciting their requirements for developing future AR apps for teaching.

- *Section 1: Demographics.* There are 6 questions: role (type of school), age, gender, country of residence, teaching subject, years of teaching experience.
- *Section 2: General AR Usage for Teaching.* There are 10 questions, asking why, how long and how often they use AR for teaching; whether and why they (do not) intend to use AR more for teaching; which hardware they use and the school provision on computing devices for running AR apps; their confidence in using AR and what can be done to improve it.
- *Section 3: Most Recent AR Usage for Teaching.* There are 12 questions, asking what the app is, the domain and topic; the age-group and class size of students involved; the setting, lesson duration and the teaching method; the perceived usefulness of the app; the overall user experience of students and teacher; the improvement suggestions for the app.

**Teacher Interview.** The questions posed in the teacher interview are based largely on those of the Teacher Survey. The major difference is that interviewees can be probed to elaborate their responses. For a semi-structured interview, an interviewer does not have to follow strictly the questions given in the survey and can modify them when needs arise.

## 2.3 Secondary School Student Survey

The survey consists of three sections with altogether 27 questions (Appendix B). It follows the same structure as that of Teacher Survey with the same overall rationales. Nonetheless, the questions are adapted to focus on learning rather than teaching and are phrased with age-specific language.



- *Section 1: Demographics.* There are 3 questions: gender, age and country of residence.
- *Section 2: General AR Usage for Learning.* There are 12 questions, asking who has suggested the use of AR app, usage frequency and duration, intention to use more and associated support, hardware, liked/disliked features, preferred types of help, and collaborative interaction.
- *Section 3: Most Recent AR Usage for Learning.* There are 10 questions, asking what the AR app is, when, how, where and for how long it is used, and what the topic is, the perceived usefulness, overall user experience, and proposed improvement suggestions.

## 2.4 Primary School Student Survey

The survey consists of altogether 16 questions (Appendix C). The structure is different from that of the Secondary School Survey. The questions and instructions are shortened (e.g. no section headings to reduce the demand on reading), phrased with age-specific language, and enlivened with relevant images. Specifically, the first 3 questions are on demographics, including gender, age and country of residence. Then there is a set of 5 questions on general usage of AR, including the purpose (learning, others), frequency, whose suggestion, device, and location. Next is a set of 7 questions on using AR for learning at school, asking how many AR apps used, the topics covered, perceived ease of use, how much they are liked, and devices available.

## 2.5 Multi-channel Dissemination of the Questionnaires

The three surveys have been distributed to different channels: (1) the ARETE websites; (2) the ARETE newsletters; (3) the networks of teachers and schools with which EUN is well connected; (4) personal and professional contacts of the partners involved. Details are given in the following.

The three surveys were featured in the “News / Events” section of the ARETE homepage (<https://www.areteproject.eu/newsevents/>) five times in irregular intervals:

- On 28 July, 2020 the surveys were teased with an article describing their purpose and telling the readers that we are currently in the progress of translating them. This was done to pique the interest of prospective participants.  
(<https://www.areteproject.eu/newsevents/body,505745,en.html>)
- On 23 September, 2020 a detailed article was published, describing the questionnaires and providing individual links to each survey for every different language. This was done to inform prospective participants about the surveys and how to find them. This article was also linked in the social media promotion of the surveys, to give context and detail to the short messages distributed there.  
(<https://www.areteproject.eu/newsevents/body,513853,en.html>)
- On 28 October, 2020 a reminder was published, telling teachers and students that the surveys are still live and that their input would be greatly appreciated.  
(<https://www.areteproject.eu/newsevents/body,518492,en.html>)
- On 11 January, 2021 another article was published advertising the surveys by describing their purpose and providing direct links to each survey in every language.  
(<https://www.areteproject.eu/newsevents/body,532256,en.html>)



- Lastly, in a final attempt to boost the numbers of participants on 29 March, 2021 a final article was published, reporting on the current number of responses and asking teachers and students to participate. Links to the English language surveys were provided directly, other languages could be accessed through a link to the second article described above.

(<https://www.areteproject.eu/newsevents/body,541636,en.html>)

The link to the ARETE news article describing and linking to the different surveys has been distributed on Twitter<sup>2</sup>, Facebook<sup>3</sup>, and LinkedIn<sup>4</sup> by the official ARETE Twitter/Facebook/LinkedIn account as well as by ARETE partners (e.g. WWL<sup>5</sup>, VU<sup>6</sup>, EUN<sup>7</sup>). In addition to the link to the article, the official ARETE ULEIC account has also posted the direct link to each survey on Twitter, Facebook, and LinkedIn on multiple occasions (e.g. on 18/09/2020<sup>8</sup>, 08/10/2020<sup>9</sup>, 03/11/2020<sup>10</sup>, 24/11/2020<sup>11</sup>, 16/12/2020<sup>12</sup> [the example links are from twitter, as it is freely accessible, but the all posts have been distributed on Twitter, Facebook, and LinkedIn in parallel]), which was favoured and shared by the private (e.g. @SuiGoei, @KristinaFoerst5) and institutional (e.g. @wowoworld, @Clever\_Books) social media accounts of different ARETE partners as well.

In collaboration with EUN two tasks for teachers from Scientix (i.e. a community of science teachers in Europe<sup>13</sup>) were created, one to fill out the teacher survey themselves and one to distribute the primary or secondary school student survey in their classrooms. From the teachers who applied to participate in these tasks, unfortunately only 10 had used AR in the classroom before. Those were instructed on which survey links to distribute to their students.

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<sup>2</sup> <https://twitter.com/ARETEH2020/status/1321728481496092673>, on 29/10/2021

<sup>3</sup> <https://www.facebook.com/groups/1348168335375937/permalink/1682038638655570/>, on 29/10/2021

<sup>4</sup> [https://www.linkedin.com/posts/arete-education\\_news-events-activity-6727847016023523328-c7RI](https://www.linkedin.com/posts/arete-education_news-events-activity-6727847016023523328-c7RI), on 29/10/2021

<sup>5</sup> <https://twitter.com/wowoworld/status/1316721275482636289>

<sup>6</sup> <https://twitter.com/lerarenacademie/status/1322081810633891840>

<sup>7</sup> <https://twitter.com/EunMattia/status/1323915654659977217>

<sup>8</sup> Primary School Students: <https://twitter.com/AreteUle/status/1306875204497530883>;  
Secondary School Students: <https://twitter.com/AreteUle/status/1306876098479783936>;  
Teachers: <https://twitter.com/AreteUle/status/1306876829756796929>

<sup>9</sup> Primary School Students: <https://twitter.com/AreteUle/status/1314141295812792320>;  
Secondary School Students: <https://twitter.com/AreteUle/status/1314142974817771521>;  
Teachers: <https://twitter.com/AreteUle/status/1314143444512759808>

<sup>10</sup> Primary School Students: <https://twitter.com/areteule/status/1323627543245787140>;  
Secondary School Students: <https://twitter.com/AreteUle/status/1323627904358633473>;  
Teachers: <https://twitter.com/AreteUle/status/1323627995169513472>

<sup>11</sup> Primary School Students: <https://twitter.com/AreteUle/status/1331165144454471681>;  
Secondary School Students: <https://twitter.com/AreteUle/status/1331165473698942978>;  
Teachers: <https://twitter.com/AreteUle/status/1331164464104824833>

<sup>12</sup> Primary School Students: <https://twitter.com/AreteUle/status/1339187779083833351>;  
Secondary School Students: <https://twitter.com/AreteUle/status/1339187779083833351>;  
Teachers: <https://twitter.com/AreteUle/status/1339190330885894150>

<sup>13</sup> <http://www.scientix.eu/>



Besides distributing the information about and links to the surveys, we also made use of the personal and professional contacts of ARETE partners, by asking them to send the survey details, for example, to their mailing lists. For Leicester, an email containing information about the surveys was sent to the School of Education PGCE offices requesting them to distribute to their students. Additionally, the email containing information about the surveys (purpose and links) was forwarded to colleagues in the School of Education itself, for sharing with their networks and for consideration for the next partnership newsletter.

To collect as many responses to the surveys as possible, we have applied a variety of several different ways of dissemination. Due to the anonymous nature of the surveys it is unfortunately not possible to determine the success rate of each individual channel, but we believe that the mixture of distribution methods all contributed to the amount of responses we received.

Nonetheless, as participations in the surveys are entirely on a voluntary basis, it is proved to be extremely hard to elicit responses during the pandemic, despite many reminders having been issued in the meantime.

## 2.6 Data Analysis Methods

The three surveys contain both close-ended and open-ended questions; the former and the latter requires quantitative and qualitative data analysis methods, respectively.

**Quantitative data analysis:** Descriptive statistics, including frequency, means, standard deviation and range, is computed for individual questions. As no hypothesis testing is involved, inferential statistics is not applied.

**Qualitative data analysis:** The Leicester team have undertaken the process of analysing, codifying, and synthesising the responses to the surveys in order to understand the respondents' needs with regard to deploying AR as educational tools and convert such needs into actionable user requirements. Specifically, we have applied thematic analysis (Braun & Clarke, 2019) – an inductive bottom-up approach, identifying from raw data some emergent themes (codes), clustering related themes into categories and translating such categories into requirements. Furthermore, we have assigned an **importance level** to each of the requirements to signify the level of potential impact as a design feature of an AR educational application. For the task of assigning the importance level, three HCI researchers first carried it out individually, and then they discussed the initial ratings to draw consensus on the discrepant ones.

- **Low importance (L):** the rating is given to requirements that can slightly improve the overall experience of end-users of an AR app for teaching/learning, but that may not hinder its use if they are not implemented.
- **Medium importance (M):** this rating is given to requirements that can moderately enhance user experience, positively affect the overall sense of quality of an AR app, and that have been required by various teachers/students in the sample.
- **High importance (H):** this rating is given to requirements that can significantly improve the overall user experience and the perception of software quality of an AR app, and that can pose as an obstacle for end-users if they are not implemented.



### 3 Results: Teacher Survey

Altogether there were 1746 visits to the survey website, but only 65 responses were complete (i.e. all the questions of the survey were answered). The distribution of the “start language” is as follows: 56 Dutch, 67 German, 60 Greek, 161 Italian, 200 Spanish and 1202 English. While we cannot identify actual reasons for the high incompleteness rate, we speculate that many of the visitors considered themselves ineligible when they read the following statement in the beginning of the survey: “*This survey targets educators who have used AR in their teaching. If you have never used AR before for educational purposes, your input will not be required.*” If our speculation was true, it would imply that only **3.7%** of the teachers whom we sampled had experience in deploying AR for educational purposes. One may argue that this could be an artefact of our sampling strategy. Nonetheless, the low percentage is not totally surprising because the actual usage of AR educational applications in everyday teaching is still a nascent phenomenon.

#### 3.1 Demographic Data

##### 3.1.1 Country

The 65 complete responses came from 17 countries and 2 unspecified ones with seven of them having only one response (Figure 1). This unusual distribution might be related to the low adoption of AR in real-life teaching. A caveat is that while we aimed to understand how AR educational applications could be deployed by teachers with different backgrounds (i.e. country, specialty, computer competence, teaching experience), we did not aim to conduct any cross-cultural comparisons. Instead, those attributes could help us interpret their responses.

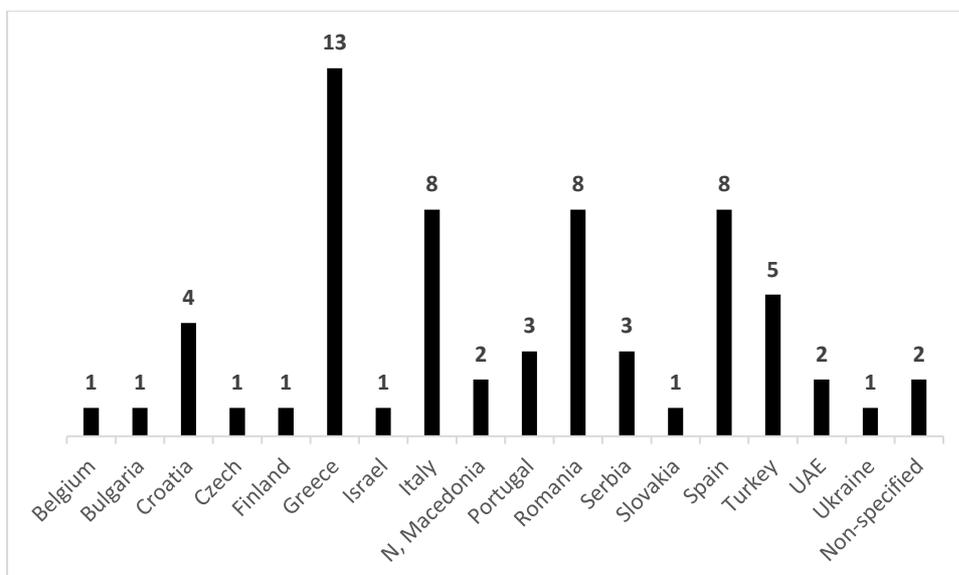


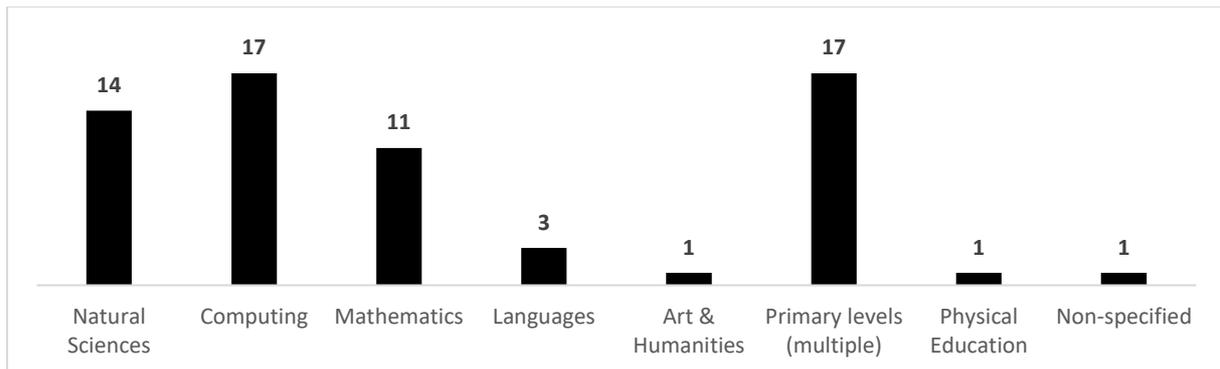
Figure 1: Distribution of the Teacher Survey respondents' country of residence

##### 3.1.2 Role, Gender, Age, Teaching Subject and Experience

In the sample, 35 teachers were in secondary schools, 27 in primary schools, one in an infant school, and two further in education colleges. The gender distribution with 44 female and 21



male is higher than a typical ratio of 3:1 in the teaching profession. In terms of age-group, the distribution is as follows: 31-40 (n=20), 41-50 (n=26), 51-60 (n=16), >60 (n=3). With regard to teaching subjects, the majority of respondents reported to teach mostly STEM subjects, and most of the primary school teachers said to teach more than one main subject (Figure 2). The average teaching experience in years was 17.2 (SD =7.02, Range= 4-45).



**Figure 2:** Distribution of the Teacher Survey respondents' teaching subjects

### 3.2 General AR Usage for Teaching

The results reported below refer to the questions in Section 2 of the survey (Appendix A).

#### 3.2.1 Rationale

In response to why they had used AR as part of their teaching (Note: they could choose more than one reason), the majority of the respondents (n=52) chose the option *out of curiosity*. The two other frequent options were *following the recommendation of colleagues* (n=12) and *being drawn attention to it by students* (n=8). A handful chose the option *following the guidelines of the ministry of education* (n=3) or *school board* (n=3). The rest chose a different reason (n=8). Some elaborated their rationales such as “*I wanted to try something new*” (T271), “*I believe it may have the potential to stimulate learning*” (T254, translated from Italian), “*To teach my students to create augmented reality applications.*” (T366).

#### 3.2.2 Usage

The majority of respondents said to have used AR in their teaching for less than a year (n=15), between 1-2 years (n=20), or between 3-4 years (n=14), whereas few teachers said to have experienced with AR for more than four years (n=7); the rest did not specify (n=9). As for the frequency of usage, several teachers, who used AR weekly or fortnightly (17%, n=10), could be considered as active AR users whereas 45% (n=26) were moderately active with the usage frequency between monthly and every-three-months. Nonetheless, 38% (n=22) of the teachers were less active, using AR educational apps for teaching every six months or less frequent. As a follow-up question, the teachers were asked whether they would like to use more AR for teaching, 57 indicated ‘yes’, 4 selected ‘no’ and 4 teachers were unsure. Reasons why teachers were unsure about using AR more often for teaching were because “*It is not easy for my students to keep attention alive*” (T492), “*...not sure if it is a pedagogical advance*” (T305), and “*...there are a lot of AR apps out there that are not so good*” (T1290).



### 3.2.3 Needs

Teachers were additionally asked about their needs to increase the usage of AR technologies in their teaching, 44 selected the option *to have better access to AR hardware*, 38 *know which AR applications are suitable*, 27 *find the time*, and 19 *more help to use AR apps* (Note: they could choose more than one option). When asked to expand about these needs, most participants said to have significant **financial constraints** (n = 24) such as the lack of budget and equipment at their schools, closely followed by the **need of training** (n = 21) to be able to use AR apps. Examples of the related comments are: *“in my school there are no tablets for students, they use their mobile phones, moreover, my colleagues are not keen on using ICT and do not encourage students. I am the only one that pushes for this”* (T1486); *“Regular training on what is new would also be very useful.”* (T1444). Teachers also explained to be facing other types of **restrictions** (n = 15) such as the lack of time or national laws forbidding students to use electronic devices in the classroom. For instance, T1476 commented that *“actually more than the lack of apps, there is a lack of ready-made materials, which would considerably reduce time spent in creating AR activities suitable to foreign language teaching.”* The limited availability of **quality materials** (n = 18) in AR apps were also mentioned several times by the respondents. For instance, T1292 remarked that *“There has only been two really good apps for AR and now are no longer supported so I find the current AR apps on the market quite limited to exchange learning.”* At last, **technical improvements** (n = 4) on the software were said to be needed for teachers to increase their usage of AR for teaching. These needs were translated into user requirements (details see Section 3.4).

### 3.2.4 Experience in the classroom

In the sample, most teachers had used smartphones for teaching with AR (n=51), followed by tablets (n=33), desktop or laptops (n=23), and in very few cases game consoles (n=3) and VR glasses (n=1). Table 1 below shows the descriptive statistics on the types of devices available at schools where the respondents teach.

**Table 1:** Descriptive statistics of the device availability as reported in Teacher Survey

|                  | Average | SD    | Range     |
|------------------|---------|-------|-----------|
| Smartphone       | 22      | 116.5 | 0 - 800   |
| Tablet           | 38      | 194   | 0 - 1400* |
| Desktop + webcam | 3       | 6.7   | 0 - 30    |
| Laptop + webcam  | 44      | 197.7 | 0 - 1400* |

\* NB: One school provides one tablet/laptop per student

In four cases, teachers mentioned they needed to bring their own devices to the classroom to teach with AR, and six teachers had to ask their students to bring their own smartphones or tablets to learn with AR. The average number of students per class in this sample was 23 (SD= 5.64, range= 12-40).

### 3.2.5 Teacher confidence in using AR



Most teachers rated their confidence in using AR for teaching as fairly high, with only a few teachers still struggling (Table 2).

**Table 2:** Distribution of level of confidence in using AR as reported by teacher respondents

| Very low | Low | Medium | High | Very high |
|----------|-----|--------|------|-----------|
| 3        | 7   | 24     | 24   | 7         |

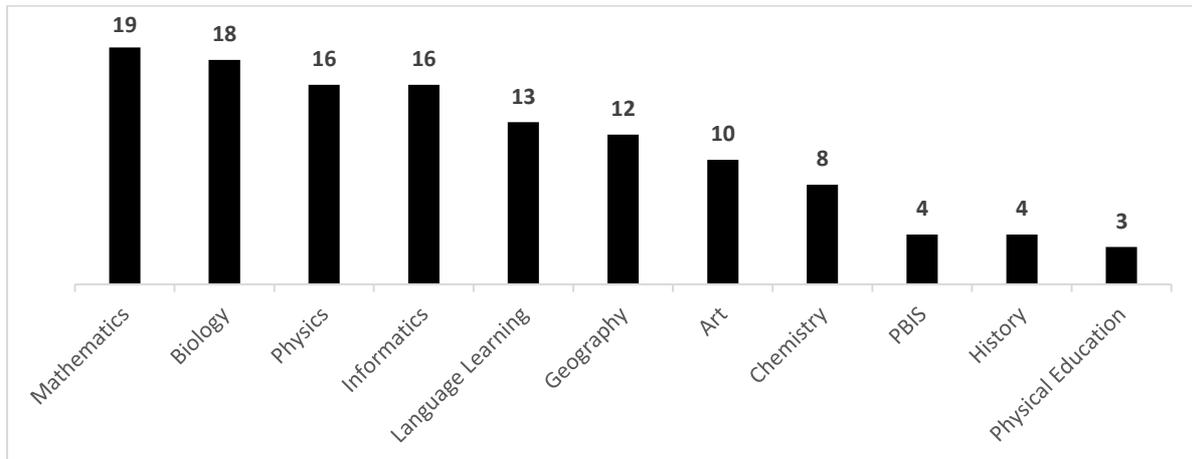
In responding to the question how AR apps could be changed to further improve their confidence in using AR for teaching, teachers provided various responses, which can be categorised into four aspects: Access (n = 6), Training (n = 11), Content (n = 23) and Technical Enhancement (n = 14). Responses pertaining to Access include “By creating repositories with easy access” (T247); “Applications that can be installed on PC Desktop for use in the classroom, because not all students have modern personal devices to work with them” (T337). In this sample, most teachers explained that they need better and more suitable contents to use AR for teaching, as often the contents do not align well with the curricula or with the cognitive level of their students. “Including pre-made activities and templates” (T299); “By knowing exactly what they include, how they work, how they relate to the curriculum and in which classes it is best to apply” (T1387). Another topic mentioned frequently by teachers was the need for applications to be fast, reliable, and compatible with more than one operating system. For instance, “Devices that can handle AR as the students get frustrated or give up waiting for the graphics to load, being able to manipulate objects on a small screen, etc. The answer would be to have an app that would work with tablet devices.” (T1292). With less emphasis, teachers also claimed to need more training and guidance to be more confident while using AR apps for teaching as well as better access to equipment and free AR apps (details see Section 3.4).

### 3.3 More Recent AR Usage for Teaching

In this section we report the results of the questions in Section 3 of the survey (Appendix A).

#### 3.3.1 Software

In response to which AR applications teachers had used most recently, various names were mentioned, with the most popular ones being Quiver (n=11), GeoGebra (n=7) and HP Reveal (n=5). The other applications mentioned twice are: *Architect by Twinkle*, *Aurasma*, *Curioscope*, *iSolarSystemAR*, *Merge Cube*, *Metaverse*, *SchoolAR*. The most common domains covered by the AR apps were Mathematics, Biology, Physics, and Informatics (Figure 3). In total, 53 out of the 65 teachers said to have used an AR application to teach at least once in the last year.



**Figure 3.** Distribution of the domains of the AR apps recently used by teacher respondents

### 3.3.2 Experience

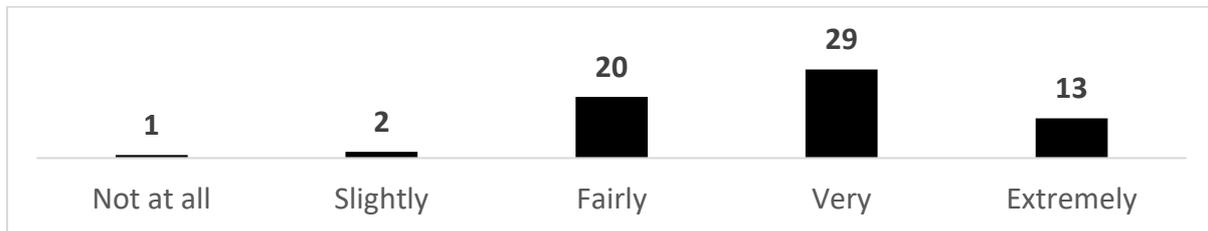
The respondents reported that they had used the AR apps with students of different age groups, ranging from 11-13 years old (n=28, 43%), followed by two age groups: 8-10 years old (n=13, 20%) and 14-16 years old (n=14, 21.5%). A small number of classes had students between 5-7 years old (n=3, 4.6%) or students older than 17 years old (n=6, 9.2%). On average, students spent 43 minutes using the AR apps the last time they had an opportunity. Students used the AR software mostly in the classroom (n=53, 82%), but some used it somewhere else in their schools (n=7, 11%), at home (n=11, 17%), in a museum (n=5, 8%), outdoors (n=5, 8%) or elsewhere (n=2, 3%). With regard to the usage method, the more common ones are students working in groups while sharing a device (n = 35) and the teacher presenting the AR app in front of the class (n = 35). Less common methods are students working in groups with each having a device (n=13) and students working individually with a device (n=9). These results corroborated with the one about the inadequate infrastructural support provided by schools.

Most teachers perceived the AR software as fairly or very useful to support students to learn a topic (Figure 4). Positive rationale included reasons such as:

- *“Students were active, moving around, searching for answers. They were highly motivated to finish the hunt. All the students worked on math problems trying to solve them in order to proceed. Only 1-2% students did not solve the problems. Comparing to 20-25% when they didn’t use the app it is a great success”* (T77)
- *“this is motivating and a very practical educational way of learning”* (T234);
- *“It is a learning experience that is hard to replicate and it is easy to resource”* (T1290);
- *“Through the use of AR, I was able to visualize knowledge. The children learned through playful learning, which piqued their interest, made them look forward to the next application and be happy. In addition, they showed that they better understand and assimilate the concepts of the lesson.”* (T1444);

Negative comments included topics related to

- *“Beyond the initial surprise, then they lost interest as soon as they saw that it was to explain part of the functioning of the body”* (T211);
- *“A little difficult to use”* (T260);
- *“There is always the risk that students could be interested in other things”* (T492).



**Figure 4.** Perceived usefulness of AR apps for students to learn the topics concerned

Moreover, teachers also considered that the overall student experience while using the app was positive (n=38, 58%) or very positive (n=24, 37%); only a few teachers were neutral on their response (n=3, 5%). When asked to elaborate on this answer, some responses of teachers were:

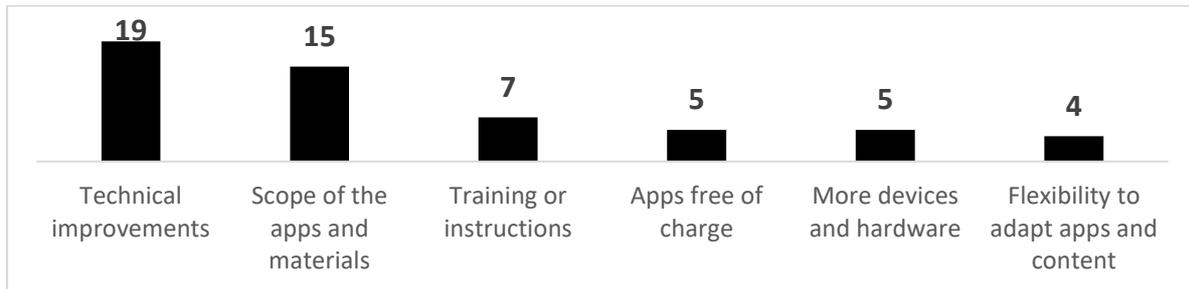
- *“They liked it very much. They learned several things that were not in the textbook. Many children bought similar books for their own home.” (T240)*
- *“It was a pleasant and at the same time constructive teaching and learning experience” (T339);*
- *“Students had fun and the overall experience was positive” (T305).*
- *“Also weaker students were engaged and contributed [to] learning about their town ... It was for them “strange” to actually see some important people who lived in our town” (T1476).*

Teachers also rated their own overall use experience as positive (n=40, 61%) and very positive (n=22, 34%) for the most part; with only a handful of teachers being neutral about their experience (n=3, 5%). Teachers selecting “neutral” explained that they were:

- *“...not familiar using AR during teaching and would like to learn more” (T348);*
- *“...not sure that it really contributes much” (T305).*

### **3.3.3 Improvement suggestions**

Answers to how AR apps could be improved to better support their teaching from participants in this sample were classified in six categories (Figure 5). Technical improvements were selected by teachers as the factor that could benefit them the most. The majority of teachers wanted the applications to be faster, to have more functionalities, and to work on different operating systems. In addition, increasing the scope of the materials available was another suggestion made often by teachers, who mentioned once that there could be more resources that would help teachers to save time and different applications suitable for the student level, which should include not only a larger catalogue of apps, resources, and scenarios, but also their availability in different languages. Also, several teachers considered that attending workshops for teachers and having face-to-face tutorials or instructions for students could greatly support their teaching and facilitate the use of AR apps in the classroom. Other requirements expressed by teachers include providing flexible apps that could be adapted for specific purposes, more hardware in their schools, and a larger stock of free apps.



**Figure 5.** Improvement suggestions for improving AR apps made by teacher respondents

### 3.4 Teacher Requirements

The requirements are grouped and listed in three tables. The first table (Table 3) presents **functional requirements** (i.e. what the system should do) whereas the second table (Table 4) presents **non-functional requirements** (i.e. quality in use that the system must satisfy). The third table (Table 5) lists **organisational and pedagogical requirements** that enable teachers to deploy AR as educational resources. In each table, individual requirements are assigned a unique code, they are described and supported with direct quotes, and qualified with an importance rating (L/M/H) (cf. Section 2.6).



**Table 3:** List of Functional Requirements (FR) from the responses of Teacher Survey (TS)

| Code   | Requirement  | Supportive Quotes  | Importance |
|--------|--|--|------------|
| TS-FR1 | AR applications should be available in different languages   | <ul style="list-style-type: none"><li>• "... have support in multiple languages"</li><li>• "Development in Greek"</li></ul>  | H          |
| TS-FR2 | AR applications should offer user-specific instructions and help options   | <ul style="list-style-type: none"><li>• "Better instructions for students"</li><li>• "More instruction how to use, and learning scenarios for teaching"</li><li>• "More tips for smaller children"</li><li>• "Summarise the application of augmented reality in the presentation of information in very specific steps"</li></ul>  | M/H        |
| TS-FR3 | AR applications should be flexible and allow customization   | <ul style="list-style-type: none"><li>• "the possibility of programming more applications for each student"</li><li>• "to be able to create groups of students"</li><li>• "Allow teachers to add information themselves"</li><li>• "Allowing to add new drawings, drawn by students"</li><li>• "I would like to develop my own content and add it to the application"</li></ul>  | M/H        |
| TS-FR4 | AR applications must support different styles of presentation (e.g., teacher to class, students in groups, or students individually) | <ol style="list-style-type: none"><li>1. "have a limited device for showing children"</li><li>2. "I only have my own tablet to show groups of AR children on various topics"</li><li>3. "My school doesn't provide tablets for students and they have to use their own devices. Not all my students own smartphones and tablets"</li></ol> <ul style="list-style-type: none"><li>• "There is no equipment available in the Kindergarten, I use my own equipment"</li></ul> | M          |
| TS-FR5 | AR applications can work offline   | <ul style="list-style-type: none"><li>• "I expect an offline version but I think it's impossible"</li></ul>  | L          |



**Table 4:** List of Non-Functional Requirements (NFR) from responses of Teacher Survey (TS)

| Code    | Requirement  | Supportive Quotes   | Importance |
|---------|--|---|------------|
| TS-NFR1 | All functionalities in AR apps must be and stay free of charge                                     | <ul style="list-style-type: none"> <li>• “I can’t find enough good free applications at the moment”</li> <li>• ““They could be free of charge”</li> <li>• “Free licenses”</li> <li>• “The app would be improved if it became free for content creation”</li> <li>• “This app could give all the drawings for free”</li> </ul>   | H          |
| TS-NFR2 | AR apps should be fast and always available  | <ul style="list-style-type: none"> <li>• “Be faster and require less memory to run”</li> <li>• “Make it faster”</li> </ul>  | H          |
| TS-NFR3 | AR apps should recover from errors immediately   | <ul style="list-style-type: none"> <li>• “Devices that can handle AR as the students get frustrated or give up waiting for the graphics to load, being able to manipulate objects on a small screen, etc.”</li> </ul>   | H          |
| TS-NFR4 | AR applications should be portable and need to run in any major mobile or desktop operating system | <ul style="list-style-type: none"> <li>• “Applications that can be installed on PC Desktop for use in the classroom, because not all students have modern personal devices to work them”</li> <li>• “Become more device-friendly”</li> <li>• “...to have an app that would work with tablet device.”</li> <li>• “I would make some apps usable on all systems in the same way in order to guarantee their use on students' personal devices in the BYOD logic”</li> <li>• “Maybe if the possible incompatibility problems with some devices / applications are solved”</li> <li>• “Some of them only work on iOS. So I have to balance between using them and discriminate students that have iOS devices and not using them.”</li> <li>• “to run in more than 1 software (e.g. Android and iOS)”</li> <li>• “If it had an Android version it would be awesome”</li> <li>• “The app is already very powerful and should also be released in the Android and Google stores”</li> </ul> | H          |
| TS-NFR5 | AR apps must be usable, learnable (easy and quick to learn to use)                                 | <ul style="list-style-type: none"> <li>• “Create easy-to-use, intuitive tools; select item, overlay content, and run”</li> <li>• “I do not have enough knowledge about AR”</li> </ul>   | M          |



|         |  |  |   |
|---------|--|--|---|
|         |  | <ul style="list-style-type: none"> <li>● “AR is a relatively new application and its use in teaching, although very attractive, requires searching and preparation”</li> </ul>   |   |
| TS-NFR6 | AR apps should support teachers to develop AR-based learning content and design learning activities with AR. | <ul style="list-style-type: none"> <li>● “To prepare a lesson plan using AR it takes me 2-3 weeks to find suitable apps and 2-3 weeks more to ‘build’ a lesson...”</li> <li>● “it takes time to prepare good activity with the usage of AR.”</li> <li>● “I need to find work time in which to develop educational experiences that require more than one hour of continuous work”</li> <li>● “There are still no simple applications for the use of students”</li> <li>● “I use HP Reveal with my students, for its ease of carrying out augmented reality, as well as for them to use it in a simple way. Currently, I do not know of any intuitive tool for them to develop tasks with these tools”</li> </ul> | M |
| TS-NFR7 | AR apps should offer up-to-date, clear and clean sequences and user interfaces                               | <ul style="list-style-type: none"> <li>● “To have simpler menus...”</li> <li>● “It would be nice to have additional areas to explore within the app”</li> <li>● “More elements could be incorporated to enhance student engagement and apply exploratory approaches”</li> <li>● “More functionalities”</li> <li>● “More management tools - more regular updates”</li> </ul>  | M |

**Table 5.** List of Pedagogical and Organisational Requirements (POR) from responses of Teacher Survey (TS)

| Code    | Requirement   | Supportive Quotes   | Importance |
|---------|---|---|------------|
| TS-POR1 | School management should care about providing the appropriate infrastructure and hardware/equipment, including the Internet and mobile devices to run AR apps (tablets, smartphones), | <ul style="list-style-type: none"> <li>● “all my students should have the necessary gadgets”</li> <li>● “I bring my tablet etc”</li> <li>● “I cannot depend on students hardware”</li> <li>● “I know AR is really good for teaching different subjects, but I do not have the hardware I need”</li> <li>● “I need more hardware because not all my students have phones that can support AR”</li> <li>● “We need at least an internet connection in our classroom, so we can use some AR apps”</li> <li>● “It also requires the use of devices that students must either bring from home or the school must procure so that everyone has access”</li> </ul> | H          |



|                |  |  |          |
|----------------|--|--|----------|
|                | <p>and ease regulatory constraints.</p>  | <ul style="list-style-type: none"> <li>● “Lack of logistical infrastructure”</li> <li>● “My school doesn’t provide tablets for students and they have to use their own devices. Not all my students own smartphones and tablets”</li> <li>● “...all this in combination with the outdated equipment, make it seem like a distant dream”</li> <li>● “students use their own smartphones”</li> <li>● “The school does not invest in this field and there is no economic interest on the part of the management”</li> <li>● “There is no equipment available in the Kindergarten, I use my own equipment”</li> <li>● “We don’t have any other devices”</li> <li>● “We need to have internet available, as well as compatible hardware”</li> <li>● “The change is not as necessary in the applications as in the devices to work. In order to enjoy this technology, an economic investment is important”</li> <li>● “If school will provide us with devices, then I will use AR more often”</li> <li>● “The use of OP but it requires equipment that schools can hardly have”</li> <li>● “Management has to buy some hardware”</li> <li>● “The possibility of using it on less powerful computers”</li> <li>● “The use of mobiles phones is generally prohibited in the classroom in the Greek educational system by law and requires bureaucracy to use them while there is no frequent access to the computer lab”</li> </ul> |          |
| <p>TS-POR2</p> | <p>Providers need to offer a broader coverage of up-to-date and ready-to-use AR educational resources, which should be creative and have high educational utility.</p> | <ul style="list-style-type: none"> <li>● “Also need apps that will work in my subject”</li> <li>● “AR apps connected with Maths”</li> <li>● “Likewise, to work well it is necessary to have material that is only a few years old and to be informed”</li> <li>● “An application bank or project can be created in the fields of physics, chemistry and biology”</li> <li>● “Have more information about the planets”</li> <li>● “I want to see different applications suitable for the level”</li> <li>● “More applications in teaching”</li> <li>● “More topics. More critical and creative knowledge”</li> <li>● “To be improved with more examples”</li> <li>● “The adaptation of application functions to didactic units will further contribute to its better educational utilization”</li> <li>● “There could be more resources that would help teachers to save the time and give them idea to apply in the classroom”</li> </ul>  | <p>H</p> |



|         |   |   |   |
|---------|---|---|---|
|         |   | <ul style="list-style-type: none"> <li>• “For the field of science; an app bank can be established and alternative applications can be located here. Subject support can be requested from teachers to develop content”</li> <li>• “Sample studies with lesson plan can be increased”</li> <li>• “It can be difficult to find interactions in physics, chemistry and biology. There is no AR bank as far as I know”</li> <li>• “Including pre-made activities and templates”</li> </ul>   |   |
| TS-POR3 | The AR activities must be short enough to fit in a lesson (~45')  | <ul style="list-style-type: none"> <li>• “...the available time [is a] very important parameter”</li> <li>• “Class time is limited”</li> <li>• “for experimental activities, physical time sometimes limits the activities of exploration, brainstorming and argumentation and deduction”</li> <li>• “have a limited device for showing children”</li> <li>• “Lack of time in classroom programming to work with AR Hardware available in primary school”</li> <li>• “WWF have some great interactive apps but some apps are just too content heavy and don't really have much of a benefit to using them”</li> </ul>   | M |
| TS-POR4 | AR apps should be gathered, categorized, and published in highly accessible and searchable online repositories. | <ul style="list-style-type: none"> <li>• “to know the latest applications to be released on the market”</li> <li>• “As AR is a new field I need more time to find more appropriate apps for my students and my subject - math”</li> <li>• “Do not know exactly what augmented reality material is available”</li> <li>• “find proper material to adopt it in the lesson”</li> <li>• “I would like to have more information about the applications that are circulating and which are compatible with the curricula. The information I have at the moment is from a personal initiative and through participation in conferences”</li> <li>• “It would be great help to have all materials at one place to use in my teaching. It is something really useful to let students explore the limits of real life”</li> <li>• “It would help a lot if all the applications were gathered somewhere with short instructions and per lesson”</li> <li>• “There has only been two really good apps for AR and now are no longer supported so I find the current AR apps on the market quite limited to exchange learning for the subject I teach”</li> <li>• “Larger catalog of resources and scenarios, as well as the pattern recognition engine for augmented reality”</li> </ul> | M |



|         |   |   |   |
|---------|---|---|---|
|         |   | <ul style="list-style-type: none"><li>● "To prepare a lesson plan using AR it takes me 2-3 weeks to find suitable apps"</li><li>● "Create repositories with easy access"</li></ul>  |   |
| TS-POR5 | Projects should offer more training and support   | <ul style="list-style-type: none"><li>● "I think there is a need for new educational seminars for improving AR skills, new workshops and webinars"</li><li>● "I want to learn how can I use it in primary education"</li><li>● "I would like help using AR hardware"</li><li>● "I would like to get to know more about the apps that I could use"</li><li>● "Learn more about AR potentialities"</li><li>● "More methodology of HOW to use AR at the lessons, more examples of good learning scenarios with AR"</li><li>● "Resources on how to use AR in the classroom would be useful"</li><li>● "There is no possibility of training correctly if it is not on your own"</li><li>● "Would need to undertake more training"</li><li>● "More dissemination among teachers"</li><li>● "There is a constant need for teacher training in new technologies and innovative teaching tools"</li><li>● "There should be more free training packages on more topics"</li></ul> | M |
| TS-POR6 | Building a community of practice for teachers using AR educational tools to discuss the related pedagogical issues. | <ul style="list-style-type: none"><li>● "Also a teachers blog or resource pages where teachers could share tips, ideas, worksheets, lesson plans with AR would be appreciated"</li><li>● "make more suitable material to follow lessons like process with lab experiments or many different examples of chemical reactions"</li><li>● "to have distribution per class, lesson and unit"</li><li>● "A limitation that I often encounter in AR applications is that their digital material does not coincide with the cognitive level of my students and the teaching objectives of the course in which I use them"</li><li>● "which AR apps are more suitable for me and the students"</li></ul>   | M |



## 4 Results: Teacher Interview

As mentioned in Section 2.2, the questions in the semi-structured interviews were taken from Teacher Survey with modification. Hence, it is deemed appropriate to report the results separately. All interviews were conducted by a research associate, who had training in HCI, through Skype. All four interviewees (I01-I04) were teachers in primary or secondary schools with three living in the United Kingdom and one in the United Arab Emirates (UAE). Three were male and one was female. They taught at different school levels with students of 4-10, 8-10, 11-18, and 6-13 years old. All have experience with AR apps and used them in their teaching at least once in the last academic year.

### 4.1 Usage Patterns and Experiences

**AR Apps and Domains:** The interviewees said to have recently used various AR apps for teaching purposes (Augmentify it, Star Chart, 4D+ Augmented Reality Cards) with the most mentioned applications being Quiver (n=3) and Aurasma (n=2). Domains covered by the AR apps that teachers had used more recently included: Physics, Biology, Geography, History, Writing, Computing, and General Sciences.

**Experiences:** Three teachers used AR apps in the classroom, through different teaching methods depending on the app or the task, demonstrating in front of the class, students working in groups sharing a single device or having their own device. In responding to the question on the usefulness of the AR apps for supporting their students to learn, one interviewee considered AR apps to be *fairly useful* (n=1) and three *very useful* (n=3) for learning a topic. The main reasons are listed as follows:

- *“I think they hold two key advantages. They help engage reluctant learners in tasks which can be presented in imaginative ways aiding their engagement and ultimately progress. secondly, i think they are very useful to bring concepts to life, things which children cannot even begin to imagine without visualisation such as scale and size”*
- *“AR apps have lots of potential and are engaging to use, especially for young children learning complex subjects... AR apps allow them to explore and look at things in their own ways, which is at the same time more entertaining for them than a regular class”*
- *“without the AR app, my students would have struggled to understand the concepts of... with it, students had a much better appreciation of the 3D definition of substances”*
- *“AR apps are very useful in bringing the learning to life. one has to be careful however that it is not gimmicky and it is used to enhance learning, or else students won’t gain anything from the experience”*

Additionally, when interviewees were asked to explain how AR apps could be improved to better support their teaching, responses were similar to those of Teacher Survey (see Section 3.3). They made different suggestions, including providing more training for teachers to be able to adequately use and adapt AR content and apps. Also, participants remarked that explaining the availability of materials and resources could greatly benefit their teaching as they continue to struggle to find suitable applications to fit in their curricula and lesson plans. Finally, some technical improvements were mentioned by participants, including having



*“smoother animations” (I04), “faster performance” (I03), and “continuous improvements and updates” (I02). Full responses to this question are as follows:*

- *“The apps available are improving constantly. I think better training to understand and use these in lessons would have been useful. It is very difficult for us [teachers] to find time of our own to learn how to use the apps... to adapt them to the school curricula... [or] the lesson plan”*
- *“Although AR engages children in learning and allows them to explore and look at things in different ways, AR apps need to provide continuous improvements and updates to satisfy the modern educational needs. Apps should be relevant to the curricula, fast, and engaging regardless the age group they are targeting”*
- *“More breadth in offering. Definitely. Only a few apps in the market are useful to include in lessons... and several topics are not available as AR. Also, the apps that I have used in the past should offer faster performance and better functionalities”*
- *“Apps need to display smoother animations and more tips or instructions for students to understand how to use them”*

#### **4.2 Teacher Requirements from Interview Data**

The interviewees also mentioned several features and requirements that they considered basic to any AR app. These were grouped in six categories, namely *Usability, Reliability, Speed, Safety, Suitability, and Access*. Several proposed features are related to the usability of the apps (e.g. *“Due to the age of the children I teach, the most important elements are simplicity and reliability”*, I01). Other features expected from AR technologies involve the reliability of the apps (*“the frustrating element of some apps is how quickly the image can be interrupted or disappear. Children also find it frustrating when images jump around. AR apps need to be reliable to engage students to use them.”*, I01), their speed (*“apps need to be quick to load and present”*, I03), their safety (*“the most important area to consider when using any app in school is their safety, and knowing that children will not be exposed to any inappropriate content”*, I02), and an easier access to AR apps ( *“[apps] designed for use on a range of devices so as not to rule the use of them out in certain schools depending on the hardware available”*, I04). These six aspects are integrated into the requirements listed in the following tables: functional, non-functional, pedagogical and organisational (Table 6, 7 and 8).



**Table 6:** List of Functional Requirements (FR) from responses in Teacher Interview (TI).

| Code   | Requirements   | Supportive Quotes   | Importance |
|--------|--|---|------------|
| TI-FR1 | AR applications should display engaging and clear interfaces   | <ul style="list-style-type: none"> <li>- “They help engage reluctant learners in tasks which can be presented in imaginative ways aiding their engagement and ultimately progress”</li> <li>- “AR apps have lots of potential and are engaging to use, especially for young children learning complex subjects...”</li> <li>- “Without it, my students would have struggled to understand the concepts of... with it, students had a much better appreciation of the 3D definition of substances”</li> <li>- “Apps need to display smoother animations...”</li> <li>- “... and engaging regardless the age group they are targeting”</li> <li>- “AR needs to be friendly and easy to use”</li> <li>- “Apps need to be quick to load and present, otherwise students lose interest in the software”</li> </ul> | H          |
| TI-FR2 | AR applications should offer pertinent instructions and/or help options  | <ul style="list-style-type: none"> <li>- “...and more tips or instructions for students to understand how to use them”</li> <li>- “[students lose interest in the software] when students don’t know how to use the app”</li> </ul>   | H          |
| TI-FR3 | AR applications should support different styles of presentation (e.g., teacher to class, students in groups, or students individually) | <ul style="list-style-type: none"> <li>- “[How I use AR apps]... depends on the nature of the task and what learning objective I wanted to get out of them. Generally, either students work in groups sharing a device as we don’t have that many, or I present the activity to the students in front of the class”</li> <li>- “I presented the app in front of the class... and then students had some time to play with it on smartphones and tablets”</li> </ul>   | M          |
| TI-FR4 | AR applications should expand on representations of the real life  | <ul style="list-style-type: none"> <li>- “I think they are very useful to bring concepts to life, things which children cannot even begin to imagine without visualisation such as scale and size”</li> <li>- “AR Apps are very useful in bringing the learning to life. One has to be careful however that it is not gimmicky and it is used to enhance learning, or else students won’t gain anything from the experience”</li> </ul>   | M          |



**Table 7:** List of Non-Functional Requirements (NFR) from responses in Teacher Interview (TI)

| Code    | Requirements   | Supportive Quotes   | Importance |
|---------|--|---|------------|
| TI-NFR1 | AR applications should be usable, safe, secure and present appropriate content     | -“Then obviously, the most important area to consider when using any app in school is their safety, and knowing that children will not be exposed to any inappropriate content.”<br>-“Designed sensibly for young children”   | H          |
| TI-NFR2 | AR applications should be fast and reliable  | - “Also, the apps that I have used in the past should offer faster performance and better functionalities”<br>- “Due to the age of the children I teach, the most important elements are simplicity and reliability. It needs to be easy for the pupils to work the app ensuring the image will appear quickly and simply, for example, using a simple QR code to scan.”<br>- “AR apps need to be reliable to engage students to use them.” | H          |
| TI-NFR3 | AR applications should recover from errors immediately                             | - “The frustrating element of some apps is how quickly the image can be interrupted or disappear. Children also find it frustrating when images jump around...”<br>- “[students lose interest in the software] if it crashes”   | H          |
| TI-NFR4 | AR applications should run in any of the major mobile or desktop operating system. | - “designed for use on a range of devices so as not to rule the use of them out in certain schools depending on the hardware available”   | H          |
| TI-NFR5 | AR apps should be fun  | - “[AR apps] allow them to explore and look at things in their own ways, which is at the same time more entertaining for them than a regular class”   | M          |
| TI-NFR6 | AR applications should continuously update   | - “Although AR engages children in learning and allows them to explore and look at things in different ways, AR apps need to provide continuous improvements and updates to satisfy the modern educational needs”   | M          |



**Table 8:** List of Pedagogical and Organisational Requirements (POR) from responses of Teacher Interview (TI)

|         | Requirement  | Supportive Quotations  | Importance |
|---------|--|--|------------|
| T1-POR1 | AR applications should be linked to the curricula        | <ul style="list-style-type: none"><li>- “Apps should be relevant to the curricula”</li><li>- “More breadth in offering. Definitely. Only a few apps in the market are useful to include in lessons... and several topics are not available as AR”</li><li>- “That the AR will be relevant to the topic and easy to find what topics it covers.”</li><li>- “[students lose interest in the software] if the app does not contain enough interesting activities for them to do”</li><li>- “Clear links to the curriculum being taught”</li></ul> | H          |
| TI-POR2 | School management should offer more training and support | “The apps available are improving constantly. I think better training to understand and use these in lessons would have been useful. It is very difficult for us [teachers] to find time of our own to learn how to use the apps... to adapt them to the school curricula... [or] the lesson plan”   | M          |



## 5 Results from Secondary School Student Survey

Altogether 1157 students visited the survey, but only 65 responses were complete. While we cannot identify the actual reasons for high incompleteness rate, the same speculation for Teacher Survey (Section 4) may be applied here. Specifically, we speculate that many of the students considered themselves ineligible when they read the following statement in the beginning of the survey: *“Don’t answer the questions if you have never used Augmented Reality for learning.”* If our speculation was correct, it would imply that only **5.6%** of the secondary school students answering to our survey had used AR to learn.

### 5.1 Demographic Data

Out of the 65 valid responses in the sample, 34 students were female, 30 were male, and one preferred not to say. In terms of age-group, the distribution is as follows: 10-11 years old (n=16), 12-13 years old (n=1), 14-15 years old (n=20), 16-17 years old (n=26), >17 (n=2). The students resided in five European countries: Italy (n=22), Spain (n=17), Romania (14), Croatia (n = 11), and Greece (n = 1).

### 5.2 Experience with AR for Learning

**Usage.** Most participants said to have used AR for learning on a monthly basis (n=40), whereas the rest of students said to have used it weekly (n=12), daily (n=4), or not very often (n=9). On average, students spent 34 minutes (SD=19.52, range = 0-100) using AR software for learning in one continuous period.

**Experience.** In responding to the question who has suggested them to use AR for learning, the majority selected the option “my teacher” (n=55), and the minority selected “my parent” (n=7), “my friend” (n=2), and “I have discovered it myself” (n=6). The distribution of the devices used by the students to interact with AR apps is: smartphone (n=51), tablet (n=24), desktop/laptop (n=26), game consoles (n=2), other (n=1, not specified). Also, students said to have used AR apps at school (n=47), at home (n=30), outdoors (n=12), or elsewhere (n=2).

**Intentions to use.** The vast majority of students said they would like to use AR more often for their learning (n=62), only a few were unsure (n=3), and none said they would not like to. In answering what would they need to increase their usage of AR for learning, their opinions were evenly divided, but the category with most votes was to *find the time* (n=28), *know which AR apps are suitable* (n = 23), *more help to use AR apps* (n=19), and *better access to AR hardware* (n=22).

When asked to expand on their needs to increase their usage of AR for learning, most students claimed that time was an issue (*“I do not have much time due to exams”*, S323), that they needed more training (*“More tutorials online about AR apps”*, S555), more apps (*“I do not know many AR apps”*, S364), or suitable access to devices (*“devices even at school”*, S354). Additionally, three students explained their reasons why they were not sure if they would like to use AR more often for learning as follows: *“Because at the end of the day it is a new method and you have to get used to it.”* (S559), *“It seems to me that my use now is adequate”* (S560), *“Because it is not an application that I can use often or a lot”* (S633). For details, see Section 5.4 on requirements.

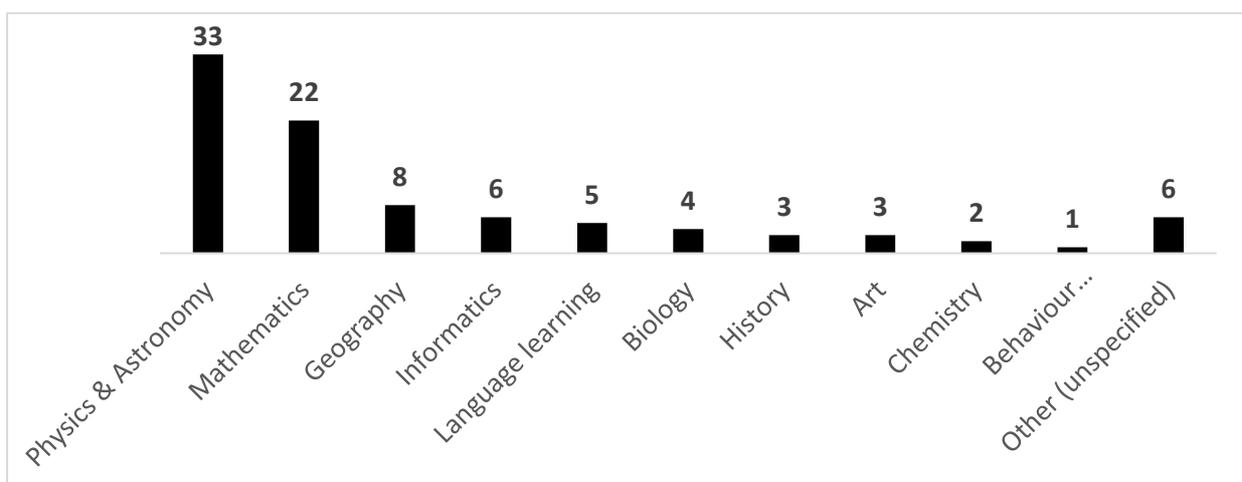


**Features.** Students in this sample were asked which features in an AR app would make it more likely for them to use AR software to learn, and their answers were grouped in 5 categories: Having fun (n=9); Related to learning (n=3); Technical improvements (n=25); About the materials (n = 15), and Creating own content (n=5). Most comments were related to technical improvements and topics covered by the AR apps. Similarly, the majority of students said they would be less inclined to use AR apps if these didn't ensure a good performance or the necessary technical features for them to learn suitably. Other reasons included the lack of equipment, knowledge, or if they were not interested in the topics offered by the AR apps. For details, see Section 5.4 on requirements.

**Interactions and help.** When asked how students would prefer getting help for using AR apps in their learning, most of them chose the option to get the help of “a real person” (n=33), followed by “video tutorials” (n=15) and “an avatar in the app” (n=14); at last, just a few students wanted to have “help text in the app” (n=3). Also, most students said they would like to interact with other learners in AR apps for learning (n=55), with just a few being unsure (n=7) or preferring not to interact with others (n=3). Their favourite way to interact with other learners would be by using a live chat (n = 39), and the other means are seeing and manipulating the same 3D objects and messages (n = 23), and using a leaderboard to compete with them (n = 11).

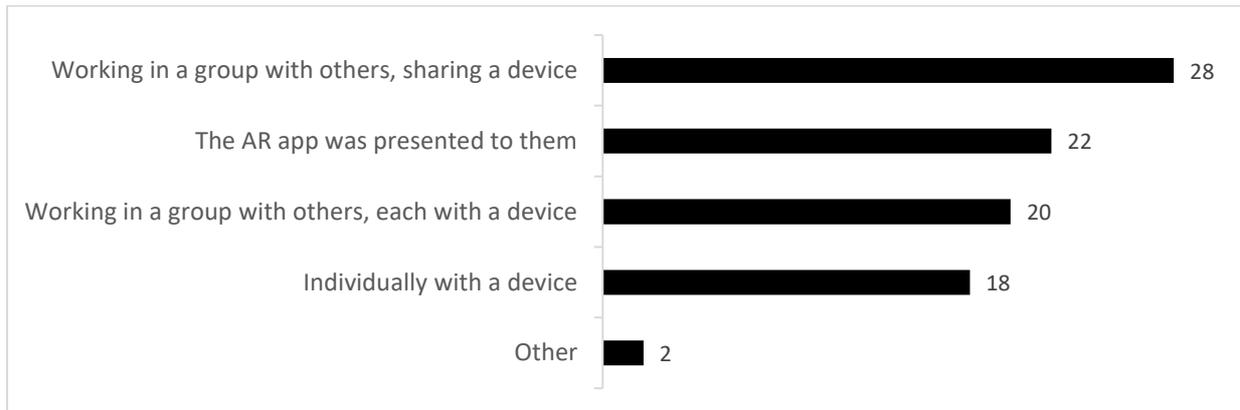
### 5.3 Most Recent AR Usage for Learning

**Usage.** AR apps that students had recently used and mentioned more often include: HP Reveal, Skymap, Skyview, and CoSpaces edu. The majority of students had used an AR app for learning in the last few days or weeks (n=48), some of them had used an AR app in the last few months (n=13) or over a year ago (n=3), and the rest did not specify. The most represented topics in the apps students had used were Mathematics, Physics, and Astronomy (Figure 6).



**Figure 6:** Distribution of the domains of the AR apps used by the secondary school students

Students used these apps mostly at school (n=47), but also at home (n=30), outdoors (n=12), and elsewhere (n=2); in different ways according to the needs of the task (Figure 7). On average, students worked with the AR app for 47 minutes (SD=41.63, range= 5-200).



**Figure 7:** Methods of using AR apps by the secondary school students.

**Usefulness and UX.** Most students rated the app they had used most recently as useful in supporting them to learn a topic: slightly useful (n = 3), fairly useful (n = 18), very useful (n = 38), and extremely useful (n = 6). Additionally, students rated their overall experience with the application as positive (n=43), very positive (n=17) or neutral (n=5), but nobody rated it as a negative or very negative experience. Suggestions students gave to improve the applications to better support their learning included mainly training and guidance or technical improvements, although many participants considered that the application did not need any improvements. For details, see Section 5.4 on requirements.

#### 5.4 Requirements from Secondary School Students

In this section, we present the requirements extracted from the 65 student responses. These requirements are recommended for the design and development of AR applications. Similar to Section 3.4 and Section 4.2, the requirements are grouped as functional, non-functional and pedagogical & organisational (Table 9, 10 and 11).



**Table 9:** List of Functional Requirements (FR) from responses of Secondary School (SS) Student Survey

| Code   | Requirements   | Supportive Quotes   | Importance |
|--------|--|---|------------|
| SS-FR1 | AR applications present appropriate instructions and/or help options to students | <p>“...someone to explain to me every function that this particular app can have, I would use it for longer and I would also be more inclined to use it”</p> <ul style="list-style-type: none"> <li>- “It takes time to learn and get used to using this type of app”</li> <li>- “More tutorials online about AR apps”</li> <li>- “sometimes they are complex and it takes me a long time to understand the different functions / how to use them in general”</li> <li>- “I would like to know how to best use AR apps”</li> <li>- “Sites that explain which app to use”</li> <li>- “More information on all aspects and functions of it”</li> <li>- “I would like a video tutorial a presenter inside of the applications”</li> <li>- “surely it could be improved by better explaining its features with for example a virtual voice to guide you in learning”</li> <li>- “avatars that explain best”</li> <li>- “increasing the amount of things to discover and with a guide that can help me better”</li> <li>- “understand and navigate this app”- “</li> </ul> | H          |
| SS-FR2 | AR applications should allow appropriate interactions                            | <ul style="list-style-type: none"> <li>- “Interaction with other students”</li> <li>- “more interaction”</li> <li>- “perhaps with virtual chats”</li> <li>- “Chat in real time”</li> </ul>  | M          |
| SS-FR3 | AR applications should be flexible and allow customization                       | <ul style="list-style-type: none"> <li>- “More animations to create”</li> <li>- “Functions for character modification and costume modification”</li> <li>- “Being able to change things more easily”</li> <li>- “Putting you to create objects”</li> </ul>  | L          |



**Table 10:** List of Non-Functional Requirements (NFR) from responses of Secondary School (SS) Student Survey

| Code    | Requirement   | Supportive Quotes   | Importance |
|---------|---|---|------------|
| SS-NFR1 | AR applications should be straightforward, aesthetically pleasant, and easy to use. | <ul style="list-style-type: none"> <li>- “More immediate interface”</li> <li>- “Simple and intuitive graphics”</li> <li>- “More precision and easier to use”</li> <li>- “Intuitive controls”</li> <li>- “Less folders, many times we get confused”</li> <li>- “To know more about what I see, to be more precise”</li> <li>- “clear indications on how the app should be used and how it works”</li> <li>- “Nice drawings and screenshots, nice graphics,..., fast movements”</li> <li>- “For graphics, voice, advance, addition”</li> <li>- “More precise controls, more 3D objects”</li> <li>- “...make commands easier”</li> <li>- “Facilitate its use”</li> <li>- “More free bookmarks”</li> <li>- “Easier controls”</li> <li>- “Simplifying the method of production of work and little else the truth”</li> </ul> | H          |
| SS-NFR2 | AR applications should be fast, reliable, and secure.                               | <ul style="list-style-type: none"> <li>- “I need the AR app to be faster”</li> <li>- “Apps that are more reliable and perform better”</li> <li>- “The problem is that there are some apps that give you viruses or are full of ads, etc.”</li> </ul>  | H          |
| SS-NFR3 | AR applications should be updated regularly   | <ul style="list-style-type: none"> <li>- “New tutorials”</li> <li>- “More updates and news”</li> <li>- “If there was always something new (updates)”</li> <li>- “I wish there was more content”</li> <li>- “Interesting content...”</li> <li>- “Translator and augmented reality, statistics”</li> </ul>  | M          |



|         |   |   |   |
|---------|---|---|---|
|         |   | <ul style="list-style-type: none"> <li>- “More functionality”</li> <li>- “With more things”</li> <li>- “Translator could be included within the application”</li> <li>- “Adding more objects or things that you can make more animated like moving or more walking or something like that”</li> </ul> |   |
| SS-NFR4 | AR applications must be engaging and fun to use | <ul style="list-style-type: none"> <li>- Games and animated stories</li> <li>- Make it entertaining and fun to use</li> <li>- The ones that teach you but make it fun for you to learn by interacting</li> <li>- Working with them can be more fun</li> </ul>   | M |

**Table 11:** List of Pedagogical and Organisational Requirements (POR) from responses of Secondary School (SS) Student Survey

| Code    | Requirement  | Supportive Quotes   | Importance |
|---------|--|---|------------|
| SS-POR1 | Projects / schools should offer enough and appropriate hardware for the use of AR apps | <ul style="list-style-type: none"> <li>- “Problem is equipment in our school”</li> <li>- “Better access to AR hardware...”</li> <li>- “I have no possibility to use virtual reality in the school environment”</li> </ul> | H          |



|         |  |   |   |
|---------|--|---|---|
| SS-POR2 | The content offered by AR apps must relate to the curricula and with clear explanation                               | <ul style="list-style-type: none"><li>- I like to learn more AR because I want to be an IT manager because I want to make projects because I like to create more apps</li><li>- I want to pursue a career in this field</li><li>- I needed this application because I need to learn to be an IT engineer</li><li>- I need AR APPS because I am passionate about foreign exchange and I would like to use my knowledge for certain and activities and project given at school</li><li>- I would like to learn more about using tablets to create characters</li><li>- I'd like to use AR to create more apps and to study</li><li>- Interesting lessons</li><li>- "have more detailed information or more insights on what I see"</li><li>- "Those of containing concise explanations on what I see"</li></ul> | H |
| SS-POR3 | Projects / schools should provide appropriate activities for the use of AR applications in and outside the classroom | <ul style="list-style-type: none"><li>- "I would need more time to devote to learning with augmented reality"</li><li>- "often don't have the time to devote myself more deeply to subjects with augmented reality apps"</li><li>- " I need to get more time and being able to use it in schools would be more practical"</li><li>- "The afternoon is always busy with sports or study. It would be nice to be able to use AR at school too."</li><li>- "I don't' have time to do virtual reality activities"</li><li>- " I don't have enough time because they send me a lot of homework and I have a lot of exams."</li><li>- I found it to be a very interesting activity and very entertaining and that is why I would like to take more time</li></ul>   | M |



|         |  |  |   |
|---------|--|--|---|
| SS-POR4 | AR apps should be gathered, categorized, and published in free online repositories | <ul style="list-style-type: none"><li>- Free apps</li><li>- I'd like to know which apps are the best to learn, as there are so many to choose from and it wouldn't be possible to try them all one by one</li><li>- Know which apps are best suited for what I'm going to do</li><li>- knowing which are the best and clearest apps would help me a lot in choosing</li><li>- "Cheaper apps and full versions"</li><li>- "that it would be easier to access them, in the sense that it is difficult to carry out RA [research activity] by yourself, if the work is already done by someone else and you just have to observe and things change"</li></ul> | M |
|---------|--|--|---|



## 6 Results from Primary School Student Survey

Altogether there were 1083 visits to the survey, only 130 responses were complete. Similar to the Teacher and Secondary School Student Survey, we cannot identify actual reasons for the high incompleteness rate. Nonetheless, we speculate that many of the visitors considered themselves ineligible when they read the following statement in the beginning of the survey: *“Don’t answer the questions if you have never used Augmented Reality for learning.”* If our speculation was correct, it would imply that only **12%** of the students answering to our survey had used AR to learn. This resonates with the finding of our systematic literature review on AR educational applications of which many have been designed for primary school students (D4.1, M15).

### 6.1 Demographics

Out of the 130 complete responses in the sample, 53 students were female, 73 were male, and one preferred not to say. In terms of age-group, the distribution is as follows: 5-6 years old (n=1), 7-8 years old (n=30), 9-10 years old (n=51), 11-12 years old (n=27), >12 (n=21). The responses came from three European countries: Greece (n = 112), Spain (n = 17) and Ireland (n = 1). The distribution is obviously skewed.

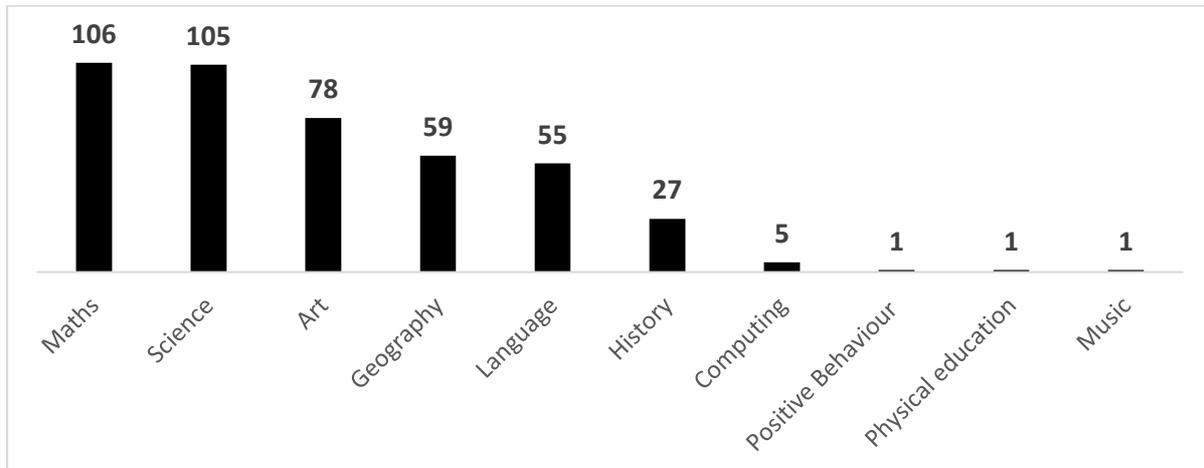
### 6.2 General Usage and Experience with AR

**Usage.** In response to how many times students had used AR applications in the past, the majority of participants said to have used AR software more than three times (n=106), whereas the rest of students said to have used it two to three times (n=15) or only once (n=9). Students also explained that they had used AR software mostly for learning and playing (n=109), only for learning (n=12), or for playing only (n=8), with one participant not specifying an answer for the chosen option “other”. The majority of students used AR applications as suggested by their teachers (n=123), but a few got the idea from their parents (n=4), their friends (n=4), the TV (n=1), or discovered the apps by themselves (n=4).

**Devices.** The most popular devices used by students to interact with AR applications were tablet (n=114), mobile phone (n=60), desktop/laptop (n=12), game console (n=6), other (unspecified, n =1). Primary School students used AR apps at school (n=116), at home (n=50), outdoors (n=31), or elsewhere (n=5).

### 6.3 Using AR Applications at School

**Usage.** The majority of students had used at least 5 AR applications for learning purposes at school (n=74), but some students had used 2-4 AR applications (n=33) or only one application (n=23). Common subjects that students learnt while using AR were: mathematics, science, and art (Figure 8). On average, students spent around 30 minutes (SD=12.12, range 6-100) using AR applications for learning at school in one go.



**Figure 8:** Distribution of the domains of the AR apps used by the primary school students

When asked which devices were available at their schools, students named tablets (n=118), desktop computers (n=19), laptops (n=13), mobile phones (n=15), and in some cases none (n=4). Also, most students claimed that there were only a few devices available for students to work in groups at school (n=112), with very few cases in which students were given their own device to work with (n=6), and sometimes having only one device for the teacher to use (n=7).

**Experience.** On a 5-point scale, most students rated the AR applications as *very easy* (n=79) or *easy* to use (n=39); some considered it *okay* (n=12), but none thought using the AR apps was *hard* or *very hard*. When asked to expand on their answer, most students said positive things and only a few had negative comments on the usability of the applications. Such comments have been integrated into the requirements (Section 6.4). Likewise, when students were asked how much they liked the AR applications they have used for learning at school, most rated the experience as *fantastic* (n=92), *really good* (n=27), or *okay* (n=11), but none thought using AR was *not very good* or *awful*.

#### 6.4 Requirements from Primary School Students

In this section, we present the requirements extracted from the 130 primary school student responses. These requirements are recommended for the design and development of AR applications. Similar to Section 5.4, the requirements are grouped as functional, non-functional and pedagogical & organisational (Table 12, 13 and 14).



**Table 12:** List of Functional Requirements (FR) from responses of Primary School (PS) Student Survey

| Code   | Requirement  | Supportive Quotes  | Importance |
|--------|--|--|------------|
| PS-FR1 | AR applications should display true representations of the real world on the interface | - "...one can see everything"<br>- "Because they were all related to animals and it seemed that they were in front of us, they were very real"<br>- "It is very childish at times even for children" | M          |
| PS-FR2 | AR applications shall present appropriate instructions and/or help options to students | - "You need guidance until you understand how to use the app"<br>- "There are things that are difficult for me to know how to do"  | M          |

**Table 13:** List of Non-Functional Requirements (NFR) from responses of Primary School (PS) Student Survey

| Code    | Requirement   | Supportive Quotes  | Importance |
|---------|---|--|------------|
| PS-NFR1 | AR applications should be straightforward, aesthetically pleasant, and easy to use. | - "I like them [AR apps] a lot and they are simple to use"<br>- "They are easy to use"<br>- "The process was very simple"<br>- "Because you just had to click what you wanted to see and it would work"<br>- "It was also not at all difficult to follow the instructions given by the teacher"<br>- "Why it was very easy, it was obvious what had to be done"<br>- "... I didn't find it difficult to use it"<br>- "The application that I used seemed like a simple and easy to use application"<br>- "They are simple" | H          |



|         |   |  |   |
|---------|---|--|---|
| PS-NFR2 | AR applications should be fast, reliable, and always available. | <ul style="list-style-type: none"> <li>- “Because some apps did not work well and those applications could not be accessed”</li> <li>- “Make them faster and easier to access them”</li> <li>- “Can be further improved...”</li> </ul> | H |
|---------|---|--|---|

**Table 14:** List of Pedagogical and Organisational Requirements (POR) from responses of Primary School (PS) Student Survey

| Code    | Requirement   | Supportive Quotes  | Importance |
|---------|---|--|------------|
| PS-POR1 | Projects / schools should provide appropriate support for the use of AR apps for learning | <ul style="list-style-type: none"> <li>● “Schools administrators need to be more informed to make these applications more accessible to children”</li> <li>- “More augmented reality devices should be included in Greek schools because they lack of technology”</li> </ul>   | M          |
| PS-POR2 | AR applications must be engaging and fun for young children to use                        | <ul style="list-style-type: none"> <li>- “It was a fun and enjoyable way to learn”</li> <li>- “They are fun and help me to learn”</li> <li>- “Because they were easy and fun and I learned a lot”</li> <li>- “It is really fun”</li> <li>- “They are fun and entertaining”</li> <li>- “They are very visual and fun”</li> <li>- “Because it was easy, entertaining, it changes your routine, and you could have fun with your partner”</li> <li>- “It was something fun and different”</li> <li>- “It’s fun”</li> <li>- “It is a pleasant way of learning and it is entertaining”</li> </ul> | M          |
| PS-POR3 | The content offered by AR apps must relate to the curricula                               | <ul style="list-style-type: none"> <li>- “Because the subject interested me and I was curious about how to do the work”</li> </ul>   | M          |



## 7 Conclusion

To capture user requirements for future development of a system, different empirical approaches can be adopted. One viable way is to base them on participants' past usage and experience with the system (or its variations) to identify enhancement suggestions. Given this premise, we developed three surveys for the ARETE target groups, exploring respondents' general as well as specific feedback on AR applications for teaching/learning.

### 7.1 Summary of User Needs and Requirements

Based on the responses of the teachers in the sample, it is obvious that their needs are not particularly technical, but that teachers need more access to hardware and training to be able to use AR software more often in their teaching. Also, for several times teachers suggested that a repository of apps and lessons in topics as part of the curricula in their countries would be ideal for them to best utilize these tools and their time. Among the most important non-functional requirements mentioned, AR apps should be free, fast, reliable, intuitive, easy to learn and use, available for different topics and in different languages, and executable in major operating systems or commonly used devices.

Regardless of the data collection instrument, be it survey or interview, teacher responses are similar to what they expected from AR applications for educational purposes. Among others, popular teacher requirements include: the need of having fun and engaging interfaces (i.e. user experience), clear instructions, and appropriate lessons to use with their students. Additionally, teachers expected the system to run smoothly on different types of devices, have constant updates, and be safe. Teachers also claimed it could be useful for them to have access to better training and support.

The secondary school students involved did not find AR apps to be easy or intuitive to use. Most of their comments on how to improve the applications involved the software providing better instructions, content, and easier interfaces for students to interact with. Similar to the opinion of teachers, students also expressed that it would be useful for them to have repositories of AR apps so they could more easily find one that is suitable for them and the topics of their lessons. The students in secondary schools surveyed were aware that the lack of access to appropriate apps and hardware could be an issue for their learning. Other factors they mentioned in this regard included not having enough time, support, or resources. Fast, reliable, secure, up-to-date, and adequate software were characteristics that the secondary school students were looking for in the design of AR applications.

Comments from the primary school respondents in the sample were mostly positive. They perceived the AR applications they had used as useful, fun, and simple enough for them to use. Hence, those are basic requirements of AR applications designed for educational purposes. Unlike the teachers' comments mentioned above, the majority of primary school students in the sample did not particularly care about the lack of infrastructure or devices in their schools as an obstacle for them to use AR applications to learn. Perhaps a reason for this is the lack of young children's awareness of the potential impact of this factor.



## 7.2 Future Plan

The above described user requirements are derived largely from the respondents' past usage and experiences with AR for teaching or learning. The respondents projected what they would like to see to be improved on the existing AR applications. While many AR applications are marker-based (D4.1, M15), their marker-less counterparts, especially head mounted device (HMD)-based, are on the rise.

An intriguing observation is that none of the teacher or student respondents mentioned the use of holographic AR or HMD in the description about their most recent experience of using AR for teaching/learning. There are several possible explanations for this observation: One is that the samples of the surveys are too small to cover a broad coverage of usage. Another one is that respondents may consider the use of HMD is more for VR than AR applications (cf. the confusing definition of Mixed Reality; Speicher et al. 2019). Yet another viable reason is that HMD and holographic equipment such as HoloLens or Google Glass is too expensive for regular schools to purchase. The vision about the widespread use of the emerging Mixed Reality technologies in general education, despite the prevailing enthusiasm being fuelled by the tech giants, seems not realisable in the near future. In fact, one of the salient themes arising from the responses to the Teacher Survey and Interview is the insufficient financial support from the school management. Availability of basic hardware like the number of mobile phones, tablets or computers with camera for running AR applications is generally low. Hence, the need for even much more expensive equipment seems very difficult to meet. While the usability and user experience of HMDs is improving, their affordability remains a concern.

Presumably many teachers or students have not had holographic interaction experience. It would be challenging for them to envision innovative uses of such emerging technology for educational purposes. Hence, it is deemed necessary and useful to organise participatory design (PD) workshops where teachers and students will be provided opportunities to experience first-hand holographic interactions and explore their potential educational uses, thereby generating visionary use scenarios for AR/MR in education. This can be more effective than showing a pre-recorded demo as a video-based tutorial. Such workshops will be held in the near future when the pandemic condition eases and thus allows for such activities.

## References

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## Appendices

### Appendix A: Teacher Survey

#### Sharing Practical Experiences about Augmented Reality

ARETE (<https://www.areteproject.eu>) is an EU-funded project, aiming to develop and evaluate the effectiveness of an interactive Augmented Reality (AR) content toolkit. This will give students and teachers access to innovative AR content to enhance their learning and teaching.

**NOTE:** *This survey targets educators who have used AR in their teaching. If you have never used AR before for educational purposes, your input will not be required. Nonetheless, you are much welcome to visit the ARETE website to learn about our exciting research and development.*

With this survey we would like to gather your experiences with AR. It will take about 15 minutes to answer altogether 30 questions in three sections.

Your participation is voluntary and completely anonymous. Your responses will be handled confidentially and in accordance with General Data Protection Regulation (GDPR) <<https://www.ucd.ie/gdpr/about/>>. The data will be processed in batch and will not be identified individually. Please note that you have the right to withdraw from the survey at any time without the need to provide any reason.

In case you have any concerns and questions about this survey, please contact the University of Leicester (UoL) ARETE team <[arete.ule@gmail.com](mailto:arete.ule@gmail.com)>.

Many thanks in advance for your kind support and cooperation.

Yours,

Matthias Heintz

Research Associate, PhD

(on behalf of the UoL ARETE team)

You are asked to give us your consent to using your anonymous responses for our research work by checking the box on the left.

#### Section 1: Demographics

1. What is your **role**?

(please choose **only one** of the following)

- infant/junior school teacher
- primary school teacher
- secondary school teacher
- other:

2. What is your **gender**?

(please choose **only one** of the following)



- female
- male
- prefer not to say
- prefer to self-describe:

3. What is your **age**?

(please choose **only one** of the following)

- <21
- 21-30
- 31-40
- 41-50
- 51-60
- >60

4. What is your **country** of residence?

- Belgium
- Germany
- Ireland
- Italy
- Netherlands
- Spain
- United Kingdom
- Other:

5. What is your main teaching **subject**?

6. How many **years of teaching experience** do you have?

years

## Section 2: General AR Usage for Teaching

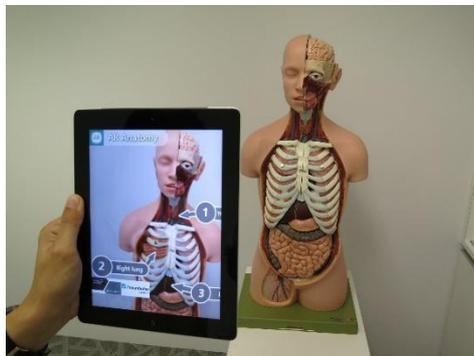
AR refers to the real-time digital overlay of information over physical elements. For example, the image of the real world displayed on the screen of a smartphone or tablet is enhanced by showing virtual annotations or digital objects on top of it.



<https://play.google.com/store/apps/details?id=eu.cleverbooks.space&hl=gs>  
w



<https://edtechreview.in/for/technology-in-education?start=260>



<https://pixabay.com/photos/augmented-reality-medical-3d-1957411/>



<https://www.curiscope.com/products/virtuali-tee>

1. **Why** have you used AR in your teaching?

(please choose **all** that apply)

- I have followed the guidelines given by our Ministry of Education.
- I have followed the guidelines given by my school board of governors.
- I have followed the recommendation given by my colleagues.
- My students have drawn my attention to it.
- It has been out of my curiosity to find out how it works in my teaching.
- Other reasons:

2. **How long** have you used AR in your teaching?

3. On average, **how often** have you used AR in your teaching?

(please choose **only one** of the following)

- weekly
- every two weeks
- monthly
- every three months
- every six months
- yearly



other:

4. On average, **how many minutes** have you used AR for teaching **in one continuous period?**

minutes

5. Would you like to use AR **more often** for your teaching?

(please choose **only one** of the following)

- yes
- no
- don't know

6. a) What do you **need** to increase your usage of AR for teaching?

(please choose **all** that apply)

- find the time
- know which AR apps are suitable
- more help to use AR apps
- better access to AR hardware (e.g. smartphone, tablet)
- other:

Please **explain** the above need(s):

b) Please **explain**, why you would **not** like to use AR more often for teaching:

c) Please **explain**, why you are not sure if you would like to use AR more often for teaching:

7. Which **hardware** have you used for teaching with AR?

(please choose **all** that apply)

- Smartphone
- Tablet



- Desktop/laptop and webcam
- Game console
- Other

8. **How many devices does your school provide** to support your teaching with AR?  
(Each answer must be at least 0)

|                      | Number of devices |
|----------------------|-------------------|
| Smartphones          | 0                 |
| Tablets              | 0                 |
| Desktops with webcam | 0                 |
| Laptops with webcam  | 0                 |

Please specify any **other** device types and numbers below:

9. What is the **average number of students per class** in your school?

10. How would you rate your current **level of confidence** in using AR in your teaching?

(please choose **only one** of the following)

- very low
- low
- medium
- high
- very high

Please **explain** your rating:

How could AR apps be changed to **further improve** your confidence in using AR in your teaching?



### Section 3: Most Recent AR Usage for Teaching

The following questions refer to your experience with the AR app that you have used **most recently** for teaching with your students:

1. **What** was the AR app you used?

(name is mandatory)

name:

website (URL), if any:

short description (optional):

2. **When** did you last use this app?

3. Which **domain** did this app cover?

(please choose **all** that apply)

- native language learning
- foreign language learning
- mathematics
- positive behaviour interventions & support
- physics
- chemistry
- biology
- geography
- history
- informatics
- art
- music
- P.E. (physical education)
- other:

4. Which **topic** did this app cover?

5. Which **age group** were your **students**?

(please choose **only one** of the following)

- 5-7



- 8-10
- 11-13
- 14-16
- 17-18
- 18+

6. **Where** did your students use this app?

(please choose **all** that apply)

- in a classroom
- at school, but outside the classroom
- in a museum
- at home
- other location:

7. **How** did your students use this app?

(please choose **all** that apply)

- I was presenting the AR app in front of the class.
- Students worked in groups, sharing a device.
- Students worked in groups, and each of them had a device.
- Students worked individually with a device.
- Other arrangement:

Please **elaborate** your choice:

8. **How many minutes** did your students spend using this app last time they used it?

 minutes

9. How **useful** was this app in supporting your students to **learn the topic**?

(please choose **only one** of the following)

- not at all
- slightly
- fairly
- very
- extremely

Please **explain** your rating:



10. How would you rate your **students' overall use experience** with this app?

(please choose **only one** of the following)

- very negative
- negative
- neutral
- positive
- very positive

Please **explain** your rating:

11. How would you rate **your overall use experience** with this app?

(please choose **only one** of the following)

- very negative
- negative
- neutral
- positive
- very positive

Please **explain** your rating:

12. How could this app be **improved** to better support your teaching?

13. **Any further comments** on using AR for teaching you would like to share with us?

\*\*\*\*\*



If you would like to provide feedback to another app, please click here...

Report on the results of this survey will be available in our ARETE project website (<https://www.areteproject.eu>) in due course.

**Thank you very much** for your kind cooperation. We much appreciate your time and effort.



## Appendix B: Secondary School Student Survey

### Your use of Augmented Reality

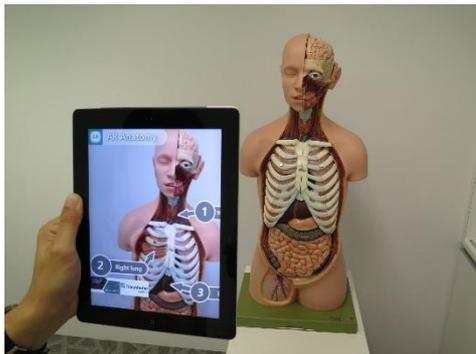
**Augmented Reality (AR)** refers to the real-time digital overlay of information over physical elements. For example, the image of the real world displayed on the screen of a smartphone or tablet is enhanced by showing virtual annotations or digital objects on top of it: You open the AR app, the AR activates and 3D images or messages appear on top of your surroundings displayed on the screen. You can move your device around to see the virtual object from different angles or discover more messages.



<https://www.youtube.com/watch?v=fCmPjVaOkTg>



<https://edtechreview.in/for/technology-in-education?start=260>



<https://pixabay.com/photos/augmented-reality-medical-3d-1957411/>



<https://www.curiscope.com/products/virtuali-tee>

With the following questionnaire, we would like to know about your experiences using AR for learning. Your responses will help us improve AR as an educational tool. It will take about 15 minutes to answer altogether 27 questions in three sections. Don't answer the questions if you have never used AR for learning.

Your participation is voluntary. Your responses will be handled confidentially and in accordance with data protection laws and regulations <<https://www.ucd.ie/gdpr/about/>>. The data will be processed in a way that makes it impossible to identify which answers have been given by you. You have the right to stop filling out the questionnaire at any time without the need to provide any reason.

In case you have any questions, please feel free to email the University of Leicester (UoL) ARETE team <[arete.ule@gmail.com](mailto:arete.ule@gmail.com)>.



Thanks for your help,  
Matthias Heintz  
(on behalf of the UoL ARETE team)

Please tick the box if you are happy to participate and allow us to use your anonymous responses for our research.

### Section 1: Background

1. What is your **gender**?

(please choose **only one** of the following)

- female
- male
- prefer not to say
- prefer to self-describe: \_\_\_\_\_

2. What is your **age**?

(please choose **only one** of the following)

- 10-11
- 12-13
- 14-15
- 16-17
- > 17

3. Which **country** are you living in at the moment?

- Belgium
- Germany
- Ireland
- Italy
- Netherlands
- Spain
- United Kingdom
- Other:



## Section 2: General Augmented Reality (AR) Usage for Learning

1. Who has **suggested** you to use AR for learning?

(please choose **all** that apply)

- my teacher
- my parent
- my brother/sister
- my friend
- I have discovered it myself.
- other

4. How many **times** have you used AR for learning?

5. How **frequently** have you used AR for learning?

- daily
- weekly
- monthly
- other

6. On average, **how many minutes** have you used AR for learning **in one continuous period?**

 minutes

7. Would you like to use AR **more often** for your learning?

(please choose **only one** of the following)

- yes
- no
- don't know

8. a) What do you **need** to increase your usage of AR for learning?

(please choose **all** that apply)

- find the time
- know which AR apps are suitable
- more help to use AR apps
- better access to AR hardware (e.g. smartphone, tablet)
- other

Please **explain** the above need(s):



b) Please **explain**, why you would **not** like to use AR more often for learning:

c) Please **explain**, why you are not sure if you would like to use AR more often for learning:

9. Which **devices** have you used for learning with AR?

(please choose **all** that apply)

- Smartphone
- Tablet
- Desktop/laptop and webcam
- Game console
- Other

10. Which **features** in an AR app for learning will make it **more likely** that you are going to **use it**?

11. Which **features** in an AR app for learning will make it **less likely** that you are going to **use it**?

12. What is your most **preferred way to get help** using AR apps for learning?

(please choose **only one** of the following)

- A real person (e.g. teacher/parent/friend)
- A video tutorial



- Help text in the app
- An avatar in the app
- Other:

13. Do you want to **interact** with other learners in AR apps for learning?

(please choose **only one** of the following)

- yes
- no
- don't know

14. a) How would you like to **interact** with other learners?

(please choose **all** that apply)

- live chat
- see and manipulate the same 3D objects and messages
- leaderboards to compete with them
- other:

Please **elaborate** your choice:

b) Please **explain**, why you would **not** like to interact with other learners:

c) Please **explain**, why you are not sure if you would like to interact with other learners:



### Section 3: Most Recent Augmented Reality (AR) Usage for Learning

The following questions refer to your experience with the AR app that you have used **most recently** for learning:

1. **What** was the AR app you used?

name:

website (URL), if any:

short description (optional):

2. **When** did you last use this app?

3. Which **subject** did this app cover?

(please choose **all** that apply)

- native language learning
- foreign language learning
- mathematics
- positive behaviour interventions & support
- physics
- chemistry
- biology
- geography
- history
- informatics
- art
- music
- P.E. (physical education)
- other:

4. Which **topic** did this app cover?

5. **Where** did you use this app?

(please choose **all** that apply)

- at school
- in a museum
- at home
- outdoors
- other location:



6. **How** did you use this app?

(please choose **all** that apply)

- The AR app was presented to me.
- I worked in a group with others, sharing a device.
- I worked in a group with others, and each of us had a device.
- I worked individually with a device.
- Other arrangement:

Please **elaborate** your choice:

7. **How many minutes** did you spend using this app last time you used it?

minutes

8. How **useful** was this app in supporting you to **learn the topic**?

(please choose **only one** of the following)

- not at all
- slightly
- fairly
- very
- extremely

Please **explain** your rating:

9. How would you rate your **overall use experience** with this app?

(please choose **only one** of the following)

- very negative
- negative
- neutral
- positive
- very positive

Please **explain** your rating:



10. How could this app be **improved** to better support your learning?

11. **Any further comments** on using AR for learning you would like to share with us?

\*\*\*

If you would like to provide feedback to another app, please click [here](#)...  
Thank you very much for your great help by answering our questions.



## Appendix C: Primary School Student Survey

### Your use of Augmented Reality

Augmented Reality can take images and bring them to life. There are a few different ways Augmented Reality can do this, but mostly, with an app. You open it and hold your device (phone or tablet) over a page, the Augmented Reality activates and a 3D image appears on your screen, on top of your surroundings. For example, it could be an image of the letter 'T' and in Augmented Reality it animates into a tiger that roars.



<https://www.amazon.com/dp/B071X3MXHK>



<https://www.curiscope.com/products/virtuali-tee>



<https://www.youtube.com/watch?v=fCmPjVaOkTg>



<https://edtechreview.in/for/technology-in-education?start=260>

Below are some questions we would like to ask you. It will take about 10 minutes to complete. Your answers will help us to know how you have used Augmented Reality and how to make it better for you. Don't answer the questions if you have never used Augmented Reality for learning.

It is up to you to decide to take part in this activity. If you do, you will be rewarded with a certificate to print and keep in the end. Your answers will **not** be linked to your name at all.

Many thanks,  
Your ARETE Leicester team

Please tick the box if you are happy to take part in this activity by answering 16 questions below.



1. I am:
- female
  - male
  - prefer not to say

2. My **age** is:
- 5-6
  - 7-8
  - 9-10
  - 11-12
  - > 12



3. Which **country** are you living in at the moment?

Belgium  
Germany  
Ireland  
Italy  
Netherlands  
Spain  
United Kingdom  
Other:

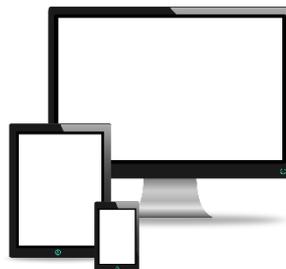


4. How many **times** have you used Augmented Reality apps?
- once
  - about two to three times
  - more than three times
- 



5. **What** have you used Augmented Reality apps **for**?
- learning only
  - playing only
  - both learning and playing
  - other: \_\_\_\_\_
- 

6. Who has **suggested you use** Augmented Reality apps? (you can pick more than one answer)
- my teacher
  - my parent
  - my brother/sister
  - my friend
  - I have discovered it myself.
  - other: \_\_\_\_\_
- 



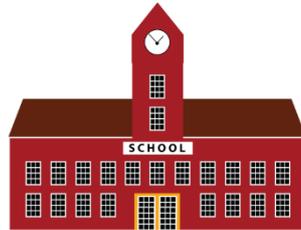
7. On **which devices** have you used Augmented Reality apps? (you can pick more than one)



- mobile phone
  - tablet
  - desktop/laptop
  - game console
  - other: \_\_\_\_\_
- 

8. **Where** have you used Augmented Reality apps? (you can pick more than one answer)

- school
  - home
  - outdoors
  - other: Where? \_\_\_\_\_
- 



\*\*\* The following questions are about how you have used **Augmented Reality apps for learning at school** \*\*\*

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9. **How many Augmented Reality apps** have you used for learning at school?

- 1
  - 2-4
  - 5 or more
- 

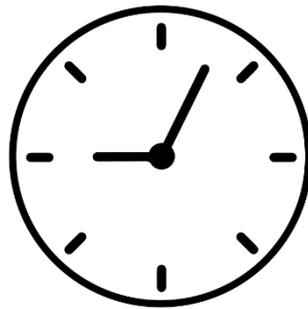


10. Which **subjects** were the Augmented Reality apps for learning at school about? (you can pick more than one answer)

- native language



- foreign language
- maths
- science
- behaviour
- geography
- history
- computer
- art
- music
- P.E. (physical education)
- just for fun
- other



11. For **how many minutes** have you used the Augmented Reality apps for learning at school **in one go**?



12. How **easy** did you find the Augmented Reality apps for learning at school to use?





very hard

hard

okay

easy

very easy

**Why** is it so?

---

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13. How did you **like** the Augmented Reality apps that you used for learning at school?



awful



not very good



okay



really good



fantastic

**Why** is it so?

---

---

14. **Which devices** does **your school have** to use the Augmented Reality apps? (you can pick more than one answer)

- mobile phone
- tablet
- laptop
- computer (desktop)
- none of the above

---

15. **How many devices** does **your school have** to use Augmented Reality apps?

- only one device for the teacher
- few devices for students to work with in groups
- each student is given her or his device to work with
- none of the above

---

16. Is there **anything else** you want to tell us about Augmented Reality apps? Please write in this box.



---

**Thank you very much** for your great help by answering our questions.  
Please download your certificate from the following link, print it, and fill your name in the blanks: