Dutch teachers’ perception of the educational potential of virtual reality

Alexander van Zijll Langhout

Utrecht University

Abstract

The educational value of virtual reality has been extensively theorised over, yet practical tests have been scattered and disparate. The aim of this baseline study was to analyse Dutch secondary school science teachers' perceptions of the educational value of virtual reality. This was done with the intent of finding avenues for further research and innovation of educational virtual reality. The research was done using a questionnaire that was completed by 115 participants. The results were analysed as a whole sample but also subdivided into smaller groups based upon participants' teaching subject, secondary school level, gender and years of teaching experience. On the whole participants showed a positive, yet hesitant, inclination toward educational virtual reality. They saw the appeal for students but were tentative to applying it in their own lessons. The highest demand for it was in the VWO biology curriculum domain of organism-level metabolism (domein-B3) and it was VMBO teachers, biology teachers and teachers that were still in the beginning phase of their career that were most enthusiastic about educational virtual reality. Primary difficulties faced in this project were the fact that the presence of participation bias could neither be confirmed nor disproven and that the 6-point Likert scale used in the questionnaire was not ideally suited for the responses received. The results obtained here were general inclinations of the Dutch secondary school teaching populace and further research should be aimed at receiving more exact answers.

Table of contents

Introduction

Virtual reality is a technology which allows its user to immerse themselves in an artificial world. This is done by meticulously stimulating the user’s senses in such a way that the brain processes it to create an artificial reality. The products of the technology are usually designed in such a way that the user cannot only perceive the artificial reality, but also interact with it. These combined factors create what is called a ’sense of presence’, meaning that the user genuinely feels as though they are present in this artificial reality.

The artificially created reality need not comply to the natural laws of our physical reality. Thus, while virtual reality can be used to artificially conduct a science experiment or visit a place on the other side of the planet, it can also be used to visit places that are normally unfeasible such as the moon. Take this is a step further and users may even alter the very principle of gravity itself and experience the effects. The possibilities and uses of such alternate realities are limitless.

As with many new technologies, the educational value of virtual reality is being explored. The fundamental theoretical underpinning for such exploration has been eloquently compiled by Dede (2009). In his review, Dede identifies three theoretical factors that prove the educational potential inherent in this technology: multiple perspectives, situated experiences and transfer.

Since virtual reality is still a developing technology that can be implemented in so many different ways, the research field with respect to educational potential is scattered. This, combined with the fact that actual implementation of virtual reality in education at a secondary school level is still minimal, begs for action to be taken. Conducting research into virtual reality and developing new modules and hardware is a costly affair and therefore it is important that what is being investigated and created is ultimately what the consumers want. In the case of educational virtual reality the consumers are teachers who would use the technology to teach their students. If teachers’ current knowledge in combination with their demands for virtual reality are known, then research and development can be focussed to address it. This thought aligns with the research aim of this research project, which is to analyse teachers’ perceptions of the educational value of virtual reality in science education.

The conducted research project is a baseline study of the perception and knowledge of Dutch secondary school science teachers. It is carried out by means of a large scale online questionnaire designed to evaluate a knowledge score and determine teachers’ attitude toward virtual reality and ICT in general. The general attitude toward virtual reality of the science teaching populace will help evaluate whether there is a demand for virtual reality modules and hardware. Additionally, participants are also asked in which topics of their subject they would want to apply virtual reality, if any. This could help pinpoint topics for which virtual reality demand is highest, which may help virtual reality creators in making future designs.

In order to investigate the research aim, two primary research questions have been devised. They are as follows:

What is the average Dutch secondary school science teacher's attitude toward virtual reality?

How and when would Dutch secondary school science teachers use virtual reality in their teaching?

Within the scope of the method, which is explained further in this project, several secondary questions have also been thought out, they are as follows:

Is there a difference in perception of virtual reality between teachers of different science disciplines (e.g. biology, chemistry, physics and mathematics)?

Is there a difference in perception of virtual reality between teachers of varying secondary school levels (gymnasium, VWO, HAVO, VMBO)?

Do any other factors, such as gender or years of teaching experience, have a significant effect on science teachers' perception of virtual reality?

Theoretical background

Educational potential of virtual reality

As mentioned earlier, in a review by Dede (2009) three theoretical factors were identified that showed the educational potential of virtual reality. The first of these three factors is that of multiple perspectives. This factor argues that by allowing students to shift between exocentric (outside an object/space/phenomenon) and egocentric (inside the object/space/phenomenon) frames of reference virtual reality can let students combine the unique learning attributes of both of these views and more easily relate the two of them. The reason why this factor is uniquely fitted to virtual reality is because the stronger the immersion of a teaching method is, the more easily students can attain an egocentric frame of reference. Essentially virtual reality helps scaffold students to more easily observe and experience certain phenomena from multiple perspectives, which helps them create a concrete and thorough understanding.

The second factor described by Dede is situated learning. Virtual reality provides the opportunity to study almost all information in a relevant context that enhances learning, examples of this are the virtual field trips described and employed by Minocha *et al.* (2018) or a virtual reality module that mimics a science practical as presented in the news article by Rodrigues (2018) (Coleman, Smith, & Ferrier, 2018). The enhanced learning of situated experience is based around an older concept of situated cognition, which describes that learned knowledge cannot be fully abstracted from the context in which it is learned and used (Brown, Collins, & Duguid, 1989). This means that all knowledge taught in a classroom is inevitably affected by the school culture, but by teaching outside the traditional classroom as is the case with a field trip and a science practical this is counteracted in part. Virtual reality may achieve these effects with significantly less logistical planning and organisation. Additionally, virtual reality can even further extrapolate this concept and simulate situated learning and cognition in situations which are not possible or economically feasible in the real world (Schott & Marshall, 2018), such as full immersion into an aquatic habitat (Barab, Sadler, Heiselt, Hickey & Zuiker, 2007).

The third and final factor described by Dede is that of transfer. This factor is strongly intertwined with that of situated learning. By teaching students information in a situated learning context that mimics the real-life context, the amount of transfer required to be able to apply what has been learned to the real-world is significantly decreased, compared to when learning it in a disjointed context such as a traditional classroom (Mestre, 2002).

In conclusion, virtual reality is nestled in a very firm foundation of theoretical underpinning and has great potential for implementation in secondary school education.

Teachers' openness to change

In one of their chapters, Black and Atkin (1996) describe seven elements typical of change in teachers. Some are important to consider when trying to analyse the openness of Dutch secondary school teachers to virtual reality. In their article, Blau and Peled (2012) showed that there is a positive correlation between teachers' general openness to change and their attitude toward ICT, and thus by extension possibly toward new ICT innovations such as virtual reality.

The first element identified is that change begins with disequilibrium. It states that change is more likely to occur when teachers are dissatisfied with their current situation. In the context of this research it is, therefore, important to identify subjects in the teachers' curriculum where their current tools are insufficient and virtual reality could fill the rift.

A second relevant element is the teachers' exposure to other ideas, resources and opportunities. This element states that the more aware teachers are of alternatives to what they are doing presently, the more open they are to adopting these. With this element in mind it is important to analyse the Dutch secondary school teachers' current knowledge of virtual reality. If knowledge is low, then teachers are less inclined to use the technology.

Third is the concept of *existence proof*. This is the idea that if teachers know of colleagues or associates that successfully employ an innovation they will be more trusting and likely to try it for themselves. As such, an inquiry into potential use of virtual reality in a teachers' environment, both professional and personal, may be of interest.

The final relevant element is the environment within the school. Some schools are more open to or actively encourage experimentation amongst their staff. Evidence of this is reflected in Baylor and Ritchie's (2002) finding of how much school administrators can influence the technological environment within a school and amongst the staff.

Current stage of innovation

Virtual reality as a technology exceeds just the field of education and is not directed by just one organisation or company, yet its implementation within the context of education can be interpreted much like a traditional innovation. For that reason, it is beneficial to briefly illuminate it as though it were a traditional innovation, so that we may interpret in which it currently is, where it needs to go and the role of this research project in getting it there.

Van den Akker (1998), whilst describing the implementation of new curricula, cut the process of innovation into six stages. In this project, the first two, the *ideal* and *formal* stages, are relevant. Although some classroom experiments have already been done, the overall large-scale implementation of virtual reality in education is still in the *ideal* phase. This may be said because although the overall educational potential of virtual reality has been identified and primarily theorised over, the actual place for it, if there is one, is still unknown. This research project may provide the necessary information of the Dutch educational community to find a place for virtual reality. Once that is done then the innovation may enter the *formal* stage where focused research and implementations can be planned.

Hall, George and Rutherford (1977) identified several stages of concern within which a teaching community may find itself when an innovation is implemented. Now that the stage of innovation of virtual reality within the teaching community has been identified, it is important to assess the stage of concern so that it can be taken into account during the implementation. This research project can help assess the first three potential stages of concern: *Awareness*, *Informational* and *Personal* by judging participants' knowledge of virtual reality, confidence in using it and disposition toward it. Appropriately, these three stages of concern are most likely to be encountered during the beginning stages of an innovation (*ideal* and *formal*).

Methods

This research project made use of a large-scale questionnaire, which can be found in full in appendix A. The selection of participants, dissemination and design of the questionnaire, and the way in which attained results were analysed are discussed in this section.

Participants

At present, there are 649 secondary schools in the Netherlands (2018), and with a multitude of science teachers per school it is not feasible to ask every single one of them to fill out the questionnaire. As such, a random sampling method was used to select participants. This was done by using a random number generator in tandem with the website: 10000scholen.nl, which can be filtered to only show secondary schools. A comprehensive list was kept to ensure no school was selected twice and to check for coincidental bias toward certain areas. No such bias was found and a total of 263 schools were contacted over the course of November 2018 using this method. Prior to the full survey 25 schools were asked to participate in a smaller pilot survey.

With the present state of privacy laws it is impossible to find individual e-mails of science teachers, as such the school administrators were e-mailed to spread the survey amongst their staff. Initially, the intention was to ask the school administrators for the individual e-mail addresses of the teachers to ensure every teacher received the questionnaire, but, as became clear in the pilot, administrators were understandably hesitant to hand out individual e-mail addresses. Therefore, it was settled to simply e-mailing the administrators, but the sample size was increased in compensation since the pilot showed that this method had a low response rate. For every two schools e-mailed, roughly one teacher filled out the questionnaire (13/25 in the pilot; 130/263 in the full survey). This would suggest a response rate of 50%, but since every school has a multitude of science teachers the response rate is actually far lower.

Two criteria that the sample had to adhere to were also set-up at the start of the research project. First, in order to counteract administrator influence, shown by Baylor and Ritchie (2002), no more than three teachers of the same secondary school were allowed to participate in the survey. Baylor and Ritchie (2002) showed that the influence of technological leadership and administrators that promote technology use on teacher's opinions can be massive. As such, it was predicted that the attitude of teachers in schools with such leadership would be relatively homogenous. The implications of this on a population wide sample could result in an extreme participation bias originating from these schools. In order to enforce the criterium that no more than three teachers of the same secondary school can participate, a question asking about the school where the participant taught was added to the questionnaire, which would allow us to rule out teachers that surpassed the three mark. However, it was shown in the pilot that multiple participants were uncomfortable answering this question because it compromised their anonymity, resulting in the discarding of the entire questionnaire. As a result this question was made optional instead, slightly weakening our ability to rule out participation bias. The other option would have been to request administrators not to send the questionnaire through to more than three different teachers in their staff, but this option was discarded after the pilot when the low response rate became apparent. The second criterium was that the three teachers from each of the schools would preferentially be of different subject backgrounds, to ensure the sample would be various enough. This criterium was carried out by requesting the administrators to spread the questionnaire to each of the appropriate faculties, which were explicitly listed in the e-mail to avoid confusion.

Since only a limited amount of teachers were allowed to fill out the survey per school, there was a chance that only those teachers that were already interested in virtual reality would take the opportunity to fill in the questionnaire, which could once again lead to a participation bias. To check for this, several extra questions were added to the beginning of the questionnaire, which aimed to assess the teachers' affinity for ICT and interest in ICT. The bias could also come to light in the third part of the questionnaire where teachers' prior knowledge of virtual reality was evaluated. The results of this are discussed in the results section.

The initial calculations for the projected sample size were as follows. Since we desired to identify statistically significant effects between independent groups an α of 0.05 was set and a desired power of 0.90. The research is still exploratory, as such medium effects were regarded as sufficient for the effect size and Cohen's d was valued at 0.50. The total sample would need to be cut into smaller groups to make the appropriate comparisons for the secondary questions. The largest number of pairwise comparisons between groups is three, and the appropriate Bonferroni correction was carried out. With those numbers set the sample size required for each individual group came out at 111 participants. With three groups at the most, the total sample size would need to be able to split into at least three of such groups, giving a minimum total sample size of 333. However, since we could not ensure that the exact criteria would be followed, and that the sample would sort into three exact groups, a total sample size of 400 was projected. It became apparent after the pilot that this was not a feasible amount, because even if all

649 schools were contacted the response rate would not suffice to reach 400 samples. Still, the total sample needed to surpass 111 in order to make significant conclusions about the total group. The adjusted goal was, therefore, to contact at least 250 schools, which would hopefully suffice to satisfy the 111 sample mark.

Questionnaire

The full questionnaire can be found in appendix A (in Dutch, with English justifications), it was created using the information on successful questionnaire design from Ian Brace (2018). It consists of three sections and features several open questions and many closed questions that employ combinations of positive and negatively phrased statements testing the same criteria.

The questionnaire opens with a brief introduction which sets the stage for the participants. They are inquired not to press themselves too hard when answering certain questions. It is understandable that virtual reality is not a topic that the majority of teachers put a lot of conscious thought into, as such their initial reaction is more genuine than a well-thought out answer where the participant tries to piece together an attitude which they have simply never felt. Data collected in studies where participants are giving first reactions has also been reported to be most stable (Tourangeau, Rips, Rasinski, 2000). Furthermore, by requesting our participants to fill out the questionnaire quickly we prevent the onset of fatigue, which tends to occur when questionnaire are too lengthy.

The first section of the questionnaire focuses on collecting information about the participants. The first six questions regard their personal information and are essential for analysing the secondary research questions. Only information that was strictly necessary for this research is asked. In the pilot the participants were forced to fill out these questions in order to advance and a seventh question regarding the school at which they taught was included. Several teachers raised privacy concerns over these questions during the pilot and in response they were altered to be optional, though the participants were strongly urged to fill them out for the sake of the research, and the seventh question was removed. The privacy laws were reviewed and the questionnaire was deemed compliant. The seventh question of the final survey comes in the form of 10 statements with which the participants can choose to either agree or disagree. These 10 statements are modelled after those used by Blau & Peled (2012) in their research toward teachers' attitude towards ICT. These help paint a picture of our participants' general openness to change and attitude toward ICT, which provides key information as to whether virtual reality is more likely to be embraced by those teachers that are already enthusiastic about ICT and could help determine the presence of a participation bias. The three final questions are in the same vein and explore the participants' current involvement with ICT and virtual reality. This will help get a bearing on just how prevalent the idea of virtual reality already is with teachers nowadays. The questions have been set-up with additional statements to make it easier to choose, and to divide the answers into clearer categories, which negates misperception. Close care has been taken to avoid bias when writing the statements, because none of the answers should seem more socially desirable than others, which allows for more honest replies from the participants. The first sections finishes with one open question where teachers may give additional information, if they wish to further elaborate on a certain aspect or have a remark about the questionnaire.

The ten statements in the seventh question of section one are graded based on a 6-point Likert scale, the same one is used for statement questions in section two. This form of even-numbered grading was selected because we did not want participants to use a neutral-option as a way to avoid thinking about the statements, and three options on either side should give sufficient room for nuance without making it too difficult to choose. Research carried out by Coelho and Esteves (2007) support this choice by showing that mid-point scores were often bloated beyond what they should be when present and therefore detract from the validity of a questionnaire. Saris and Gallhofer (2014) also showed that removing the neutral option improved both the reliability and validity of collected data. We do not want participants to overthink, but we do want to stimulate them to think to the point of forming an initial opinion and therefore either agreeing or disagreeing, if only slightly. Brace (2018) showed that there are also several biases that need to be taken into account when designing a Likert-scale. Two of these biases, *order effect* and *acquiescence* are put up against one another to cancel one another out as much as possible. *Order effect* states that options on the left are chosen more often than options on the right. *Acquiescence* states that participants tend to agree more often than they disagree. Thus, by putting negative options on the left, we make these biases contradict one another and cancel each other as much as possible. The *acquiescence* bias is also brought more in check by the questionnaire's use of positively and negatively phrased statements that measure the same criterium.

The second section of the questionnaire focusses on the participant's disposition toward virtual reality use in the classroom. It is split into two questions each with a large number of statements that are to be answered on the same 6-point Likert scale described above. The first set of statements analyses the participants' attitudes toward virtual reality, with a particular focus on the educational aspects. As with the statements in section one the statements have been scrambled so that they do not appear to be in any apparent order, but they in fact consist of three categories that are being test, with each featuring at least one negatively phrased statement. By randomising and giving each category multiple statements, the participant must re-evaluate their stance each time, and thus increases the reliability of the results if they show a consistent opinion. The second set of statements follow all the same design principles already described and are aimed at exploring the potential use of virtual reality within the classroom. This section finishes with an open question inquiring into what topics within the sciences teachers would deem most appropriate to use virtual reality in. This question is important because if there is a topic in which there appears to be a lot of demand for virtual reality then future modules may be designed to meet this demand. Once again space is given for participants to elaborate and comment if they so desire.

The third and final section of the questionnaire is aimed at interpreting the participants’ knowledge of virtual reality. It consists of seven knowledge multiple-choice questions which can be used to create a knowledge score for each of the participants. These questions have two goals, the first is to see if there are certain bits of knowledge that may correlate with enthusiasm for the technology. For example, there may be a statistically significant correlation between a positive attitude toward educational virtual reality and correctly answering a certain knowledge question. This could give an indication that when the participant is informed and aware of that portion of virtual reality they become more enthusiastic toward its academic potential. This could help future innovators begin their large scale implementation by making the teaching community aware of that fact and as such arousing enthusiasm amongst the teaching community. The second goal of the questions is to once again check for participation bias, if the large majority of participants have a high knowledge score then this may be an indicator of participation bias. The seven knowledge questions are preceded by a single question aimed at assessing the participants’ confidence in their level of knowledge. This may not correlate with their actual level of knowledge, and could therefore serve as an indicator of participants’ under or over estimation of the complexity of virtual reality. Some people may dismiss it too readily, whilst others could fear its inaccessibility due to wrongly perceived complexity of the topic.

The knowledge section of the questionnaire was chosen to be last because the participants’ initial reactions are desired for the two earlier sections. Some participants may not be well informed about virtual reality, but they may not be aware of it until they are confronted with the knowledge questions. We do not want participants’ realisation of their lack own of knowledge, if present, to interfere with their gut reaction. This also coincides with the choice made to not give participants a clear definition of virtual reality at any time throughout the questionnaire. The participants’ personal idea and definition of what virtual reality, and especially educational virtual reality, entails is a crucial component of their perception and should therefore not be primed in any way.

Instruments

The survey was carried out using the SurveyMonkey software. This online software was selected because of it allows the survey to be accessed with just a link which can be plugged into a large-scale e-mail. This allows participants to access it without having to provide any personal information and protects their anonymity. Data analysis was conducted using SPSS statistics.

Data analysis

The data analysis was split into three parts, the first being a statistical analysis of the statements regarding the participants’ attitude toward virtual reality. This was done using SPSS statistics and consisted entirely of finding mean values of statement categories and comparing these between groups of participants for any statistical significance. The exact tests used are mentioned the appropriate results in the results section. This method could be used because when designing the questionnaire the statements were split into various categories for which they tested. During the analysis the participants were split into groups in four separate ways. Each of these will be briefly illuminated in the following paragraphs, because it required some formulating since participants often fell into multiple groups. If a participant fell into multiple groups they would be disqualified from that analysis, which harmed sample size. The groups were therefore created in such a way as to encompass as many participants as possible, while maintaining validity of the secondary questions.

The first way in which participants were split was based on the secondary school subject that they taught. This was split into three different groups: biology, chemistry & physics and mathematics. These three groups were chosen because it was found that many participants taught multiple subjects and these were the most widely encompassing groups, especially with the existence of the subject NASK, which literally means both chemistry and physics. This split of participants also formed groups of sizes that had a chance of garnering significant results.

The second split of participants was based on the secondary school level in which they taught. This was divided into two groups: Gymnasium/VWO/Havo and VMBO. This split was chosen because it creates a clean division between the more theoretical profiles and the more practical ones. It was also far more common for teachers to combine VWO with either Havo or Gymnasium than for VMBO to be combined with any of the other three.

The third split was based on gender and does not require much explanation. There were a few participants that did not fill out their gender for unknown reasons, nonetheless it could be separated into male and female cleanly.

The final split was based on the participants’ years of teaching experience and the groups were created using findings of Klassen & Chiu (2010) and Hargreaves (2005). In their article Klassen & Chiu explore several effects on teachers’ self-efficacy, one of which is years of teaching experience. They split self-efficacy into three smaller sub-categories, but all three followed a similar trend, namely a hill shaped curve peaking between 20 and 25 years, this is shown in figure 1.

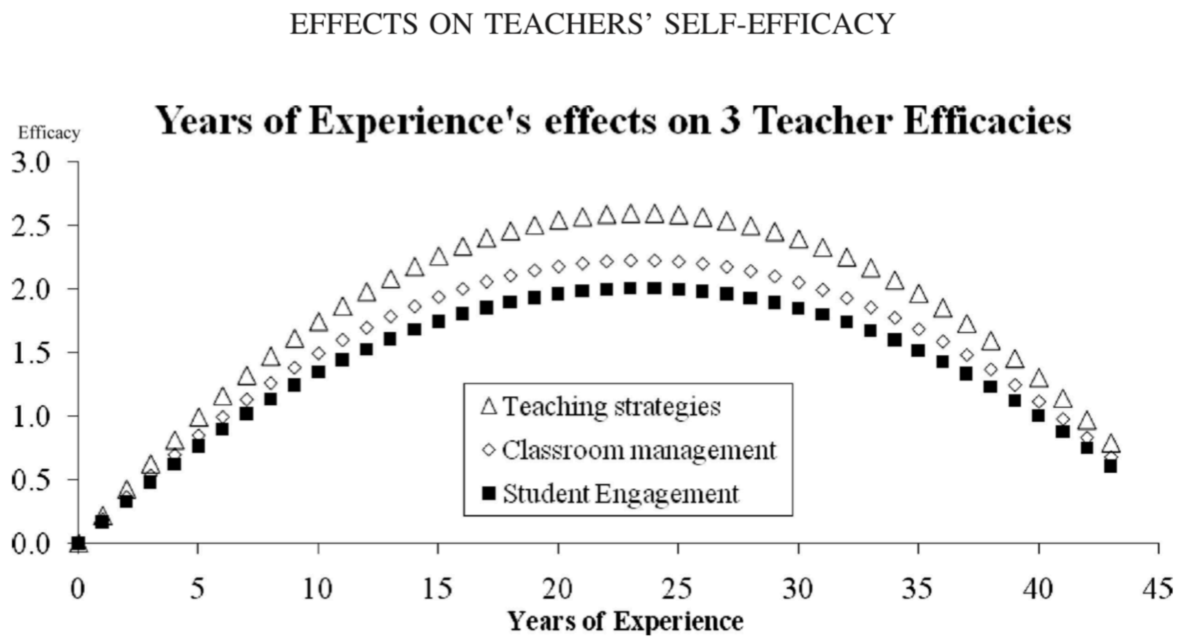

Figure 1. Graph created by Klassen & Chiu (2010) showing the results of their findings of teachers’ years of experience on self-efficacy.

Klassen & Chiu’s findings are mirrored in Hargreaves’ article about teachers’ emotional responses to educational change, although Hargreaves uses the looser definitions of early, mid and late career and defines his late career as 20+ years of teaching experience. Therefore, Hargreaves supports an earlier peak when it comes to teachers’ openness to educational change. With these two articles in mind, and the distribution of our participants’ experience, it was decided to cut the participants into five groups based on their years of teaching experience.1-9 years, 10-14 years, 15-19 years, 20-24 years and 25+ years.

The second part of the data analysis was centered on the final question of the attitude toward virtual reality portion of the questionnaire, where participants were asked to fill out as many curriculum topics in which they could envision themselves employing virtual reality as they could. This was an open question and therefore participants were free to fill out the question in whatever way they desired. In order to relate these open answers given to theory they were to be coded against the various secondary school curricula (VWO, HAVO, VMBO). A single participants' answer could fit into multiple curriculum domains but they could not give a single domain multiple points if they gave multiple suggestions that fit into it. At the end of this analysis it would be the hope that several curriculum domains come forth that are most often mentioned and therefore prime opportunities for potential implementation of virtual reality.

The third and final part of the data analysis was to analyse the various measures set in place for checking participation bias. This consists simply of finding averages of the sample's attitude toward virtual reality and creating a knowledge score for the participants' knowledge of virtual reality.

Ethics

In this research project the guidelines of the Ethical Committee of the Faculty of Science (UU) will be followed.

Results

There were a total of 130 responses to the full-scale survey. Unfortunately, several of these skipped portions of the questionnaire or were not a science teacher, which invalidated their data. The final number of usable data was 115 (n=115), which gives a completion rate of 88%.

In order to evaluate the statement based questions numerical scores were used. If a participant 'strongly agreed' with a statement that answer was given a score of 6, where 'strongly disagreed' gave a score of 1. Using this method it was possible to obtain average scores for each of the statements. These could then be added to one another according to the categories to which they belonged (the negatively phrased statements were first corrected so that a 'strongly disagree' gave a score of 6 and a 'strongly agree' a score of 1) when necessary.

1. Attitude towards virtual reality

First, the participants' attitudes towards virtual reality were analysed using the data from section two. This was done using the whole sample first, and afterwards the secondary research questions were explored by checking for significant differences amongst each of the specified categories (secondary school level, teaching subject, gender, years of teaching experience).

1.1 Whole sample results

The first set of statements of section two were analysed first. This set of statements could be split into three categories: private interest in virtual reality, professional interest in educational virtual reality and expected student reaction to educational virtual reality. The average score for participants' private interest in virtual reality was 3.72, which is very close to neutral (3.5). This indicates that the participants were on average indifferent, if ever so slightly interested, in the use of virtual reality in their private lives. The average score for participants' professional interest in educational virtual reality was 3.82, which is also still very close to neutral but further toward 'slightly agree' (4) than their private interest. This indicates that the participants were on average between indifferent and slightly interested in the use of virtual reality in their professional lives. The average score for the participants' expected student reaction to educational virtual reality, however, was 4.72, which is close to 'agree' (5). This indicates that the participants expected their students to be interested and enthusiastic toward the use of educational virtual reality. All results are shown in figure 2 below. A one-sample T-test showed the differences between both participants' professional and private interest in virtual reality and their expected student reaction to educational virtual reality to be significant (p=.000). This shows that the participants find educational virtual reality an interesting prospect when placing themselves in their students' shoes, however the thought of having to work with it themselves is less enthusing.

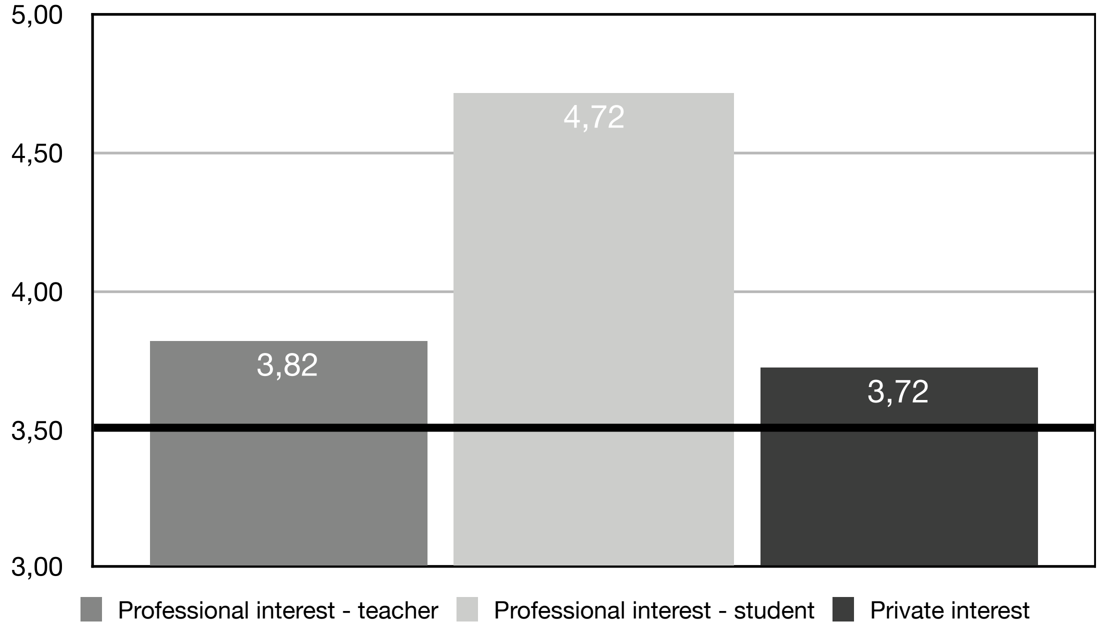

Figure 2. Graph showing the average whole sample results for the participants' professional interest in educational virtual reality, their expected student reaction to educational virtual reality and their private interest in virtual reality. The thick black line represents the indifference point of 3.5.

The second set of statements were split into five categories, which will each be handled independently of one another. The first of these categories was related to whether the participants believe there is a place within their subject curriculum where educational virtual reality could strengthen their teaching. The average score that participants gave in this category was 4.68, therefore on average the participants agreed, if only slightly.

The second category looked into whether participants would prefer to use educational virtual reality in either a full classroom context or a one-on-one mentoring context. The average score for a full classroom context was 3.66 and for a one-on-one context was a 3.37, therefore participants were more or less indifferent to the use of educational virtual reality in both a full classroom and a one-on-one mentoring context. The results are shown in figure 3 below. However, a one-sample T-test showed the difference between the two answers to be statistically significant (p=.018), on average the participants were therefore significantly more interested in using educational virtual reality

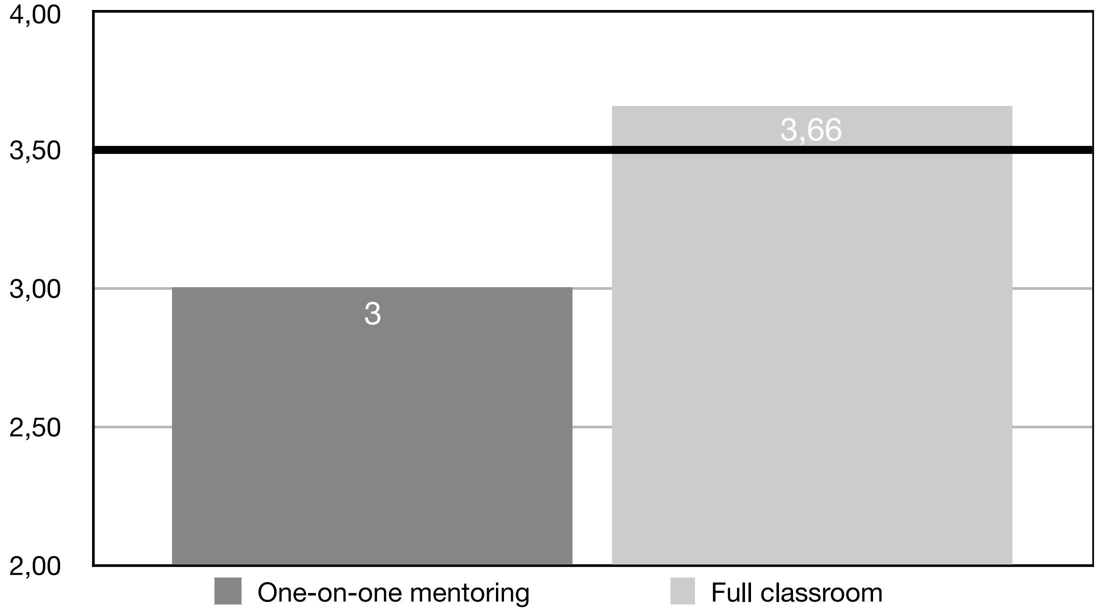

Figure 3. Graph showing the whole sample average scores given for using educational virtual reality in a one-on-one mentoring context and a full classroom context. The thick black line represents the indifference point of 3.5.

in a classroom context than in a one-on-one mentoring situation.

The third category focussed on the kinds of activities that participants' would want to perform with educational virtual reality in their lessons. The average score given for an interactive activity (e.g. a virtual experiment or field trip) was 4.23. Participants also scored their interest in using educational virtual reality as a novel form of presenting information (e.g. a 360 degree video) at 4.12 (shown in figure 4). In both instances the participants were slightly interested in using educational virtual reality for such activities.

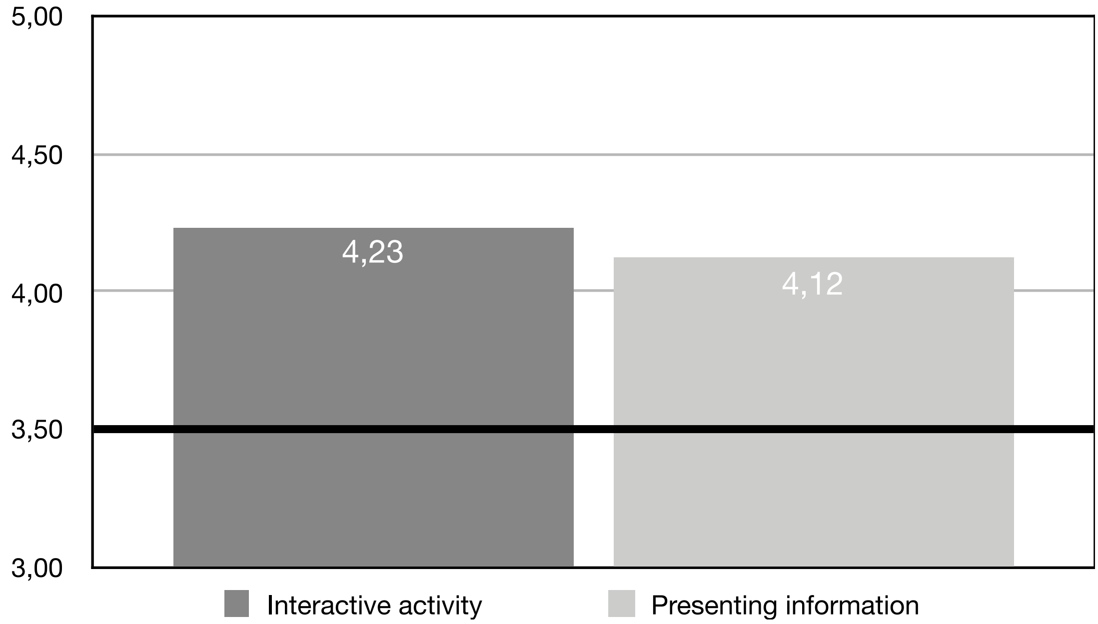

Figure 4. Graph showing the whole sample average scores given for using educational virtual reality as an interactive activity and as a novel means of presenting information. The thick black line represents the indifference point of 3.5.

The fourth category interpreted the ages of students with which participants would like to use educational virtual reality. A score of 3,88 was given for working with older students (bovenbouw) and a score of 4.16 was given for younger students (onderbouw) (shown in figure 5). A one-sample T-test confirmed this to be a statistically significant difference (p=.017). On average the participants were therefore significantly more interesting in using educational virtual reality with younger students (onderbouw).

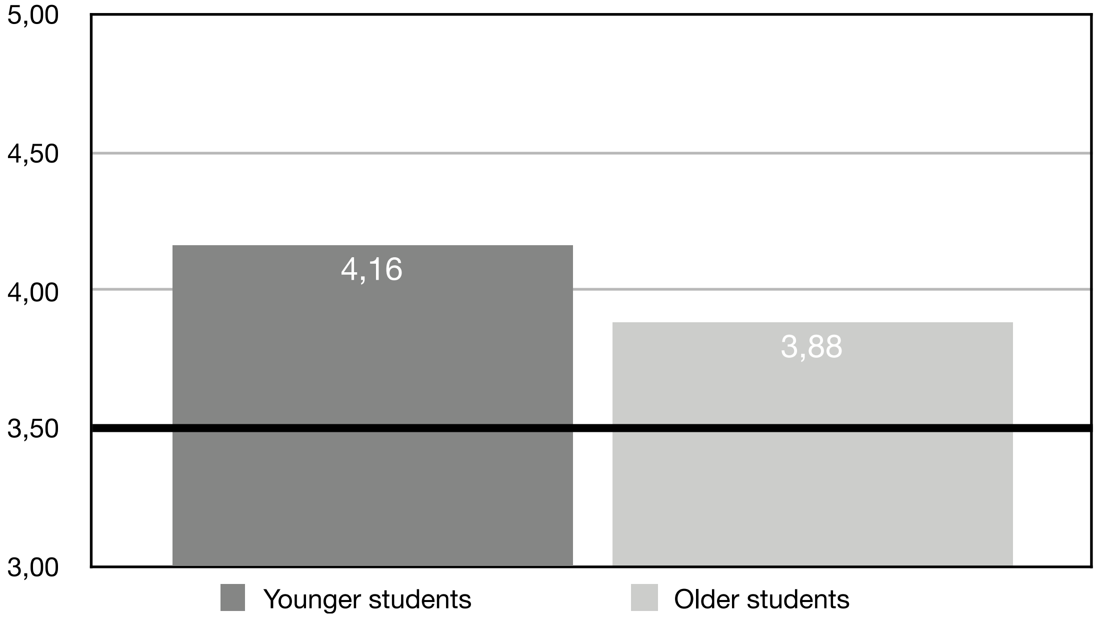

Figure 5. Graph showing the whole sample average scores given for using educational virtual reality with younger students (onderbouw) and with older students (bovenbouw). The thick black line represents the indifference point of 3.5.

The final category judged how likely participants would be to use educational virtual reality if it were available to them and suitable for the topic. The average score obtained was 4.15, which indicates that participants slightly agreed with the statements, corresponding to them slightly agreeing that they would employ educational virtual reality every time it was available and suitable for their lesson.

<u>1.2 Teaching subject</u>

The same statement categories as described in the whole sample were analysed again, but this time by means of either a one-way ANOVA or its non-parametric counterpart, the Kruskal-Wallis H-test, depending on which was appropriate for the data, to see if there were any significant differences in the answers given by participants who taught different subjects. As explained in the methods, the participants were split into three categories: Biology, Chemistry and Physics, and Maths. All relevant findings are mentioned below, if a particular category is not mentioned then it had no relevant findings.

Before carrying out any of the statistical analyses the assumptions for the one-way ANOVA were checked for each of the categories. Unfortunately, some of the categories failed at the normal-distribution check and since the group sizes are strongly variable we could not rely on the robustness of the ANOVA, as such the Kruskal-Wallis H test was used for those categories. If there is a significant result the used test is mentioned.

The data indicated that biology teachers were slightly more enthusiastic toward virtual reality from a teachers' stand point than both chemistry and physics teachers and maths teachers (bio, 3.93; chem/phys, 3.79; math, 3.4). Unfortunately the sample was not large enough for these differences to be significant.

In the second set of statements there was also an indication that biology teachers were more optimistic about there being a place for virtual reality within their curriculum (bio, 4.87; chem/phys, 4.56; math, 4.24). Unfortunately, the sample was again not large enough for these differences to be significant.

The Kruskal-Wallis H test did report a significant difference ($p = 0.003$) amongst the groups when it came to enthusiasm about implementing virtual realty as a means of presenting information to students. Biologists were the most enthusiastic with an average score of 4.53, chemists and physicists second with 3.90 and mathematics teachers were not as enthusiastic with a score of 3.64. Since it is a non-parametric test we are unable to say between which two groups this significant difference lies, but the averages themselves provide a strong indication, represented visually in figure 6. It is interesting to note that biologists were also the only ones that rated virtual reality as a means of presenting information higher than using it as an interactive medium.

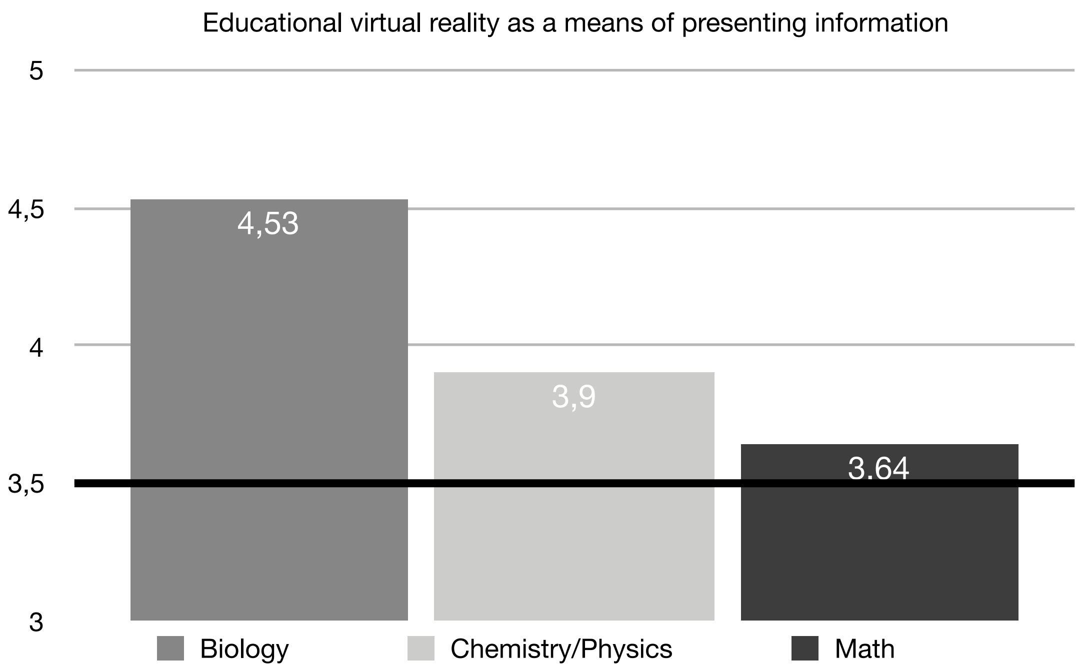

Figure 6. Graph showing the average score given by biology, chemistry/physics and maths teachers when asked whether they could envision themselves using educational virtual reality as a means of presenting information. The thick black line represents the indifference point of 3.5.

No significant differences were found for the age of students, however it is interesting to note that chemists and physicists were the only ones to rate using virtual reality with younger students higher than using it with older students.

1.3 Secondary school level

Once again the same statement categories were analysed, but this time by means of an independent samples T-Test, or the Mann-Whitney U test if the category did not meet the required assumptions, to see if there were any differences in answers between participants that taught at different secondary school levels. A T-test was used because participants were only split into two groups for this analysis: VMBO and HAVO/VWO/Gymnasium. The categories were checked for the assumptions beforehand. All except for one failed in terms of the normality check and since the group sizes were strongly variable we could not rely on the robustness of the T-test, thus the Mann-Whitney U test was used for all categories except for private interest in virtual reality. Nonetheless, the used test is reported with any significant results. All relevant findings in this analysis are mentioned in this section.

The Mann-Whitney U test showed that VMBO teachers were significantly ($p=.022$) more enthusiastic about using VR in one-on-one mentoring situations than HAVO/VWO/Gymnasium teachers (VMBO, 3.89; HAVO/VWO/Gym, 3.17)(shown in figure 7).

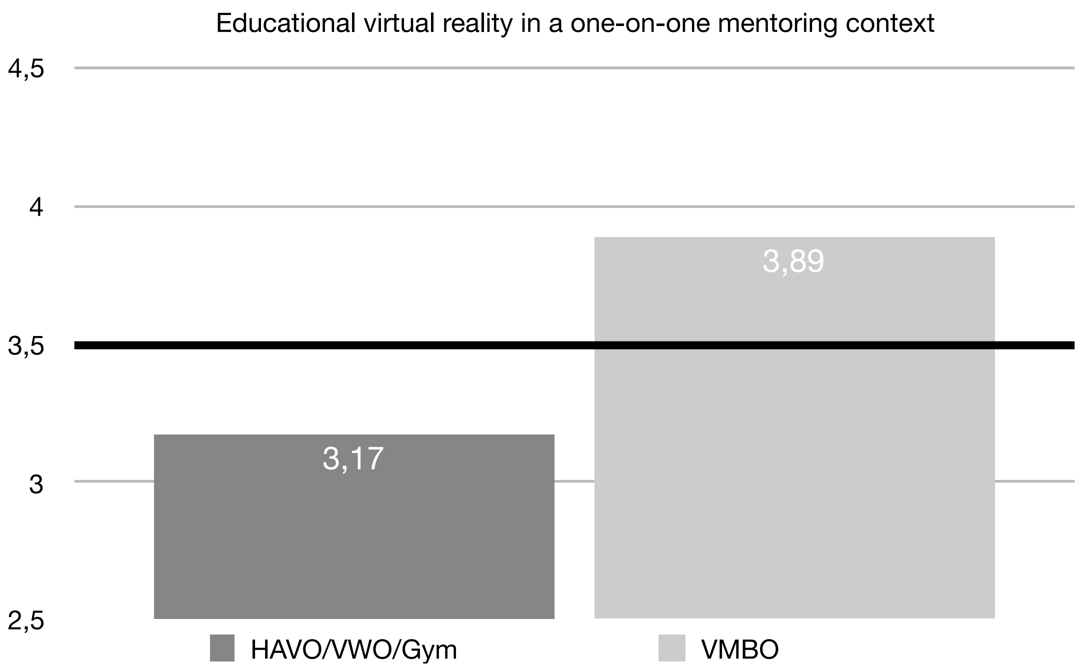

Figure 7. Graph showing the average score given by HAVO/VWO/Gym and VMBO teachers when asked about whether they could envision themselves using educational virtual reality in a one-on-one mentoring situation. The thick black line represents the indifference point of 3.5.

A weak significant difference (p=.043) was also found between the secondary school levels when it came to using virtual reality as a means of presenting information (VMBO, 4.42; HAVO/VWO/Gym, 4.03). This means that VMBO teachers were significantly more interested in using virtual reality as a means of presenting information. It is interesting to note that VMBO teachers were also almost significantly (p=.055) more interested in using virtual reality as an interactive medium (VMBO, 4.53; HAVO/VWO/Gym, 4.08). In both instances the VMBO teachers were therefore more enthusiastic.

1.4 Gender

For gender an independent samples T-test or Mann-Whitney U test was again used to assess the same statement categories depending on which was appropriate. Unfortunately not a single significant different was found, nonetheless the few noteworthy findings are shortly mentioned below.

An independent T-test showed that there was a nearly significant difference in enthusiasm toward virtual reality in private time between male science teachers and female science teachers (male, 3,84; female, 3,58; p=.075)

Male science teachers were also nearly significantly (Mann Whitney U-test, p=.063) more enthusiastic about the use of virtual reality as an interactive learning activity than female science teachers (male, 4,42; female, 4,02). On the contrary there was an indication that female science teachers were more enthusiastic about implementing virtual reality as a novel means of presenting information (male, 4.00; female, 4.33, p=.124).

1.5 Years of teaching experience

Teaching experience consisted of five different groups, therefore either a one-way ANOVA or a Kruskal-Wallis H test was used depending on which assumptions were met. As described in the methods the five groups were: 1-9 years, 10-14 years, 15-19 years, 20-24 years and 25+ years.

A one-way ANOVA was used to find a significant difference between teachers of 10-14 years of experience with teachers of 25+ years of experience when it came to interest in using virtual reality in their private time (10-14 years, 4.06; 25+ years, 3.32; p=.009). The difference between teachers of 10-14 years of experience and teachers of 20-24 years of experience was also nearly significant (10-14 years, 4,06; 20-24 years, 3,42; p=.091).

There was also a near significant difference in how often teachers would use virtual reality were it available to them and suitable for the topic (p=.055). This difference was found using a Kruskal-Wallis H test, so it cannot with 100% certainty be said with which groups this attained p-value corresponds, however the difference between 10-14 years of experience and 25+ years of experience is the largest difference in mean and therefore most probable (10-14 years, 4,66; 25+ years, 3.69).

The Kruskal-Wallis H test also revealed a strong significant difference in enthusiasm with regards to using educational virtual reality with older students (p=.005). This difference is most likely between teachers with 10-14 years of experience and teachers with 15-19 years of experience (10-14 years, 4,38; 15-19 years, 3,07), although teachers with 20-24 years of experience have a nearly equally low enthusiasm for the prospect with a score of 3,08 (all averages shown in figure 8).

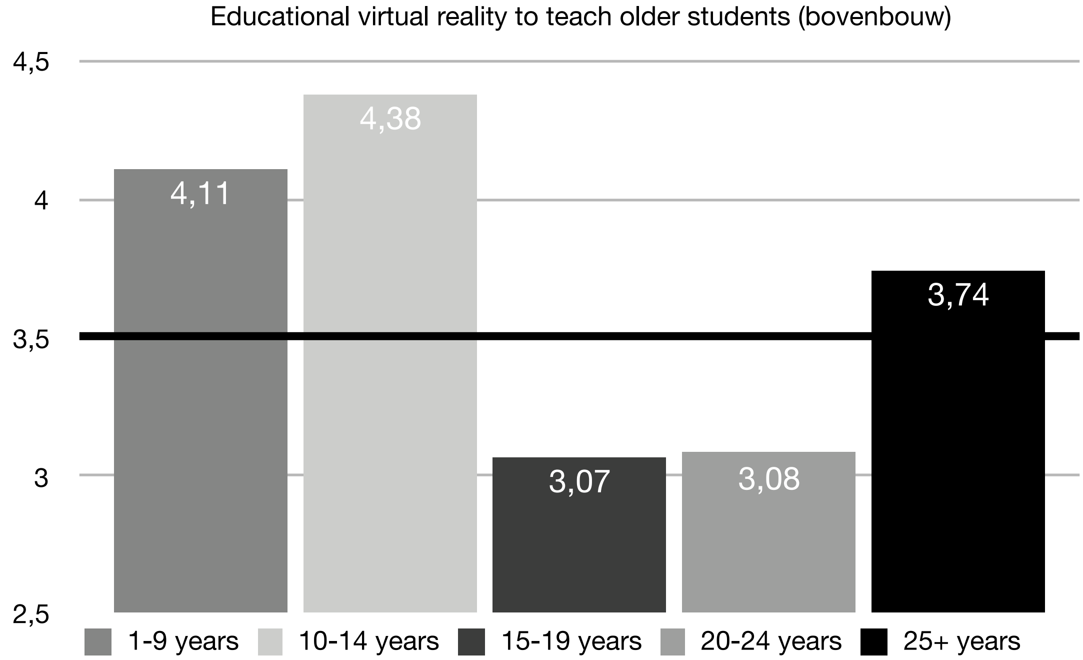

Figure 8. Graph showing the average score given by participants with varying years of teaching experience when asked about whether they could envision themselves using educational virtual reality to teach older students (bovenbouw). The thick black line represents the indifference point of 3.5.

Only the most noteworthy results were discussed above, however, it is interesting to note that these results were part of a greater trend. The two youngest groups (1-9 years and 10-14 years) were consistently the highest scoring group, with only two exceptions, namely: teachers with 15-19 years of experience were the most enthusiastic about using virtual reality as a novel means of presenting information and teachers with 25+ years of experience were actually the most enthusiastic about using virtual in one-on-one mentoring situations. These two cases however were far from significant and the differences were small, on the whole the younger teachers were by far the most enthusiastic about educational virtual reality.

2. Curriculum topics for virtual reality

At the end of the 'attitude toward virtual reality' section of the questionnaire one final open question was asked which requested participants fill out as many curriculum topics as they could think of in which they could envision themselves employing virtual reality. This question was completely open and some participants were more succinct than others, creating a little difficulty when analysing the answers. The initial intention, as outlined in the methods, was to analyse and code the answers based on the various teaching curricula, however using the various curricula of VWO, HAVO and VMBO, not to mention the wide-array of lower secondary school methods and curricula, amounted to too many groups, which made coding difficult. So, instead it was opted to code them based just on the topics of the VWO curriculum (2018 edition) because the researcher was most familiar with these and they enveloped all given answers. It must still be noted that fitting many of the answers into curriculum domains was not an easy task, many of the answers were given with a specific lesson or module in mind. This leaves the answer open to interpretation and the coder's subjectivity as to in which overarching curriculum domain such a lesson or module could be employed and takes a toll on the reliability of the coded results. The effects of this will be analysed further in the discussion. Only the most relevant domains and topics are discussed below, however all of the coded results can be found in appendix B.

The most commonly mentioned curriculum domain was organism-level metabolism (B3 - stofwisseling van het organisme), with mentions by 33 separate participants, which is 29% of the total sample and an astounding 87% of all the biology teachers. This could in part be because this is a very broad domain which encompasses both animal and plant biology, however almost all of the mentions which were categorised into this topic were regarding animal biology, more specifically that of humans. There was a lot of interest in the three main organ systems covered in this topic: the respiratory system, circulatory system and digestive system. Many participants also framed their interest in this topic in the context of experiencing a virtual journey through the body.

The other two most prevalent biology topics mentioned were ecology and cell biology, which both received 16 mentions. These topics were split into curriculum domains of cell-level metabolism (B2 - Stofwisseling van cellen), regulation of ecosystems (B8 - Regulatie van ecosystemen), self-organisation of ecosystems (C3 - Zelforganisatie van ecosystemen) and interaction of ecosystems (D5 - Interactie van ecosystemen).

The most commonly mentioned chemistry domain was molecules (B1 - deeltjesmodellen), which was mentioned 14 times. This is another large domain that envelops a lot of chemistry material, however most answers framed in the context of using virtual reality as a tool to help visualize molecular and atomic structures.

The most commonly mentioned physics domain was that of electromagnetic radiation (E2 - Elektromagnetische straling en materie) with a total of 13 mentions. Most mentions were more specifically directed at the topic of optics. The second most commonly mentioned physics domain was gravity (C3 - gravitatie), more specifically in the context of astrophysics and celestial mechanics, which received a total of 11 mentions. These were followed by smaller scale mechanics in the domain of force and movement (C1 - kracht en beweging), which was mentioned 9 times.

Unfortunately, only very few math domains were mentioned and none more than just twice. Perhaps indicating that the maths curriculum is not as ideally suited for implementation of virtual reality as the other three, despite the slightly positive inclination of maths teachers towards the technology.

3. Participation bias

The first method of checking for a potential participation bias was to begin the questionnaire with a way to interpret the participant’s attitude toward ICT in general. This was done using a series of 10 statements based on earlier research carried out by Blau & Peled and three multiple choice questions. The results of these are discussed first. Afterwards, the second method which was based on assessing participants’ prior knowledge of virtual reality will be discussed.

The 10 statements could be separated into 4 separate categories each answered using a Likert-scale ranging from 1-6, the categories were as follows: internet usage during private time (private usage), attitude toward internet usage for communication with colleagues (communication), attitude toward using internet as a way of gathering scientific knowledge (gathering knowledge) and the likelihood of recommending internet usage to students (recommend). The average score for each of these categories was above 4 (private usage, 4.35; communication, 4,18; gathering knowledge, 4.33; recommend, 4.13), indicating that the average participant was at least slightly positively inclined toward the internet and ICT in all of these regards. At first glance it could be assumed that since the average lies significantly above the indifference point of 3.5 in all of these categories the sample is disproportionately positive towards ICT, which would be an indication of participant bias. However, in the modern day and age it is unusual to find anyone who is entirely opposed to the use of technology. This could be the case for this sample, especially with many Dutch secondary schools actively pushing toward a more ICT-heavy environment. Unfortunately, there is no population-wide number with which these results can be compared, so it is impossible to solidly vouch either for or against a participation bias. Nonetheless, these results are sufficient to alarm for the possibility, and this should be kept in mind when viewing all the results obtained in this research. It is also the hope that these results can be used for reference in the future.

The three multiple choice questions assessed how often participants already used ICT in their teaching, how often they had come into contact with virtual reality in their private of professional life, and how interested they would proclaim themselves to be in virtual reality. They had the option of choosing between 5 answers which gave a range which ran from entirely negative to fully affirmative. These answers were scored with a 1 being entirely negative and a 5 for the most positive, and the average was taken for the three questions. On average the participants scored a 3.20 on the amount of ICT they used in their lessons, where 3 is the mid-point of the scale. They scored only a 2.27 on the amount of times they had come into contact with virtual reality and they had a score of 2.80 with regards to their interest in virtual reality. Unfortunately, all three of these averages hover around the mid-point, once again not providing a clear indication as to whether there is a potential participation bias or not.

The final way of checking for a potential participation bias was by assessing participants' prior knowledge. This was done by asking 7 multiple choice knowledge questions, if a participant answered the question correctly they were awarded a point. If a participant was knowledgeable about virtual reality they could therefore earn a total of 7 points. The number of points a participant received would indicate their knowledge score. It was one of the intention of the pilot to find participants' knowledge scores and cross reference these to their actual knowledge using semi-structured interview, unfortunately no interviews could be conducted during the study, so there was no solid-way of judging where the cut-off point that distinguished highly knowledgeable participants from less knowledgeable participants lay. As it stands the average knowledge score obtained by the participants was a 5.65/7, which is quite high. Unfortunately, we cannot with confidence say whether this high score can be attributed to the high knowledge of the participants or the relative simpleness of the questions. Once again, not giving any clear evidence answers as to whether any participation bias was present.

Discussion

The research aim of this project was to analyse teachers' perceptions of the educational value of virtual reality in science education. The first primary research question devised to investigate this research aim was focused on finding the average Dutch secondary school science teacher's attitude toward virtual reality. This question can be most definitively answered using the data obtained from the statements regarding attitude toward virtual reality, which were the first half of the second section. The data can best be summarised as showing a positive, yet hesitant, inclination. The average participant was ever so slightly positively inclined toward the professional use of educational virtual reality with a score of 3.82, which was just barely above the indifference point. When asked how they would expect their students to react to it, however, there was a more resounding positivity with a score of 4.72, which was shown to be statistically significantly higher. Thus, despite seeing the allure of educational virtual reality from a student's stand-point the average Dutch secondary school teacher remains hesitant about implementing it. It would be an interesting follow-up research to see where this disparity arises. What are the average Dutch secondary school science teachers' concerns regarding the implementation of educational virtual reality?

The second primary research question focused on how and when Dutch secondary school science teachers would use virtual reality in their teaching. This question is best answered using the whole sample data received in the second part of the second section of the questionnaire and the final open question, which focussed on the potential use of educational virtual reality by the participants'. The data showed that the average participant was relatively positive (4.68) that there was a place in their curriculum in which they would implement educational virtual reality. The average participant was significantly more interested in using educational virtual reality in a whole-classroom context than in a one-on-one mentoring context. They were positive toward using educational virtual reality as both an interactive activity and as a novel means of presenting information. They were significantly more interested in using educational virtual reality with younger students (onderbouw) than with older ones (bovenbouw). This data gives a broad indication of where educational virtual reality could be implemented, however, it is not as conclusive as it appears. For example, one-on-one mentoring contexts were significantly higher rated by VMBO teachers than by HAVO/VWO/Gymnasium teachers. As such, a niche for one-on-one educational virtual reality most likely still exists. It must also be noted that the HAVO/VWO/Gymnasium group had a significantly higher representation in the whole-sample which may have skewed the whole sample data in their favour. All in all, it is highly recommended to look at the individual results presented in the previous section when looking to implement educational virtual reality in the Netherlands, because it provides a more nuanced picture of the situation. The participants also answered in which curriculum topics they could envision themselves using educational virtual reality. Since the answers were given in an open format this question was somewhat difficult to get a conclusive and objective answer to, nonetheless, the largest demand in biology appeared to be for the topics: organism-level metabolism, cell-level metabolism and all three topics regarding ecology (regulation, self-organisation and interactions of). The largest demand in chemistry was for the topic of molecules with a particular focus on aiding the visualisation of the infinitesimal structures of molecules and even atoms. Within physics the most demand was found for the topics of electromagnetic radiation, gravity and force and movement.

The results found for the primary research questions are intriguing, yet they are far too general for any future educational virtual reality innovations to be based upon, in an attempt to alleviate this, several secondary questions were also posed. The first of these inquired whether there were any differences in opinion amongst participants of different teaching subjects. The participants were separated into three groups: biology, chemistry & physics, and mathematics. On the whole the biology teachers were consistently the most enthusiastic group and maths teachers were consistently the lowest scoring. Yet, the only statistically significant difference found showed that biology teachers were more interested in using educational virtual reality as novel means of presenting information (e.g. a 360 degree video) than chemistry & physics and mathematics teachers. It is interesting to note that they were also the only group that rated educational virtual reality as a means of presenting information higher than using it as an interactive activity. These results, mirroring the fact that the biology topics were most often mentioned in the second primary questions, again show that the biology curriculum is the most appealing for future educational virtual reality innovation.

The second secondary question focused on the difference of opinion between teachers of the traditionally more theoretical curricula of Gymnasium, VWO and HAVO and the more pratical curriculum taught at the VMBO. On the whole the VMBO teachers were consistently more enthusiastic throughout the various categories tested. Statistically significant differences were found in the categories of using educational virtual reality in a one-on-one mentoring context, using it as a novel means of presenting information and also almost in using it as an interactive activity. These results clearly show the VMBO curriculum to be more appealing for implementation of virtual reality, since its teachers are far more enthusiastic and receptive.

The final secondary question looked into any further factors that may play a role in the implementation of educational virtual reality. The first factor explored was the participants’ gender. There were no statistically significant differences found for this category. The only truly noteworthy difference was the fact that male participants were more inclined toward interactive activities, where female teachers were more enthusiastic about using virtual reality as a novel means of presenting information instead. However, the differences are small and since this is a difficult factor to take into account when actually implementing the technology anyways, it is of the researcher’s opinion that this does not warrant further research, especially with the other factors being more significant and pressing.

The final factor explored was that of the participants’ years of teaching experience. The results around this factor showed a trend throughout the categories with the two least experienced groups (1-9 years and 10-14 years) being the consistently most enthusiastic groups, with only two minimal exceptions. Unfortunately, there were only three statistically significant differences found, and two of those, interest in virtual reality during private time and frequency of use, do not provide a great amount of insight for future implementation to be based upon. The other statistically significant difference showed that participants with 10-14 years of teaching experience were more interested in using educational virtual reality with older students that participants with 15-19 years of teaching experience. This again does not give any hard evidence to be worked with. These results suggest that future innovators would do best to adjust and market their educational virtual reality products to newer teachers. It appears that those teachers that are still new to their field are most receptive toward the technology. The results, however, are not absolute and this factor most certainly requires and deserves further investigation.

Difficulties

There were several aspects of the project which proved difficult, they will be mentioned and briefly discussed here to aid future investigation and to put the currently attained results into context. The first of these difficulties was a part of the fundamental design of the questionnaire. Since this was a baseline study, and a first of its kind, it was difficult to predict what sort of responses would be attained. For this reason the questions were posed in such a way that a wide range of answers, ranging from very negative to very positive could be given. However, to prevent participant exhaustion during the filling out of the questionnaire, it was opted to not make the Likert scale too extensive, leading to the 6-point scale used in the final design. This appeared to be a wise decision as the completion rate was high, however since the vast majority of all answers given were on the positive side of the indifference point, the participants only had 3 points to work with to nuance their answers. It is very possible that given more points to work with, the differences between groups may have become more pronounced and more statistically significant answers could have been attained. This could have been achieved by using a skewed 6/7-point Likert scale, where there are only 2 negative options and 4/5 positive options, had the researcher known what to expect beforehand. This is something that must most certainly be taken into consideration in similar research in the future.

The second difficulty is that of participation bias. The eventuality of this was given plenty of consideration during the planning stages of the questionnaire, unfortunately the measures put into place to check for it proved insufficient. The primary reason for this was because there was nothing to compare the attained data to. Conducting interviews may have helped to nuance the gathered data somewhat, but since this study is a first of its kind, the fact that we cannot determine participation bias is logical in hindsight. That said, this study forms a baseline for future studies. If in future studies the same questions and set-up are used to check for participation bias than the results obtained in this study may function as a comparison. With retroactive function those future studies may then also place this study into a context, thus perhaps shedding some insight into whether or not participation bias had occurred in this study or not. As for now, it remains unclear and therefore damages the validity of the obtained results.

The final large difficulty was the classifying of participants' answers about potential topics in which they would use virtual reality into curriculum topics. In the end the answers were classified based on the VWO curriculum because the researcher was most familiar with it and it enveloped all answers given. Nonetheless, this did some injustice to the answers given as in some cases the fit into the curriculum was not quite perfect. In some cases, nuance was also lost, for example the most mentioned topic, organism-level metabolism, is extremely broad and the vast majority of answers were focused on animals, whilst the curriculum topic itself does not distinguish between animals and plants. As such, when looking at the results obtained it is possible to interpret a large interest in plant biology, when in fact this was not present. The initial intent of leaving this question open was to give participants an opportunity to add nuance to their answers, it is therefore a shame that the method of analysis once more removed this nuance. It must be noted that most participants gave their answers in the format of a particular lesson or a specific topic which was only a small portion of the overarching curriculum domain. For this reason, it may be beneficial in future research to also rate these answers in the context of such smaller, but more specific topics, both because it does the answers more justice and because it may be of more benefit to those using the attained results. If this is to be done, however, clearly defined categories will need to be set up ahead of time, perhaps based on a pilot. In this research this was not done ahead of time and therefore to avoid posterior subjectivity in defining the categories this approach was not carried out.

Further research

The most immediate requirement for further research is interviews. The current results give indications and general ideas of what the teaching populace want and expect of educational virtual reality but more specific information will be required for actual virtual reality modules to be based upon. Using the results obtained in this study the interviews could be focussed on groups showing enthusiasm for educational virtual reality, such as new biology teachers.

It would also be very beneficial to begin testing with preliminary virtual reality modules in classroom contexts. It is one thing to investigate teacher expectations and another entirely to see if those expectations can be met and to see actual teacher reactions. Modules can also be made to accommodate the most enthusiastic teachers, as amongst them researchers may be most likely to find willing participants. This form of research would also give answer to the fundamental question delineated in the theoretical background, whether the vast potential of educational virtual reality can become reality.

References

Barab, S.A., Sadler, T.D., Heiselt, C., Hickey, D., & Zuiker, S. (2007). Relating narrative, inquiry, and inscriptions: Supporting consequential play. *Journal of Science Education and Technology, 16, 59-82.*

Baylor, A.L., & Ritchie, D. (2002). What factors facilitate teacher skill, teacher morale, and perceived student learning in technology-using classrooms? *Computers & Education, 39, 395-414.*

Black, P., & Atkin, J.M. (Eds.) (1996). Teachers and change. In P. Black & J.M. Atkin (Eds.) *Changing the subject: Innovations in science, mathematics and technology education* (ch. 5; fragment:pp. 144-149). London: Routledge.

Blau, I., & Peled, Y. (2012). Teachers' openness to change and attitude towards ICT: Comparison of laptop per teacher and laptop per students programs. *Interdisciplinary Journal of E-Learning and Learning Objects, 8, 73-82.*

Brace, I. (2018). *Questionnaire design: How to plan, structure and write survey material for effective market research.* London, United Kingdom: Kogan Page Limited.

Brown, J.S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher, 18, 32-42.*

Coelho, P.S., & Esteves, S.P. (2007). The choice between a five-point and a ten-point scale in the framework of customer satisfaction measurement. *International Journal of Market Research, 49, 313-339.*

Coleman, S.K., Smith, C.L., & Ferrier, C. (2018). Using virtual reality laboratories to improve engagement and understanding for wet laboratory practical sessions. In: *Society for Experimental Biology: Masters of Biology*, 03-06 July 2018, Florence, Italy.

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science, 323, 66-69.*

Hall, G.E., George, A.A., & Rutherford, W.L. (1977). Measuring stages of concern about the innovation. *Austin, Texas: University of Texas.*

Hargreaves, A. (2005). Educational change takes ages: Life, career and generational factors in teachers' emotional responses to educational change. *Teaching and teacher education, 21, 967-983.*

Klassen, R.M., & Chiu, M. M. (2010). Effect on teachers' self-efficacy and job satisfaction: teacher gender, years of experience, and job stress. *Journal of Educational Psychology, 102, 741-756.*

Mestre, J. (2002). Transfer of learning: Issues and research agenda. *Arlington, Virginia: National Science Foundation.*

Minocha, S., Tilling, S., & Tudor, A.D. (2018). Role of virtual reality in geography and science fieldwork education. In: *Knowledge exchange seminar series, learning from new technology*, 25 April 2018, Belfast, Northern Ireland.

Rodrigues, J. (2018). Roger williams university partners with google and labster to launch virtual reality science labs. *Featured News Story, 211.*

Saris, W.E., & Gallhofer, I.N. (2014). *Design, Evaluation, and Analysis of Questionnaires for Survey Research.* Hoboken, New Jersey: John Wiley & Sons, Inc.

Schott, C, & Marshall, S. (2018). Virtual reality and situated experiential education: A conceptualization and exploratory trial. *Journal of Computer Assisted Learning, 34, 843-852.*

Tourangeau, R., Rips, L.J., & Rasinski, K. (2000). *The psychology of Survey Response.* Cambridge, United Kingdom: Cambridge University Press.

van den Akker, J. (1998). The science curriculum: Between ideals and outcomes. In B.J. Fraser & K.G. Tobin (Eds.). *International handbook of science education* (pp. 421-447). Dordrecht: Kluwer.

Appendix

Appendix A: Questionnaire

Virtual reality questionnaire

Welkom!

Bedankt voor het meedoen aan deze questionnaire! Middels deze questionnaire willen wij in kaart brengen wat de gemiddelde Nederlandse wetenschapsdocent van virtual reality vindt en er over weet. Wij gaan u daarom ook geen concrete definitie van virtual reality geven, en verzoeken u deze ook niet op te zoeken. Wij leren veel meer als u de vragen beantwoord vanuit uw eigen conceptie van virtual reality.

Wij willen ook graag uw eerste reactie ontvangen bij de meeste van onze vragen, daarom verzoeken wij u om niet te lang na te denken bij ieder van de vragen. Vooral wanneer u aan moet geven in hoe verre u het eens bent met een uitspraak, kunt u dit snel invullen. Dit zorgt er voor dat wij mooie data ontvangen, en nog belangrijker, dat deze questionnaire niet veel van uw tijd in beslag zal nemen!

Bedankt voor uw participatie!

Deel 1: Informatie over de deelnemer

In deel 1 van deze questionnaire willen wij graag wat informatie over u vergaren. In het kader van de nieuwe privacy wetgeving zijn al deze vragen optioneel, hoewel wij u wel sterk verzoeken om ze in te vullen omdat deze essentieel zijn voor onze secundaire onderzoeksdoelen. Alle informatie die u opgeeft zal anoniem behandeld worden en nergens buiten dit onderzoek gedeeld worden.

Dit onderdeel bestaat uit een aantal korte vragen die u vrij in kunt vullen, een paar meerkeuze vragen en 10 uitspraken waar u aan moet geven of u het er mee eens of oneens bent. Aan het eind vind u één open vraag die u mag invullen indien u het gevoel heeft dat u meer toe heeft te voegen dan wat al behandeld is. U mag er ook voor kiezen deze laatste vraag over te slaan.

---

1. Hoe oud bent u?

2. Wat is uw geslacht?

3. In welk(e) vak(ken) geeft u les?

4. Op welk(e) niveau(s) geeft u les? (b.v. Gymnasium, VWO, HAVO,…)

5. Hoeveel jaar geeft u al les op middelbare school?

6. Welke opleiding tot docentschap heeft u gevolgd?

7. Geef bij de volgende uitspraken aan in hoeverre u het er mee eens of oneens bent.

Uitspraken	**6 – punt Likert schaal**					
	Sterk mee oneens	Mee oneens	Een beetje mee oneens	Een beetje mee eens	Mee eens	Sterk mee eens
1. Ik communiceer graag online met familie en vrienden						
2. Ik geloof dat het internet communicatie tussen mij en mijn collegas stimuleert						
3. Ik vind informatie gevonden op het internet onbetrouwbaar.						
4. Ik vind het fijn om online te kunnen communiceren met mijn collegas						
5. Ik vind het spannend dat jongeren tegenwoordig zo veel van hun informatie via het internet krijgen						
6. Ik gebruik het internet graag om informatie voor mijn lessen te vinden						
7. Ik gebruik het internet graag gedurende mijn vrije tijd						
8. Ik vind e-mailen met mijn collegas onhandig						
9. Ik raad mijn leerlingen aan om ook online informatie te vergaren						
10. Ik geloof dat ik op het internet de meest geactualiseerde informatie kan vinden voor mijn lessen						

Ervaring met educatieve ICT

In deze questionnaire wordt met het concept van educatieve ICT alles bedoeld waarbij technologie gebruikt wordt om op een interactieve manier les te geven. In dit geval moet de ICT dus een centrale functie in de les activiteit hebben, b.v. een online quiz, een interactieve webpagina, enz... Als ICT alleen gebruikt wordt als ondersteuning of 'tool', dan telt het niet mee. Voorbeelden hiervan zijn: een ondersteunende powerpoint presentatie of een filmpje.
Om het simpeler te maken: Als de activiteit net zo gemakkelijk uitgevoerd had kunnen worden zonder ICT, dan telt het niet mee.

8. Hoe vaak maakt u gebruik van educatieve ICT in uw lessen?

Antwoord	Mogelijke uitspraken bij antwoord
Nooit	-Ik heb een voorkeur voor les geven zonder ICT, en bouw mijn lessen altijd zo op dat ICT niet nodig is.
Zelden	-Ik geef het liefst les zonder ICT, maar gebruik het wel af en toe als ik het het meest geschikt vind voor een bepaald onderwerp.
Soms	-Ik gebruik educatieve ICT wanneer ik het goed vind passen bij een onderwerp, maar doe het net zo graag zonder als ik dit meer geschikt vind.
Vaak	-Educatieve ICT is mijn voorkeurs werkwijze, maar ik geef af en toe ook les zonder ICT wanneer ik dit meer geschikt vind.
Elke les	-Educatieve ICT is mijn voorkeurs werkwijze, en probeer in elke les een ICT activiteit te verwerken.

9. Hoe vaak bent u persoonlijk in aanraking met virtual reality gekomen? Zowel in uw persoonlijk als professioneel leven.

Antwoord	Mogelijke uitspraken bij antwoord
Nooit	-Ik heb nog geen enkele ervaring met virtual reality.
Eénmaal	-Ik heb virtual reality wel eens meegemaakt, maar dat was één enkele keer.
Meerdere keren	-Ik heb in meerdere geïsoleerde gevallen virtual reality mogen ervaren.
Regelmatig	-Ik mag regelmatig gebruik maken van virtual reality.
Vaak	-Ik bezit zelf een virtual reality bril en gebruik het graag in mijn vrije tijd.

10. Hoe vaak hoort u over virtual reality? Zowel in uw persoonlijk als professioneel leven.

Antwoord	Mogelijke uitspraken bij antwoord
Nooit	-Ik heb nog nooit van virtual reality gehoord.
Zelden	-Ik heb een aantal keer over virtual reality gelezen/gehoord, maar ben er niet in geïnteresseerd.
Soms	-Ik heb kennissen/collegas die virtual reality gebruiken en hier over spreken. -Ik lees af en toe over virtual reality in het nieuws of op het internet wanneer dit mij aangeraden wordt.
Regelmatig	-Ik lees graag nieuws over virtual reality wanneer ik dit zie en praat er graag over met kennissen/collegas.
Vaak	-Ik volg actief de nieuwe ontwikkelingen binnen virtual reality en zoek zelf naar nieuwe information. -Ik kaart graag het onderwerp van virtual reality aan met kennissen/collegas.

Heeft u nog meer informatie die u ergens aan toe wilt voegen? Mogelijk voor extra duidelijkheid of nuance. Dat mag hier:

Deel 2: Houding tegenover virtual reality

In deel 2 van dit questionnaire willen wij graag uw denkbeeld van virtual reality in kaart brengen. Dit willen wij doen middels een aantal uitspraken, waarbij u mag aangeven of u het er mee eens of oneens bent. U kunt ook de mate van uw mening aangeven, aan de hand van drie verschillende niveaus. Sommige uitspraken betreffen misschien onderwerpen waar u nog nooit eerder bij hebt stil gestaan, in dit geval: denk er niet te veel over na en vul uw eerste gedachten in.
Aan het eind vind u nogmaals één open vraag die u mag invullen indien u het gevoel heeft dat u meer toe te voegen heeft.

1. Geef bij de volgende uitspraken aan in hoe verre U het er mee eens of oneens bent.

Uitspraken	**6 – punt Likert schaal**					
	Sterk mee oneens	Mee oneens	Een beetje mee oneens	Een beetje mee eens	Mee eens	Sterk mee eens
1. Ik wil educatieve virtual reality in mijn klas uitproberen						
2. Educatieve virtual reality leidt leerlingen vast alleen af van de daadwerkelijke stof						
3. Ik denk dat virtual reality mijn huidige curriculum zou kunnen versterken						
4. Ik heb zelf geen behoefte aan het ervaren van virtual reality						
5. Educatieve virtual reality is een innovatie voor de toekomst, maar in het huidige stadium nog niet behulpzaam						
6. Ik zou graag virtual reality willen gebruiken in mijn vrije tijd						
7. Ik denk dat mijn leerlingen educatieve virtual reality erg leuk zouden vinden						
8. Ik vertrouw virtual reality nog niet tot er meer onderzoek naar gedaan is						

9. Ik zou graag een cursus volgen over educatieve virtual reality, zelfs als dit buiten school uren moet						
10. Ik geloof niet dat virtual reality de moeite waard is om te gebruiken gedurende mijn les						

2. Geef bij de volgende uitspraken aan in hoe verre U het er mee eens of oneens bent.

Uitspraken	6 – punt Likert schaal					
	Sterk mee oneens	Mee oneens	Een beetje mee oneens	Een beetje mee eens	Mee eens	Sterk mee eens
1. Virtual reality lijkt mij handig tijdens één-op-één bijlessen						
2. Virtual reality zou leerlingen kunnen helpen om bepaalde concepten binnen mijn vakgebied beter te visualiseren						
3. Ik vermijd liever het werken met allemaal headsets als ik geloof hetzelfde effect te kunnen bereiken met eenvoudigere methoden						
4. Ik zou liever geen virtual reality gebruiken met jongere leerlingen						
5. Als het kon, zou ik educatieve virtual reality iedere keer gebruiken wanneer het goed uitkomt met onderwerp en activiteit						
6. Ik kan een onderwerp binnen mijn curriculum bedenken waarbij virtual reality van pas zou kunnen zijn						
7. Het lijkt mij lastig om educatieve virtual reality te gebruiken met een grote klas leerlingen						
8. Ik zou virtual reality gebruiken met oudere leerlingen						

9. Ik zou virtual reality gebruiken om leerlingen interactieve ervaringen te geven (b.v. virtueel school reisje, virtueel experiment)						
10. Ik heb geen onderwerp in mijn curriculum waar virtual reality van toegevoegde waarde zou kunnen zijn op huidige methoden						
11. Ik geloof dat virtual reality gebruikt kan worden om een grote klas leerlingen te activeren						
12. Ik zou virtual reality gebruiken om informatie over te brengen aan leerlingen (b.v. 360^0 filmpjes op een headset)						
13. Ik zou waarschijnlijk nooit gebruik maken van educatieve virtual reality ook al had ik het tot mijn beschikking						

3. Bij welke onderwerpen binnen uw curriculum zou educatieve virtual reality van pas kunnen komen bij het lesgeven? U mag zo veel onderwerpen opschrijven als u kunt bedenken. Indien u geen antwoord heeft dan mag u een ‘-‘ invullen.

Heeft u nog meer informatie die u ergens aan toe wilt voegen? Mogelijk voor extra duidelijkheid of nuance. Dat mag hier:

Deel 3: Kennis van virtual reality

In dit laatste deel van de questionnaire willen wij onderzoeken hoeveel u van virtual reality weet. Wij leren het meeste van uw oprechte antwoord, en verzoeken u dus ook vriendelijk om niet het juiste antwoord op te zoeken op het internet, maar gewoon uw best te doen. Er is dus in principe één juist antwoord maar geen enkel fout antwoord. Alvast bedankt voor het invullen van deze questionnaire.

---

1. Hoe zou u uw eigen kennis omtrent virtual reality inschatten vergeleken met andere Nederlandse docenten?
   - 1 - Onderste 10%
   - 2 - Onder gemiddeld
   - 3 - Gemiddeld
   - 4 - Boven gemiddeld
   - 5 - Bovenste 10%

2. Is 360^0 video een vorm van virtual reality?
   - Ja, want met een headset op het hoofd kan de leerling dan vrij rond kijken.
   - Nee, want er kan niet geïnteracteerd worden met de virtuele wereld.

3. Is het mogelijk om met meerdere mensen tegelijkertijd in dezelfde virtuele wereld te zijn?
   - Ja
   - Nee

4. Virtual reality en augmented reality zijn beiden termen voor hetzelfde concept.
   - Goed
   - Fout

5. Welk Engels woord wordt voornamelijk gebruikt om de totale onderdompeling in een alternatieve realiteit te beschrijven?
   - Engagement
   - Involvement
   - Occupation
   - Immersion

6. Is het mogelijk om virtual reality te ervaren met een smartphone?
   - Ja, met een kartonnen headset en simpele controllers kan je het scherm van een smartphone benutten om virtual reality te ervaren
   - Nee, de hardware van een smartphone is niet krachtig genoeg om virtual reality uit te voeren.

7. Virtual reality wordt al ingezet in andere industrieën buiten videospellen.

- Goed
- Fout

8. Kan virtual reality leerlingen laten experimenteren met natuurwetten die in de normale realiteit onveranderbaar zijn?

- Nee, als er met natuurwetten gespeeld wordt gaat de leerling een gevoel van misselijkheid ervaren doordat de hersenen de signalen niet goed kunnen interpreteren.
- Ja, in de computer gesimuleerde wereld is alles mogelijk.

Appendix B: Curriculum topics for virtual reality scores

Vak	Domein	Subdomein	Aantal keer vermeld
Biologie	A - Vaardigheden	-	5
	B - Zelfregulatie	B1 - Eiwitsynthese	5
		B2 - Stofwisseling van de cel	16
		B3 - Stofwisseling van het organisme	33
		B4 - Zelfregulatie van het organisme	13
		B5 -Afweer van het organisme	15
		B6 - Beweging van het organisme	13
		B7 - Waarneming door het organisme	13
		B8 - Regulatie van ecosystemen	16
	C - Zelforganisatie	C1 - Zelforganisatie van cellen	14
		C2 - Zelforganisatie van het organisme	10
		C3 - Zelforganisatie van ecosystemen	16
	D - Interactie	D1 - Moleculaire interactie	1
		D2 - Cellulaire interactie	1
		D3 - Gedrag en interactie	4
		D4 - Seksualiteit	
		D5 - Interactie in ecosystemen	16
	E - Reproductie	E1 - DNA-replicatie	7
		E2 - Levenscyclus van de cel	5
		E3 - Reproductie van het organisme	5
	F - Evolutie	F1 - Selectie	7

Vak	Domein	Subdomein	Aantal keer vermeld
		F2 - Soortvorming	6
		F3 - Biodiversiteit	6
		F4 - Ontstaan van het leven	6
Scheikunde	A - Vaardigheden	-	8
	B - Stoffen en materialen in de chemie	B1 - Deeltjesmodellen	14
		B2 - Eigenschappen en modellen	
		B3 - Bindingen en eigenschappen	8
		B4 - Bindingen, structuren en eigenschappen	7
	C - Chemische processen en behoudswetten	C1 - Chemische processen	5
		C2 - Chemisch rekenen	4
		C3 - Behoudswetten en kringlopen	
		C4 - Reactie kinetiek	5
		C5 - Chemisch evenwicht	4
		C6 - Energieberekeningen	
		C7 - Classificatie en reacties	
		C8 - Technologische aspecten	
		C9 - Kwaliteit van energie	
		C10 - Activeringsenergie	
	D - Ontwikkelen van chemische kennis	D1 - Chemische vakmethodes	
		D2 -Veiligheid	
		D3 - Chemische synthese	2
		D4 - Molecular modelling	
	E - Innovatie en chemisch onderzoek	E1 - Chemisch onderzoek	

Vak	Domein	Subdomein	Aantal keer vermeld
		E2 - Selectiviteit en specificiteit	2
		E3 - Duurzaamheid	
		E4 - Nieuwe materialen	
		E5 - Onderzoek en ontwerp	
	F - Industriële chemische processen	F1 - Industriële processen	3
		F2 - Groene chemie	2
		F3 - Energieomzettingen	2
		F4 - Risico en veiligheid	1
		F5 - Duurzamen productieprocessen	1
	G - Maatschappij, chemie en technologie	G1 - Chemie van het leven	1
		G2 - Milieueffectreportage	
		G3 - Energie en industrie	
		G4 - Milieueisen	
		G5 - Bedrijfsprocessen	
Natuurkunde	A - Vaardigheden	-	5
	B - Golven	B1 - Informatieoverdracht	8
		B2 - Medische beeldvorming	4
	C - Beweging en wisselwerking	C1 - Kracht en beweging	9
		C2 - Energie en wisselwerking	3
		C3 - Gravitatie	11
	D - Lading en veld	D1 - Elektrische systemen	7
		D2 - Elektrische en magnetische velden	7
	E - Straling en materie	E1 - Eigenschappen van stoffen en materialen	4
		E2 - Elektromagnetische straling en materie	13

Vak	Domein	Subdomein	Aantal keer vermeld
		E3 - Kern- en deeltjesprocessen	5
	F - Quantumwereld en relativiteit	F1 - Quantumwereld	5
		F2 - Relativiteitstheorie	4
	G - Leven en aarde	G1 - Biofysica	
		G2 - Geofysica	
	H - Natuurwetten en modellen	-	1
	I - Onderzoek en ontwerp	I1 - Experiment	
		I2 - Modelstudie	
		I3 - Ontwerp	
Wiskunde A	A - Vaardigheden	A1 - Algemene vaardigheden	
		A2 - Profielspecifieke vaardigheden	
		A3 - Wiskundige vaardigheden	
	B - Algebra en tellen	B1 - Algebra	
		B2 - Telproblemen	
	C - Verbanden	C1 - Standaardfuncties	
		C2 - Functies, grafieken, vergelijkingen en ongelijkheden	2
	D - Verandering	D1 - Rijen	
		D2 - Helling	
		D3 - Afgeleide	
	E - Statistiek en kansrekening	E1 - Probleemstelling en onderzoeksontwerp	
		E2 - Visualisatie van data	
		E3 - Kwantificering	
		E4 - Kansbegrip	
		E5 - Kansverdelingen	
		E6 - Verklarende statistiek	
		E7 - Statistiek met ICT	

Vak	Domein	Subdomein	Aantal keer vermeld
	F - Keuzeonderwerpen	-	
Wiskunde B	A - Vaardigheden	A1 - Algemene vaardigheden	
		A2 - Profielspecifieke vaardigheden	
		A3 - Wiskundige vaardigheden	
	B - Functies, grafieken en vergelijkingen	B1 - Formules en functies	2
		B2 - Standaardfuncties	
		B3 - Functies en grafieken	2
		B4 - Inverse functies	
		B5 - Vergelijkingen en ongelijkheden	
		B6 - Asymptoten en limietgedrag van functies	
	C - Diferentiaal- en integraalrekening	C1 - Afgeleide functies	
		C2 - Technieken voor differentiëren	
		C3 - Integraalrekening	
	D - Goniometrische functies	-	
	E - Meetkunde met coördinaten	E1 - Meetkundige vaardigheden	
		E2 - Algebraïsche methode in de vlakke meetkunde	
		E3 - Vectoren en inproduct	2
		E4 - Toepassingen	1
	F - Keuzeonderwerpen		