Exploring Attitudes towards Augmented or Virtual Reality for Biology and Mathematics Teachers in Dutch Secondary Education

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Abstract

This research investigates the underlying reasons which secondary school biology and mathematics teachers have for their attitude towards the use of Augmented and Virtual Reality in class. It draws on an analysis of 12 semi-structured interviews with teachers from two different rural schools, during which their pre-existing knowledge, current attitude and future views on AVR are discussed. After analysis of the results several conclusions can be drawn for this exploratory research. The pre-existing knowledge of AVR of the investigated teachers was little, several teachers did not have a visual representation of how an AVR application would look like. The perceived advantages and obstacles in the use of AVR have been listed. These advantages and obstacles can give insight into the reasons why teachers possess a certain attitude towards the use of AVR in education. The main advantage of AVR in education lies, according to the participants, in the idea that AVR might help explaining spatial figures, to help students visualise. AVR might also offer a more dynamic view on teaching methods, and students could get, what they call, a learning experience. There are, however, also several obstacles which have been mentioned: participants indicated the balance of time and energy invested did not weigh up against the learning gain paired with AVR and they indicated that current used methods already suffice and do not necessarily need an innovative technology. For mathematics another obstacle comes up, because these teachers observe their curriculum not far-reaching enough to fully exploit the possibilities of AVR in education. Participants also elaborated on their future views on AVR in education, here the idea of teaching from one central point, while students viewing through their device was put up. Several conditions have been named during the interviews for AVR to eventually work in education, mobile phones should be put to use more instead of being an irritation factor and if AVR would be integrated into the teaching method, teachers would be more inclined to use it. When combining the results on pre-existing knowledge, current attitudes and future views during the research, it became clear that the investigated teachers were open to the idea of a new technology but the practical side of the implementation of AVR remained an obstacle. This research provides more specific information on teachers' attitudes towards AVR in education, however further research can be focused on exploring teachers' attitudes when these teachers have a broad view of AVR in education. When teachers have a clear example of an AVR application including the possibilities for their subject, even more specific and to the point answers can possibly be found to understand the underlying reasons for their attitudes.

Key concepts: *AVR; augmented reality; virtual reality; innovative technology; teacher attitude; secondary education*

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Introduction

Augmented or virtual reality (AVR) is an innovative technique which allows its users to immerse themselves in a (partly) virtual environment (Schott & Marshall, 2018). By displaying virtual elements using a headgear or mobile phone, AVR facilitates the observation of events which cannot easily be observed with the naked eye (Wu, Wen-Yu Lee, Chang, & Liang, 2013). Studies have shown that the use of augmented or virtual reality (AVR) offers many advantages when used in educational settings (Cheng & Tsai, 2013; Schott & Marshall, 2018; Wu et al., 2013). Most of the studies investigated in a review study reported an increase of students' performance and motivation when using AVR (Bacca, Baldiris, Fabregat, & Graf, 2014). Another review study on the use of AVR in education shows that the most frequent experienced advantages when using AVR are in the area of learner outcomes, but challenges are the technology being too difficult and time-consuming (Akçayır & Akçayır, 2017). In STEM education the use of AVR could possibly help with the visualisation of concepts that are difficult to visualise. Because the technique of AVR is not restricted to this worlds' phenomena, anything that a teacher might want to visualise for their students is possible, if the teacher has the corresponding AVR tool for the subject to be taught. The process of learning through a Virtual Reality tool in education takes place in a certain virtual environment. Schott and Marshall (2018) describe in their research three key features concerning the virtual environment which are identified as being essential for what they call a situated experiential education environment (SEEE): sense of immersion, interaction with teachers and other learners, and the complexity of what is being studied. The research carried out by Schott and Marshall (2018) will be further elaborated on in the theoretical framework. To eventually implement this innovative technique in the classroom it is important that teachers share a positive attitude towards the use of AVR. In the Dutch school system AVR is not used, or only very sparsely, so here might lie an unused potential. The fact that AVR is only sparsely used could be due to teachers' attitude towards new innovative techniques, to which AVR also belongs.

Exploratory quantitative research has already been carried out to investigate the current attitude teachers have towards the use of AVR by Langhout (Langhout, 2019). The results obtained here were general inclinations towards the use of AVR in Dutch secondary school teachers. For biology teachers teaching students aged 17-18 in pre-university education there was a high demand for AVR, mostly in teachers that were in the beginning phase of their career. Overall, biology teachers were consistently the most enthusiastic group towards the use of AVR while mathematics teachers were consistently the lowest scoring. The participants were scored on a Likert scale, indicating how willing they are to use AVR in class (Langhout, 2019). These results give indications and general ideas of what teachers in the field want and expect of AVR in educational settings. What has not yet become clear from research by Langhout (2019), is what the underlying reasons are for teachers having a particular attitude towards the use of AVR. Thus, further research should be aimed at receiving more exact answers on teachers' reasons for their attitudes towards the use of AVR in class. If future research will be focused on development of an AVR tool, it might be of importance the reasons behind teachers' attitudes are explored.

The aim of this research is to explore the reason(s) behind attitudes towards the use of AVR for biology and mathematics teachers, teaching students in Dutch pre-university education. Earlier quantitative research by Langhout (2019) showed general results on teachers' attitudes, but these results could be made more specific in follow-up research to obtain a deeper understanding of teachers' perception on AVR. A deliberate choice was made to focus this research on biology- and mathematics teachers since they were respectively the most and the least scoring group on how willing they were to use AVR in their classroom (Langhout, 2019). For example, this research will be aimed on exploring the reason(s) behind teachers having either a positive or a negative attitude. It is expected that teachers will name certain advantages or obstacles they perceive in the use of AVR which might provide this research with insight into their attitude towards AVR.

The use of AVR in the classroom can enhance learning for students as stated earlier by Cheng and Tsai (2013) and Bacca et al. (2014). However, it is not widely supported by Dutch secondary teachers (Langhout, 2019). It is of importance to explore teachers' reasons behind attitudes on AVR, to eventually make it possible to implement AVR in the classroom. Research by Davis (1989) was carried out on the Technology Acceptance Model (TAM). The TAM is used to describe under which conditions users will adopt a certain new technology. Using the TAM, Venkatesh (2000) and Lee, Cheung, & Chen (2005) showed two factors which may alter a user's Attitude (AT) towards the use of new technology. These factors are the Perceived Ease of Use (PEU) and the Perceived Usefulness (PU), which may both bring a positive and significant change on a user's AT. Using this information, which does not only hold for AVR but stretches also to other domains of implementing innovative technology, it is tried to answer the question to why teachers share their specific attitude towards AVR. The results obtained by Davis (1989) gives this current research a specific direction and it provides with a theoretical framework to build upon and to base the current results upon. Possibly the PU and PEU also plays a role in the reasons for teachers' attitudes in the current research. In the next section the TAM will be further elaborated on. The obtained results might also be significant when implementing other innovative techniques such as Flipping the Classroom for example (Rutherfoord & Rutherfoord, 2013).

To reach the research aim, the following research question will be answered in this exploratory research:

What are the reasons behind the attitudes towards the use of AVR for biology- and mathematics teachers in Dutch pre-university education?

To fully answer the research question, several sub-questions have been set up:

What aspects of AVR makes biology- and mathematics teachers either implement or reject the use of AVR in their classroom and how do they define these aspects?

Does subject (biology or mathematics) play a role in teachers' reasons behind a particular attitude towards the use of AVR in their classroom?

Theoretical Background

Towards the use of AVR

AVR consists of two parts: Augmented Reality (AR) and Virtual reality (VR). Augmented reality can be defined as a technology which overlays virtual objects (augmented components) into the real world (Akçayır & Akçayır, 2017). For example, an application created by Layar allows the user to overlay information on the video on the phone, combining real life views with digital data (Pence, 2010). Thus, if someone takes a video of a famous location with their cell phone, the Layar software adds further information on the live camera feed (Pence, 2010). Virtual reality however, provides the user with a fully immersive and highly responsive experience of a constructed virtual environment that is both visual and auditory (Schott & Marshall, 2018). For example, an application reviewed by Potkonjak (2016) showed what VR can contribute to students' laboratory skills in a fully virtual laboratory. The difference between Augmented- and Virtual Reality is in the level of immersion, where immersion is defined as: the subjective impression that one is participating in a comprehensive, realistic experience (Dede, 2009). The sense of immersion is higher in Virtual Reality (fully immersive) than in Augmented Reality (partly immersive).

Research towards the use of AVR has been conducted for decades, while around 1990 it became more lifelike when it was used as a training tool for airline and Air Force pilots, (Caudell & Mizell, 1992). Much research has been dedicated to the potential of AVR, and this innovative technology has changed a lot during these years or research. Advances in mobile technologies (especially smartphones and tablet becoming easier to use and more portable) and an increase in the number of mobile device owners made AVR available more broadly to the public (Johnson, Smith, Levine, & Haywood, 2010; Statista, 2019). Also, earlier mentioned research by Akçayır & Akçayır showed that there is a large increase in amount of published articles on AVR between 2012 and 2016, and a similar interest was expected to continue in 2016 and thereafter (Akçayır & Akçayır, 2017).

As with many new technologies, also the educational potential of AVR is explored. Research by Schott and Marshall (2018) introduces a framework that guides the creation and analysis of immersive environments that are pedagogically structured to support situated and experiential education. This "situated experiential education environment", or SEEE, framework is used to examine the impact that a virtual environment can have on the user experience of participants in a virtual space. Experiential education can be described with a variety of definitions, which can be reduced to the following: In experiential education learners are engaged in an uncertain environment where they are engaged, here the learner may experience success, failure, adventure and risk taking. The learner will be exposed to a rich variety of experiences during experiential learning using AVR. Three key features concerning the environment are identified as being essential for an SEEE: sense of immersion, interaction with teachers and other learners, and the complexity of what is being studied.

The sense of immersion is central to the SEEE, where the learner has the subjective impression that one is participating in a comprehensive, realistic experience (Dede, 2009; Schott & Marshall, 2018). The immersive experience could generate a sense of presence which is defined as "The subjective experience of being in one place of environment, even when one is physically situated in another" (Witmer & Singer, 1998, p. 225). As described earlier this research, immersion increases when going from Augmented Reality to Virtual Reality. Virtual reality will contribute more to the SEEE, because of the increased level of immersion. The resulting experience will generate a sense of presence for the learner (Schott & Marshall, 2018).

The second key feature is based on the interaction with teachers or other learners, which is an important component of experiential education (Schott & Marshall, 2018). This is mainly because direction, transaction and collaboration are core components of a theory stated by Itin (1999). This theory states that the learner is central in the learning environment, highlighting the rich variety of experiences that the learner may be exposed to, ranging from intellectual to social and physical experiences. Research by Moore (1993) has shown that interaction between students and teachers, students with their peers and interaction with the learning activities are key activities of learning environments in situated learning. The interaction between students and other actors in the learning process could possibly be facilitated in an AVR educational tool, although the possibilities here could be limited because it may require a lot of computing power.

The third and last feature is the complexity of the material to be studied and the way it is embedded in an environment or situation (Schott & Marshall, 2018). Here it is of importance that the complexity of the model should be understood in pedagogical terms. This means that the complexity of the model, however, should thus not be in the technical issues associated with the model. As stated earlier by Akçayır & Akçayır (2017) teachers think the technology is sometimes too difficult to use, this is not the complexity the students or teachers should stumble upon. The intention is to help the students develop their thinking in more sophisticated ways, as reflected by the SOLO taxonomy for example (Biggs & Collis, 1982). SEEE activities provide a means by which students can engage with concepts from multiple perspectives, receiving information in multiple modalities simultaneously and seeing information in a rich and potentially confusing context (Schott & Marshall, 2018, p. 845). In both experiential and situated learning theories, it is of utmost importance that students are able to unpack and reflect on the interconnectedness of what they are observing (Kolb, Lublin, Spoth, & Baker, 1986).

Each of the three levels can be present at varying levels of intensity, to align with the level of the study and the designed learning objectives. For example, the amount of interaction with peers and teacher will differ significantly in SEEE when independent learning is being fostered as a learning objective. The same holds for the complexity which can differ per learning situation, adjusted by decisions made on pedagogical level and reflecting the level of capabilities of the learners. However, the level of immersion is less variable in intensity. A challenge here is ensuring that the level of immersion is balanced with the learners' requirements to provide evidence of achieving the learning objectives (Schott & Marshall, 2018).

Teachers' attitudes towards AVR

When the focus of literature search shifts from general use of AVR to teachers' attitudes towards AVR, the amount of potential useful articles available drops significantly. Papers to be found are less or not relevant towards the current research. One paper that resembles this research to a larger extent is the research into the Technology Acceptance Model (TAM) by Davis (1989) which was mentioned earlier when describing the research aim. The TAM described in this paper provides a theoretical framework used to predict how and when individuals will adopt and use a new technology. Using the TAM, the factors which influence teachers' attitude towards using innovative technology can be made explicit. This is what we are currently trying to find out when researching biology- and mathematics teachers in a more practical way. Therefore, the results by Davis might be the foundation on which our results can be based upon, as we are looking for teachers' reason for their attitude towards AVR in class. Research by Venkatesh (2000) and Lee, Cheung, & Chen (2005) showed that a user's Perceived Ease of Use (PEU) and Perceived Usefulness (PU) are key determinants towards the user's Attitude (AT). PEU is the degree to which the user believes that the technology is difficult to use, based on technological and cognitive skills necessary to use the system (Ibili, Resnyansky, & Billinghurst, 2019). PU is the degree to which the user believes that this technology will improve their performance on a task when using it (Ibili et al., 2019). If users perceive a new technology as useful (PU) and easy to use (PEU), the level of adoption will increase (Ibili et al., 2019). PU and PEU however, are both influenced by external factors, which actually determine the reasons for new technology acceptance. Research carried out by Ibili et al. (2019) included different external factors like Social Norm, Anxiety and Satisfaction in the TAM. Several hypotheses are assumed to be true, supported by previous papers. Here is stated that PEU and PU both have a positive and significant effect on AT, PEU has a positive and significant effect on PU and Social Norm has a positive and significant effect on both PU and PEU (Ibili et al., 2019). This might provide this research beforehand of factors which influence teachers' attitude.

Research strategy

During this exploratory qualitative research, the information needed for answering the research question will be gathered through semi-structured interviews. As a pilot, two semi-structured interviews will be carried out to test the completeness of the questions to be asked. After the first stage, incomplete or ambiguous questions can be adjusted if needed for the next stage. In the second stage 12 semi-structured interviews will be carried out, using the adjusted and optimized questions from the first stage. The choice was made for semi-structured interviews because the research aim is to explore the reasons behind attitudes towards AVR. Therefore, using the flexibility of the semi-structured interviews, the teacher is able to elaborate on their reason(s) for their specific attitude and underpin them. This could not, or only to a minor extent, be reached when using a questionnaire or a structured interview.

Participants

In the first stage a total of 2 teachers will be interviewed: one for biology and one for mathematics, working on different schools. A selection of schools will be made by purposive homogenous sampling, where a focus lies on teachers from schools which do not specifically promote innovative learning. In homogenous sampling a group of similar cases will be selected to investigate one specific trait or characteristic. If one innovative school and one conservative school was investigated in this research, the outcome would have been biased beforehand. During the second stage a total of 12 teachers will be interviewed. This sample will consist of 12 teachers, 6 for biology and 6 for mathematics where gender was evenly distributed. These teachers come from 2 Dutch secondary schools, both in a rural area. One school uses iPads as a device for learning support, where the second school does not use any device other than regular student administration programs. Both schools teach at the same secondary school levels (VWO, HAVO and VMBO) and are of comparable size (2500 students for the first and 2300 students for the second school).

Data collection

The questions asked during the semi-structured interview were designed to provide the interviews with structure, while at the same time giving the respondents the possibility to add additional points to the interview or change the sequence of questions. Teachers will be asked not to think too long before answering, as they might not have thought consciously about AVR in education at all. Their initial reaction will be more genuine than an artificial constructed attitude which they might simply have never felt before. A study by Tourangeau, Rips and Rasinski (2000) showed that data collected by first responses of participants turned out to be the most stable. This research might provide us, combined with the research carried out by Langhout (2019), with a more deepened understanding of teachers' attitude towards AVR. Due to the qualitative nature of this research, it is tried to find more in-depth answers to why teachers have this specific attitude towards AVR.

The interview starts with showing the participant an illustration of a situation where AVR is used as a form of entertainment. Also, two examples of the use of AVR in class are shown, one for biology and one for mathematics, showing an augmented reality application of respectively the brains and a saddle-point graph. After the introduction, some exploratory questions were asked where the teachers could elaborate on their possible prior experience with virtual reality. This is followed by asking for their affection towards AVR and their willingness to collaborate on developing educational AVR tools. Finally, the aspects of educational AVR tool come to speech, where the teacher will indicate what educational aspects are seen as important in educational AVR tools to be developed where teachers are also allowed to elaborate on their future view concerning the use of AVR in education.

The interview will be audio-recorded with allowance of the participant. All interviews were held by the researcher face-to-face with the participant, one at a time, in a quiet area in their school, each interview took approximately 20-25 minutes.

Data analysis

Each interview was transcribed by hand in Dutch using edited transcription. The resulting data was then processed by computer-assisted qualitative data analysis software (CAQDAS), in the form of QDA Miner Lite (*QDA Data Miner [CAQDAS]*, 2016). The unit of analysis can be defined as an idea or attitude, which can vary between a single word or a full sentence. The coding and categorization were carried out by firstly scanning through the transcript and open-code the data, which means the spoken text was coded by summarizing the idea or attitude into a single code. This idea, sentence or word was marked and assigned a code. If this is a new code (i.e. it has not been used before) then a new code would be created. If the code has been used before, the marked text could be assigned to one code which has been mentioned by other participants earlier in the research. Due to the explorative nature of the study, it was not possible to set up a coding scheme after coding of one interview. It took a certain number of interviews to find saturation. After the first stage of open coding, specific codes will be combined into an overarching category in the second stage. In the last stage of the analysis the overarching categories will be investigated and combined to find trends in the data which may steer towards an answer to the research sub-questions and eventually also the main research question. Using the options available in the CAQDAS application, data could be grouped by code or overarching category. Also, trends will be sought for in the data to identify other factors that may play a role in the reasons for their attitude towards AVR in education, such as teaching subject, being either biology or mathematics. These results from the data analysis will be described in the results section and to guarantee the privacy of all participants, all used quotes and information will be anonymized. All codes and categories, including one example per code, could be found in Appendix 1.

Results and discussion: Exploring reasons behind teachers' attitudes towards AVR

Here the findings of the conducted interviews will be discussed. To support certain findings, quotes of participants will be given. The results section starts with a description of the teaching situation and pre-existing knowledge on AVR, followed by results on their attitude and lastly the results on future views and application characteristics will be given. The structure of the results section resembles the structure of the conducted interviews. These results are based on the second stage of data collection, using information gathered from the first stage. After analysis of the pilot interviews in the first stage it was found that the interview questions were not exhaustive enough to fully answer the sub- and main question(s). Therefore, the interview questions were adjusted, i.e. more explicitly formulated, to better determine the teachers' attitude towards AVR in class in the second stage.

Teaching situation and pre-existing knowledge

In this section the teaching situation and pre-existing knowledge is determined, to draw conclusions on teachers' attitude within the right context. As described in the book by Black & Atkins (1996), one important element towards typical change in teachers is their exposure to other ideas. It is stated that the more teachers are exposed to other ideas, the more they are likely to adopt these ideas. Therefore, it is important to define the teachers' teaching situation and pre-existing knowledge, to create a starting situation from where statements can be made concerning teachers' attitude and to better describe their environment concerning the level of innovative technology they are exposed to currently.

As mentioned earlier in the research strategy section, both schools do not promote innovative learning. The first school uses iPads in the lower grades for learning support, but the other does not use any technology other than the basic student administration programs. When participants were asked to indicate if their school uses AVR in their biology or mathematics lessons, none of the participants gave a positive reaction. However, when the participants were asked if their school used any other form of innovative technology in biology of mathematics lessons, some participants indicated that they used or see a colleague use innovative technologies:

> *"I've had colleagues who used blended learning"*
>
> *"Sometimes flipping the classroom is used, but only very sparsely".*

All participants indicated to have some pre-existing knowledge of AVR which they gained mainly through two different channels, the first one being via a colleague who has used AVR. A mathematics teacher indicated:

> *"I am not that familiar with AVR, but I had a colleague who had a certain AVR application which he showed to me."*

The second channel through which the participants are known with the concept of AVR is that they have used or seen AVR in private as a form of entertainment, two teachers indicated how they knew AVR from private entertainment*:*

> *"I am familiar with AVR in the world of gaming, where it is used regularly."*
>
> *"My son has used it once in the application from the local supermarket, for the dinosaur-images (…)".*

Even though all participants indicated to have heard of AVR in some way, none of the participants has used AVR before in their classroom. These results may give a foundation for the following results on participants' views on AVR, as a starting point from where conclusions can be drawn.

Attitude towards AVR

Concerning the attitudes towards AVR, first the participants' views on the added value of AVR is discussed, followed by the expected obstacles they experience before or during the implementation of AVR in class. During the interviews, participants were asked if AVR could be an added value to their current lessons, and if so, which part of the curriculum can be supported using AVR. All participants indicated that they see AVR as most helpful when dealing with spatial figures in class, both in biology and mathematics.

Perceived advantages of AVR

For biology, a major part of participants stated that an AVR app would be most suitable when dealing with subjects concerning spatial figures (i.e. brains, the contents of a cell or the digestive system). Also, all mathematics participants indicated that AVR might be of help with spatial figures (for instance in 3D-graphs). A biology teacher indicated the following concerning the spatial figures:

> *"When students are trying hard to visualise a concept from the book, I think then AVR could be put to use."*

This is perceived as applicable to a less extent in mathematics teaching, because during the interviews teachers discussed that the mathematics curriculum does not (or only to a minor extent) deal with spatial figures which need additional visualisation. Two mathematics teachers indicate the following:

> *"(…) 3D-geometry is a very difficult concept, and the lower grades only deal with 3D-geometry as in: this is a sphere, which is in 3D. Then I can just as well take a football with me instead of using AVR."*
>
> "*Imagine being in a 2D-plane, like a parabolic course, that figure can be drawn very well. Only when the curriculum reaches three dimensional aspects, I see the benefits of AVR in mathematics teaching."*

What also follows from the conducted interviews, especially from biology teachers, is the possibility to show concepts in a more life-like and dynamic way. One biology teacher used the example of the functioning of the kidneys:

> "*(…) Using AVR you could see the blood flowing through vessels and tissue in 3D. I think that would have even more added value than a static or physical model. You cannot show the functioning of the kidneys using physical models."*

Since more biology teachers have indicated the abovementioned, AVR might possibly help students, especially for biology, learn about processes. Here a model can be used which shows an organ while performing the task as if it was in a human body. It is not clear if the same gain also can be accomplished in mathematics. Due to the fact that during the interviews it was neither discussed nor mentioned by any mathematics teacher. However, this does not necessarily indicate that showing a dynamic model in mathematics does not have an added value in class. What might have influenced the thoughts on AVR in biology- or mathematics teachers are examples which have been used to show to participants. It shows a three-dimensional saddle-point graph and a brain respectively for mathematics and biology. The choice was made for giving the examples to make sure every participant has at least a picture of what AVR might include. However, it might also steer the results into a particular direction and give participants the idea that AVR only can be used in this form.

The last perceived advantage which participants have indicated is that students could get a learning experience when using AVR. Here the idea was discussed that participants expect students to have an experience when learning about a subject. A biology teacher has indicated the following, when explaining about students 'traveling through the human body':

> *"(…) if we could apply this in virtual reality, I think students could get a particular experience."*

Other biology teachers spoke more in general about AVR as learning experience. Where it could be implemented for a learning experience in other subjects. Subjects which have been indicated mostly are history and geography, some participants share the idea that AVR might be better put to use for these subjects. In the Theoretical Background section the SEEE was named, one factor that played a role here was that students in experiential education are engaged in an uncertain environment. Here the learner may experience success, failure, adventure and risk taking. The learner will be exposed to a rich variety of experiences during experiential learning using AVR. This is in line with what these participants indicate during the interviews and it might provide this research with deeper insights. One biology teacher indicated that easily a scene might be created in class, for example in history:

> *"I think that especially a scene could be created in class, without students having to imagine themselves very much. The possibility to create a particular ambiance without having to go on a field trip to get the same experience."*
>
> *"(…) I have talked with colleagues and they would find it useful to use it for history, being able to stroll around classical cities and show events. Surely useful for teachers who are less skilled in storytelling."*

What can be extracted from the answers given by the participants on the perceived advantages of AVR is firstly the possibility to explain certain subjects more spatially. This holds to a less extent for mathematics, because they perceive their curriculum as not far-reaching enough to deal with AVR in three-dimensional figures. Also, biology teachers have indicated that they saw possibilities to use AVR to explain their subjects in a more life-like way. Lastly, more general statement was made, namely that AVR might let students experience some parts to be explained. This is mainly for biology and could also be used in other subjects as history or geography.

Perceived obstacles before implementation of AVR

Next to the advantages associated with the use of AVR, participants were also asked to indicate whether they foresee any obstacles before AVR could be implemented in their classroom. Participants indicated obstacles as available time and energy, ICT facilities, sceptical or conservative colleagues and the decrease in students' thinking processes. In the coming section these obstacles will be elaborated on and substantiated using participants' quotes.

Half of the participants (3 for biology, 3 for mathematics) indicated they experience the investment of time or energy before implementing AVR as an obstacle. Next to their daily activities they experience it as too time- or energy-consuming. A mathematics teacher stated the following:

> *"I experience that it is incredibly busy and that I actually do not have the space to work on a new technology or idea and to use it in my lessons."*

Next to the fact that half of the participants experienced the implementation of AVR as time- or energy consuming, participants also were sceptical whether the improvements in students' learning that is associated with the implementation of AVR weighed up against the investment of time and energy that has to be put into the use of AVR. A biology teacher indicated the following:

> *"The only reason why I should not use it, is because students are not getting it, it is not working, or it takes too much time whilst the students become nothing wiser."*

The mentioned obstacles, i.e. the time- and energy-consuming new technology to be used in the busy working environment of teachers, and the experience that the learning gain does not weigh up against the investment in AVR, is more of a general obstacle. This might be a first threshold for teachers to not implement AVR into their curriculum and into their lessons.

In mathematics education, there is another obstacle related to the curriculum. As mentioned earlier in the section '*Perceived advantages of AVR'* it is discussed that AVR might specifically be of help for explanation of spatial figures. However, a major part of mathematics participants has indicated that the time to be invested in an innovative technology as AVR, might not weigh up against the small segment of the curriculum where they could use it. Mathematics teaching does not (or only to a minor extent) deal with spatial figures from which mathematics teacher think AVR can be an added value in the explanation of these spatial figures. A mathematics teacher stated:

> *"When reviewing geometry, we work in the lower grades mostly in two-dimensional space, students don't get much extra out of it when they can walk around a two-dimensional figure, a 2D-picture in the book will be sufficient then."*

This might lead to an explanation why mathematics teachers are less enthusiastic and indicate that students' improvement of learning does not weigh up against the invested time necessary to implement AVR. Earlier mentioned quantitative research by Langhout (2019) found that mathematics teachers were generally the least scoring on how willing they were to use AVR, together with the finding that the curriculum might not be as ideally suited for the implementation of AVR as in biology, chemistry or physics. The findings of Langhout (2019) might also substantiate the findings of the conducted interviews during this research, whilst the conducted interviews might give deeper insight into the results of Langhout's quantitative research. Other research by Ibili et al. (2019), also mentioned above in the Theoretical Background section, focused on the influence on the Perceived Usefulness (PU) on the level of adaptation of innovative technology. It was stated that PU is the degree to which the user believes that an innovative technology will improve their performance on a task when using it. From the conducted interviews can be concluded that teachers perceive AVR as a technology that may not fit their needs. Therefore teachers might not see the usefulness of this innovative technology which might affect their attitude on innovative technology (or AVR in this research), as follows from the described research by Ibili et al. (2019).

In more than half of the interviews, participants did not necessarily indicate an obstacle, but it was indicated they would prefer their current teaching method over the innovative technology of AVR. Seven participants indicated that the use of physical models for the visualisation of several concepts, whether for biology of mathematics, has their preference. When a biology teacher was asked to elaborate on why she would or would not use AVR in class, the answer was:

> *"I do not think it does not have any added value, it is just that we already have good alternatives which suffice"*

The quote from this biology teacher largely summarizes the approach towards AVR from the earlier mentioned seven participants. Each of the seven participants indicated that their current used methods either also suffices, take less preparation time or is even better (one participant indicated that she used a real pig's heart, to learn about the cardiovascular system). There is a different factor, partly related to the fact that teachers prefer to use current methods. It is the notion that teachers expect possible issues associated with the use of ICT and its availability. The current used methods mostly do not make use of ICT facilities, which connects the two obstacles in this section. Part of the participants indicated that they experience the practical use of ICT in classroom as an obstacle, a mathematics teacher stated it as follows:

> *"(…) I see things (as obstacle) that when you have a digital application, that your network should be working and your ICT facilities should be sufficient."*

Some conditions, for example a decently working network and the necessary ICT facilities, should be fulfilled to make AVR accessible to teachers in secondary education.

Several participants, from both schools, indicated that they perceive it as an obstacle that their colleagues are sceptical towards the use of AVR. These participants share the vision that they think there is a group of colleagues who do not support the implementation of AVR. A mathematics teacher indicated the following:

> *“I think there is a category of teachers, to which I do not belong, who are very sceptical towards these kind of things,* (i.e. AVR or innovative technology), *and how do you get these people to see that it can be of added value?”*

Research by Ibili et al. (2019) described the influence of Social Norm on technology adoption. Social Norm is defined as the subjective belief that an individual should or should not use the new system. This research pointed out that Social Norm has an important influence on intention in the early stage of adoption of innovative technology. Social Norm might also play a role in the current situation which participants describe. Moreover, this research discusses the attitude towards innovative technology from teachers who work in teams, where Social Norm might come into play. A biology teacher indicated that whenever he tried to use innovative technologies in class, his colleagues show two different reactions:

> *“(…) sometimes they are very enthusiastic, but the other time they think: “Can you just stick to what we agreed upon?”*

The last factor that was perceived as an obstacle by participants in the use of AVR, is the idea that such an application takes away the thinking process which is part of the learning trajectory for students. This is an obstacle which largely has its effect in mathematics education. A mathematics teacher describes it using the example of cutting the edges of a cube:

> *“Part of the difficulty is removed, and maybe part of what you want to accomplish when you would do the exercise using VR glasses. Because when VR glasses are used, the students see immediately: of course, that is a hexagon.”*

When students do the same exercise through textbook, they could have more difficulty visualising the three-dimensional picture out of a picture from the textbook. Another mathematics teacher also describes that part of the difficulty students are expected to master, is removed when going from learning through a book to learning through AVR. He described it as follows:

> *“When you will replace that (i.e. learning through textbooks) with AVR you practically say: We don’t expect that skill from you anymore, but we let a computer perform that skill for you and we pretend it is three-dimensional. That is fun, but then the students miss the skill to look at a flat mathematical figure and form a three-dimensional figure in their head.”*

The same teacher uses the example of a picture in the book which shows a cube, with lines running diagonally from its corners to another cube, moved slightly up and to the right. It is a skill for students to visualise this cube as if it is a three-dimensional cube, and when the students use innovative technology such as AVR, the skill of visualisation might come under pressure.

Characteristics of AVR applications and future views

During the conducted interviews, participants were asked to indicate what characteristics a well-working AVR application should have. This resulted in many suggested properties, from which we will discuss the most emphasized and most frequently mentioned. This may hopefully give some insight into the way teachers think about AVR and what their vision is on how to overcome obstacles. Since the teachers indicate what they would like to see in an AVR app, this data might also give answers for what teachers observe as obstacles. Participants were also asked to indicate whether they saw perspective in AVR and to elaborate on their future view concerning AVR in education. This resulted in very divergent answers from which several aspects will be highlighted in the coming section.

Properties of AVR applications

Every participant was asked the same question: "Which aspects or characteristics would you like to see in an educational AVR application?" This question did not result in one main thought concerning the characteristics of such an application, but the answers varied greatly. Still even though, there are several answers which could be combined and where a trend was found, because multiple participants still gave similar answers.

The aspect which participants have indicated the most is that an AVR application should be user-friendly. Ten out of twelve participants have indicated that user-friendliness (or being easy to use) should be a characteristic, whereas half of the participants also explained that they want the app to be simple. They elaborated on their statement where they define the user-friendliness of an AVR app as easy to handle, easy to operate or easy to learn. A mathematics teacher described it this way:

> *"The ease of use, or that it is logically operated by the user, that you understand how it works, that is what I would think of as important".*

The fact that a major part of participants indicated the user-friendliness as an important characteristic of an AVR application might hint towards teachers' current ideas on AVR. Earlier mentioned author Venkatesh (2000) investigated the influence of the Perceived Ease of Use (PEU) on Attitude (AT) towards innovative technology. They found that PEU has a positive and significant effect on AT. A majority of participants in the current research indicated that the user-friendliness or ease of use should be a main characteristic of the AVR application.

Another characteristic, indicated by a third of the participants, was that the application should be adaptable or should have multiple functionalities. The characteristic of adaptability can be put into practice by allowing the applications' users to modify the content in the application. A mathematician described it as follows:

> *"I think that students should be able to experiment a little with the application, preventing them from getting an assignment, doing the assignment, you will see this and that and then they are finished. I think they should be able to tinker the content of the app. That will be important in my opinion."*

This concerns mainly the adaptability of the AVR application, yet the participants indicated another characteristic which described the multifunctionality of the application. These participants indicated that it would be most suitable if there was one application which contains multiple functionalities. A biology teacher elaborated on this as follows:

> *"It would be nice if we could have one application for multiple issues, which would be all AVR for instance, but without having to download a specific app for every part of the human body. It should have multiple functionalities."*

The characteristic this biology teacher indicated also partly deals with the Perceived Ease of Use of innovative technology. One underlying line of reasoning might be: It is unhandy when one application does not have multiple functionalities, and it might be more convenient when different functionalities can be combined. If this line of reasoning is seen as the participants' Perceived Ease of Use, then it might give insight into their attitude towards this innovative technology.

One third of the participants indicated that, in general, the application should be fully functional, fully working. Hereby the participants indicated that it should be reliable, which was defined as: when you use the application for educational purposes, that you know what the possibilities are of this application and that all the functionalities really work. One biology teacher indicated the following when asked what aspects or characteristics are important in an AVR app:

> *"Well actually, just that it works. It does not have to be super simple, but just for it to be reliable."*

Another biology teacher spoke more about the graphics and the lifelikeness, and he indicated that there should be a balance between the application showing life-like pictures and the resources it takes for the application to run. As he has just indicated that having a life-like picture in the application is important, he indicated the following:

> *"On the other side, you do not want the application to stammer, that the application needs too much resources that it will not run."*

When participants were asked for their view on characteristics of AVR applications, half of the participants indicated that the application should be interactive. They indicated that just looking to a three-dimensional picture does not have the same effect as interacting with the three-dimensional picture in the application. One biology teacher pointed out concerning the characteristics:

> *"I think it should be interactive at all times, students should not only look at it, but also be able to get things out of the application"*

Participants define the term interactivity as the students being able to touch it, that it is able to move or that the students directly get feedback after an action. But when the participants were asked to define their definition of interactivity specific for AVR applications, it remains rather vague. Little to no participants have a clear definition of what they mean by interactivity. This could possibly be due to the fact that most of the participants might not have a complete image of how an AVR application would look like or in which ways it can be used. In further research it would be more suitable to let participants experience such an AVR application, to obtain more and deepened data on their attitudes on AVR applications.

A minor part of the participants showed interest in an AVR application when it is integrated into the teaching method. When using the example of mathematics education, in the current teaching method used by several participants there are sections in the book where theory is explained. This is done mostly by text, but sometimes there is a link to a video which provides additional information. A mathematics teacher indicated the following relating to the video which is integrated into the teaching method:

> *"The most ideal situation would be if it was integrated into the teaching method. (…) There should be a link to a certain AVR application."*

This could possibly facilitate the use of AVR in class, at least it may decrease the threshold for teachers to use this innovative technology.

Future views and willingness towards AVR

At the end of the interview, each participant was asked if they were willing to test certain applications in their classroom and how they think AVR can be used in the future or if they see perspective in the use of AVR. Participants' ideas may possibly give insight into their future visions of AVR in education. Yet again a variety of ideas came to speech, when discussing both their willingness and their future views.

Willingness

The participants indicated several factors which played a role in their willingness to test AVR in their classroom. On the one hand there were teachers who wanted to try AVR applications to test whether the students learned more on the corresponding subject, or some teachers have the opinion that they should help education be further developed. On the other hand, there were participants who were reserved and wanted to test only when the application fitted in the curriculum with which they are working at that specific time. Almost half of the participants are willing to test an available AVR application in class. The main reason for these teachers was that they were curious if students performed better when using AVR instead of the regular methods. A mathematics teacher motivated his willingness towards the use of AVR as follows:

> *"There should be a reason behind, when your research will point out that students learn it 10 times better when they, for instance, can walk around a cube with their iPad, then I am absolutely willing to implement that."*

Other factors which were indicated had to do with development of the education in general. More than half of the teachers told during the interview that they were open towards development. Testing in practical situations can be crucial for the development of the application, this is why a mathematician indicated the following:

> *"The moment when nobody does it (i.e. testing AVR applications) or nobody cooperates, you will not be able to develop the application."*

This summarizes largely what the other participants also indicated, meaning that these teachers are willing to try the application for testing students' improvement, but some side notes should be placed with the teachers' answers. Namely, teachers are willing to test an application which works, and most importantly, which has been indicated by multiple teachers, that the information from the application fits the curriculum. A mathematics teacher indicated her willingness towards testing AVR in class, but also directly indicated under which conditions:

> *"I am open to testing AVR in my classroom, but of course it should deal partly with the subject matter with which we are dealing in class."*

Future views

Concerning the future views of participants, there were three main lines which were indicated. The idea of teaching in a classroom from one central point using AVR, the idea that innovative technology will become more popular in the future and the idea that most mathematics teachers see less potential for AVR in their lessons, but in general participants observe possibilities in a variety of other subjects.

Teaching from a central point in class is what a third of the participants indicated as their future view of AVR in education. These participants sketched a situation where a teacher has a model which he is operating, and students are able to see exactly what the teacher sees (through VR glasses or an application on a device). A biology teacher described it as follows, also comparing it to his current method:

> *"Now we have a physical model of a torso, I can get a few things out of it, while students in the back think: "Yeah, whatever…" because they can barely see it. But if all these students had VR glasses and I was using a digital model, they will get a better picture of this torso."*

Another biology teacher combined the dynamic and spatial nature in his future view and indicated the following:

> *"A fantastic idea would be to let students use VR glasses, while the teacher has a physical model on his desk where he can show the way a blood cell travels in steps. Literally showing where the cell goes and which vessels it passes."*

Summarizing the answers given we see that in their future view, AVR might be of help in giving each student a clear view on a picture, which can even be dynamic. This is mainly indicated by biology teachers, which does not mean that it does not also hold for mathematics, but that is not indicated by any mathematics teacher. Mathematics teachers are very reserved in their future view. This might be due to the fact that the investigated mathematicians do not have a very broad picture of AVR in mathematics, while there is much research into AVR in mathematics. Other results might be obtained if the investigated teachers have a deeper view into the possibilities of AVR in education. This also plays a role in the following section where mathematicians mostly point to different subjects to use AVR in.

What specifically is indicated by mathematicians concerning AVR: they see only limited possibilities for mathematics in their future view. However, they do see possibilities outside of their own curriculum, in the use of AVR in other subjects. When a mathematics teachers was asked to elaborate whether he saw a positive perspective for AVR in education, he answered directly:

> *"Yes, I think so. But when I look to my own subject, I think the possibilities are rather limited."*

Other participants indicated that they see possibilities for AVR outside of mathematics, for instance in history or geography. Here the aspect of getting a 'learning experience' is named frequently. A biology teacher stated it as follows:

> *"The added value is that they experience it as if it were in 3D, and not being a 2D picture in the book."*

One mathematics teacher described it more explicitly:

> *"I know a video-channel on internet which makes use of a popular video game to walk around in ancient Rome or Jerusalem, and many more. You can create a lesson about how a city looked like in Roman era this way, using AVR. It makes it even more fun to tell your students: Okay, glasses on, we are in virtual reality and we walk straight through it (…)".*

The above citations indicate what these teachers see as future views on AVR, which might give insight into what other comparable teachers think of AVR. As mentioned earlier, possibly other future views for mathematics can be obtained when teachers have more insight into the current possibilities and developments of AVR in education.

A minor part of participants indicated that in the future more and more aspects of education will become digital. Together with this notion, several conditions have been discussed by the participants. One biology teacher indicated, after discussing the conditions for which AVR would work in education, that digital teaching methods will become available in education:

> *"(…) in the end we will inevitably go there, education will go there, everything will be digitalized."*

The conditions that were quoted dealt with the usability of mobile phones and the degree to which AVR would be a part of the lesson. Here the usability of students' mobile phones is discussed. One biology teacher indicated that currently mobile phones are not fully put to use in education:

> *"I think what is most important is that we should give these mobile phones, which is an irritation factor, far more attention. This way it is a device which distracts students while it should be more implemented for education."*

He elaborates on this as follows:

> *"From the first grade we should teach students how to deal responsibly with their mobile phones. Only then we could arrive at the point where we could use this application."*

When discussing the perspective of AVR in education, several participants have indicated that they see potential in AVR, but only to a minor degree. In other words, it is not an all-sufficient method. They see the use of AVR mostly as support next to a different teaching method, but not as the leading teaching method. Just as with the example given in the city of Rome, only the AVR application will not suffice, but the application could give more insight into how such a city may look like. Therefore, it should not be used as a leading teaching method, but it can be suited to deal as a supportive teaching method.

Conclusion

Using the results described in the preceding section, this research will be concluded by composing an answer on the research main- and sub-questions. The main research question was formulated as: *What are the reasons behind the attitudes towards the use of AVR for biology and mathematics in Dutch pre-university education?* This question was attempted to answer by firstly answering two sub questions, which were formulated as follows: (1) *What aspects of AVR makes biology and mathematics teachers either implement or reject the use of AVR in their classroom and how to they define these aspects? Followed by (2) Does the teaching subject play a role in teachers' reasons behind a particular attitude towards the use of AVR in their classroom?*

First the sub questions will be dealt with, followed by the main research question. For the first research sub question, several aspects are mentioned by participants. These are partly positive, indicating that AVR might help students in getting a more spatial view on particular subjects where students' visualisation comes into play. What also is indicated is the realistic or dynamic nature that an AVR application has to offer. The use of an AVR application could offer the students a learning experience in which they learn about a subject as if they experience it. These are the more positive aspects they take into consideration when deciding on whether to use AVR or not in their lessons. Yet, there are also several negative aspects, or obstacles, which they mentioned which restrain participants from their choice to use AVR in education. The main obstacle was that teachers perceive their job too time- and energy consuming to invest time in the implementation of AVR in education. Another obstacle that was mentioned, mostly in mathematics teaching, was that their curriculum is not far-reaching enough to fully employ AVR in education, since the curriculum is in 2D and AVR in 3D. Other participants were either themselves more tied to their current used methods, which may be less time-consuming or did not have an ICT part in it, or they perceive their colleagues as not being open to new technologies in education. It was indicated that mathematicians mostly perceive AVR as if it may take away crucial thinking processes for students.

Possibly the indication of AVR application characteristics could give more insight into answering the first research sub-question. Here participants could indicate what characteristics would be important in an AVR application to be used. Participants indicated several important characteristics, almost all participants mentioned the characteristic of user friendliness or ease of use, mostly defined as the application to be easy to operate, easy to handle or easy to learn. Other characteristics which have been indicated are the application having multiple functionalities, being interactive (even though teachers did not have a clear definition of the term interactive), the idea that the application should fully work and some participants also indicated that it would be easy to have the application integrated into the teaching method. Concluding on the first sub question, there are several aspects which might play a role for these teachers in their motivation to either implement or reject the use of AVR in their lessons. There are several positive aspects which might motivate teachers into the implementation of AVR in education, but there are multiple perceived obstacles that have to be overcome before teachers might perceive AVR as a more helpful teaching method compared to what they use currently.

Concerning the second research sub-question, which deals with the differences in subject, there are multiple differences to be found when comparing mathematics teachers to biology teachers. The main difference is one that has already been described earlier in the Conclusion section, namely the fact that mathematics teachers perceive that their curriculum is not far-reaching enough to use the potential which lies in AVR. Geometry was indicated where AVR could be used the most in mathematics, however this is mostly carried out in 2D, whereas 3D is only a small part of the curriculum in the higher grades. Implying that AVR is thus not 'necessary' for mathematics education. This has not come to speech at all when discussing the possibilities in biology, which might have to deal more with spatial figures even in lower grades when dealing with cells, brains or the cardiovascular system. This might make the mathematics teachers slightly more withholding, i.e. having a less positive attitude towards AVR than biology teachers.

Also, what teachers have indicated as their future view for AVR might give insight into their attitude towards its use in education. Biology teachers mostly indicated they saw perspective in AVR when they could use the technology to teach students from one central point in class, while the students could view through their device what the teacher also sees. Most mathematics teachers, however, were far more reserved in their perspective on AVR. A major part did not necessarily see perspective in AVR for mathematics education, but they did see possibilities for other subjects. It may be questionable if the differences in biology and mathematics are that big, possibly the obtained results could also be used broader than only for biology and mathematics.

To conclude this research, the main research question will be concluded, it was posed as: '*What are the reasons behind the attitudes towards the use of AVR for biology and mathematics in Dutch pre-university education?'.* When looking into the results and discussion section, it can be concluded that there are several advantages and obstacles that have been mentioned by participants. All the answers given by the participants may be combined to provide an answer to the research question why teachers have a certain attitude towards AVR. During the conducted interviews it became more and more clear that the investigated teachers were open to the idea of a new technology but the practical side of the implementation of AVR remained an obstacle. This became clear when several mathematics teachers have indicated that they think that AVR might be of help with spatial figures in geometry, but when they started to think where it could be used in their curriculum, they became more reserved. This provides us with one specific example, but it may give insight into what other teachers might also think of AVR, and also why they might not have a positive attitude towards AVR. Also the future views, which have been described for both biology and mathematics teachers, may help in answering the research main question, here biology teachers see more perspective than the mathematics teachers. Their future views could also substantiate the idea that mathematics teachers do not necessarily see the current potential in AVR. All in all, it can be concluded that there are several reasons to be called why biology of mathematics teachers are either positive or negative towards AVR, but to obtain a more clear and transparent view with more in-depth answers on their reasons for their attitude and what they hope to see in future AVR applications, further research will be necessary.

Further research

From this research several reasons have been found to indicate why teachers have a certain attitude towards the use of AVR in education. What became clear during the investigation of these teachers is that they have little experience with AVR and thus their attitudes are only built on a small foundation. Therefore, any further qualitative research should be initiated by letting participants see and explore a possible AVR application which may show the possibilities for AVR in biology and mathematics teaching.

When teachers wanted to describe the characteristic of interactivity during the interviews, they seemed not experienced enough to describe how an interactive application then would look like. Mathematics teachers also showed little enthusiasm for AVR in education, because the spatial nature of AVR is perceived as limiting. This is one of the major reasons where the investigated mathematics teachers based their attitudes on, while there are far more possibilities for mathematics education outside the teaching of geometry in higher grades. When teachers, being either biology or mathematics teachers, are known with the full possibilities and potential of AVR in education, they might come up with new insights and might also come up with different reasons for their attitudes. It could broaden the scope of the research and even more specific results could be obtained by further qualitative research.

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Appendix 1: Coding scheme including examples

Category + Code	**Example of quote:**
Pre-existing knowledge AVR	
Known via colleague	*"I've had colleagues who used blended learning"*
Known via entertainment (private life)	*"I am familiar with AVR in the world of gaming, where it is used regularly."*
Technologies at school	
Blended learning	*"I have had colleagues who used blended learning"*
iPads	*"Of course, we have our iPads"*
Flipping the classroom	*"Sometimes flipping the classroom is used, but only very sparsely".*
AVR-Proteins	*"(…) This year I want to do it again, using proteins and we get to work with this application to see how it looks in 3D."*
AVR-Heart	*"I got this T-shirt where you could view a heart if you point an app at it."*
Applications mathematics	
Spatial figures	*"You could use it for geometry, crossing lines etcetera."*
Applications biology	
Brains	"Are the brains oriented thát way?" While speaking of own experience with AVR.
Spatial subjects in general	*"When students are trying hard to visualise a concept from the book, I think then AVR could be put to use."*
Signal transmittance	"(…) if possible, I would do things in 3D as signal transmittance and nerves, to make it more visual."
Cell	"(…) showing a cell."
Digestive system	"(…) with subjects as digestive system (…)."
Cardiovascular system	"I think it would be handy if you could show a 'way' inside the body, for example look inside of veins."
Negative attitude / obstacles	
Individual versus group exercise	*"We help students mostly individual (…)" "(…) that means that all students would do that specific exercise at that specific moment."*
ICT facilities	*"(…) I see things (as obstacle) that when you have a digital application, that your network should be working and your ICT facilities should be sufficient."*
Costs time and energy	*"The only reason why I should not use it, is because students are not getting it, it is not working, or it takes too much time whilst the students become nothing wiser."*
Sceptical colleagues	*"I think there is a category of teachers, to which I do not belong, who are very sceptical towards these kind of things, (i.e. AVR or innovative technology), and how do you get these people to see that it can be of added value?"*
Holding on to current methods	*"I do not think it does not have any added value; it is just that we already have good alternatives which suffice"*
Only sometimes needed	*"I would be held back by the fact that I would need it only now and then"*

Only in 3D	*"When reviewing geometry, we work in the lower grades mostly in two-dimensional space, students don't get much extra out of it when they can walk around a two-dimensional figure, a 2D-picture in the book will be sufficient then."*
Subject too simple for application	*"When doing a practical exercise about 3D you could do very nice things, but I think you transcend the lower grades way too far."*
Skill is important	*"Part of the difficulty is removed, and maybe part of what you want to accomplish when you would do the exercise using VR glasses. Because when VR glasses are used, the students see immediately: of course, that is a hexagon."*
Theoretical knowledge important	"For the higher grades I think the spatial understanding is also important, but to a less extent. They are ought to also understand it theoretically."
Teachers are unknown of possibilities	"I haven't been in contact with it yet, also not with something of which I thought: "That is very applicable."
Gain in learning process vs only sometimes needed	"It is nice to do, but students learn less from it when it is only used once in a while."
On telephone it is still 2D	"Using it on telephone is often limited, you are still looking at a 3D image on a screen, which is in 2D again."
Positive attitude	
Gain in spatial insight	*"(…) 3D-geometry is a very difficult concept, and the lower grades only deal with 3D-geometry as in: this is a sphere, which is in 3D. Then I can just as well take a football with me instead of using AVR."*
Less teachers needed for experiments	*"You could get the same experience, but with less manpower."*
Active teaching method	*"It is a sort of variation, like we showed a video formerly, you could now take an AVR application and use it."*
Dynamic over static	*"You could show the blood streaming through veins and tissues. I think it has more value than a static or physical model."*
AVR as experience	*"(…) if we could apply this in virtual reality, I think students could get a particular experience."*
Gives a life-like or realistic image	*"(…) Using AVR you could see the blood flowing through vessels and tissue in 3D. I think that would have even more added value than a static or physical model. You cannot show the functioning of the kidneys using physical models."*
Characteristics application	
Balance gain in learning process vs time/energy	*"There should be a balance between how much energy it costs and what the benefits are."*
Simple	*"It should be very simple"*
Could be quickly put to use	*"It should be quickly opened, so it does not take too long off my lesson."*
Integrated into teaching method	*"The most ideal situation would be if it was integrated into the teaching method. (…) There should be a link to a certain AVR application."*
Functional (working)	*"Well actually, just that it works. It does not have to be super simple, but just for it to be reliable."*
User-friendly	*"The ease of use, or that it is logically operated by the user, that you understand how it works, that is what I would think of as important."*

Interactive	*"I think it should be interactive at all times, students should not only look at it, but also be able to get things out of the application"*
Multiple functionalities in one application	*"It would be nice if we could have one application for multiple issues, which would be all AVR for instance, but without having to download a specific app for every part of the human body. It should have multiple functionalities."*
Adaptability	*"I think that students should be able to experiment a little with the application, preventing them from getting an assignment, doing the assignment, you will see this and that and then they are finished. I think they should be able to tinker the content of the app. That will be important in my opinion".*
Cooperation app	
To develop application	*"The moment when nobody does it (i.e. testing AVR applications) or nobody cooperates, you will not be able to develop the application."*
To renew education	*"I don't want to teach the same way for 100 years, so it is nice to use a new technology."*
To test whether an application provided gain in learning process	*"There should be a reason behind, when your research will point out that students learn it 10 times better when they, for instance, can walk around a cube with their iPad, then I am absolutely willing to implement that."*
Not developing the app itself	*"The development of the app itself is too far-reaching for me."*
Only if fits with current curriculum	*"I am open to testing AVR in my classroom, but of course it should deal partly with the subject matter with which we are dealing in class."*
Perspective AVR Mathematics	
Application mathematics limited	*"(…) when I look to my own subject, I think the possibilities are rather limited."*
As a tool to help teaching	*"We are using a teaching method nowadays and at specific part where theory is explained there is a link to explanation videos. There could also be a link to a specific app."*
Perspective AVR Biology	
Nerve cells	*"If students could walk into nerve cells, for example. It would be nice to show them how that works."*
Teaching from central point	*"Now we have a physical model of a torso, I can get a few things out of it, while students in the back think: "Yeah, whatever…" because they can barely see it. But if all these students had VR glasses and I was using a digital model; they will get a better picture of this torso."*
Teaching experience	*"The added value is that they experience it as if it were in 3D, and not being a 2D picture in the book."*
Perspective AVR other	
Broader than biology/mathematics	*"I know a video-channel on internet which makes use of a popular video game to walk around in ancient Rome or Jerusalem, and many more. You can create a lesson about how a city looked like in Roman era this way, using AVR. It makes it even more fun to tell your students: Okay, glasses on, we are in virtual reality and we walk straight through it (…)".*
Everything becomes digital	*"(…) in the end we will inevitably go there, education will go there, everything will be digitalized."*
Put cellphones to use	*"I think what is most important is that we should give these mobile phones, which is an irritation factor, far more attention. This way it is*

	a device which distracts students while it should be more implemented for education."