

Challenges and Prospects of Virtual Reality and Augmented Reality Utilization among Primary School Teachers: A Developing Country Perspective

ABSTRACT

The concepts of virtualization for facilitating learning have become the focus of attention in several countries. Yet, the limited understanding of how technologies such as augmented reality (AR) and virtual reality (VR) can be used to improve the learning and teaching of science makes it difficult for educational policy makers to apply additional measures in order to ensure the availability of equipment and trained staff. A semi-structured interview was used to gather data from primary school teachers about the challenges and prospects of utilizing VR and AR technologies in teaching science subjects. A set of evidence and recommendations on AR and VR utilization for teaching science were provided based on an interview of 29 science teachers. It was determined that lack of competency, limited instructional design, lack of focused attention, lack of time, and limited environmental resources were common challenges in VR and AR utilization. In addition, we found that both technologies can be used to promote exploratory behavior and perceived usefulness and develop a positive attitude. Other findings related to these aspects were identified and described. The outcomes from this study can provide insights for administrators and policy makers to set priorities for using VR and AR in school practice to carry out various reflective and exploration tasks.

Keywords: virtual reality, augmented reality, teacher development, hypermedia in education, technology utilization

1. Introduction

The current utilization of immersive technologies in the education sector has proven to provide an effective utility for promoting the learning of various subjects (Al-Samarraie & Saeed, 2018). Virtual reality (VR) and augmented reality (AR) are examples that clearly illustrate the utilization of these new technologies, which provide opportunities to promote lifelong learning (Gün & Atasoy, 2017; Ozdemir, Sahin, Arcagok, & Demir, 2018). VR is defined as a real or simulated environment in which a perceiver experiences telepresence (Minocha, Tudor, & Tilling, 2017), while AR is defined as a technology that superimposes a computer-generated image on an individual's view of the surrounding environment (McMillan, Flood, & Glaeser, 2017). The review of the literature shows that VR and AR support constructivist learning principles (Bani-Salameh, Al-Gharaibeh, Jeffery, & Al-Sharif, 2017; Huang, Rauch, & Liaw, 2010; Katz & Halpern, 2015); hence, learners that utilize VR and AR would be equipped with the capability to process and control various learning related activities. They have ultimate control over where and when to explore learning. For instance, students can control the pace of their movement in a VR environment. They can communicate with friends through a network and determine the next action to be performed after the communication (Fowler, 2015; Ha & Fang, 2018). In AR, students can easily visualize virtual objects, which makes learning more interesting and more realistic than any other technology (Vosinakis, Anastassakis, & Koutsabasis, 2018; Zhu, Sun, & Luo, 2018).

In addition, learners may overlay virtual electromagnetism content on actual book pages using a handheld device (Wu, Hwang, Yang, & Chen, 2018; Al-Samarraie & Ahmad, 2016) or utilize an AR game that uses tangible cubes to enable learners to learn about different animals that are at the risk of extinction (Daineko, Dmitriyev, & Ipalakova, 2017). Despite these, there is still a notable lack of research into understanding the perceptions of teachers towards VR and AR in school teaching and learning. This, as a result, makes it difficult for decision makers and teachers to judge the suitability of each technology, particularly in the

context of science education. In most developing countries, VR and AR are new to primary school teachers, even though this is not the case for developed countries.

It is believed that exposing students to computer-simulated environments may make science learning effective (Chen, Huang, & Chou, 2017). This is because combining actual and virtual environments would result in mixed reality, which would provide learners with a wide variety of exploration options (Correia, Fonseca, Paredes, Martins, & Morgado, 2016). Several school teachers have been criticized about being less concerned or slower to recognize the potential of using VR and AR (Ab Aziz, Ab Aziz, Yusof, & Paul, 2012). In addition, the lack of evidence about the cause of delay in the utilization of VR and AR in science education makes it difficult to assess the prospects of these applications in current teaching practices. Therefore, this study is aimed at providing insights about the current challenges and prospects of VR and AR utilization among school teachers for the purpose of teaching science subjects. It is assumed that identifying the key factors slowing down the utilization of these technologies would aid educational decision makers to identify organizational and individual factors associated with the utilization these technologies, and shape strategies for delivering effective teaching and learning experiences of science subjects.

2. Rationale of the study

In Year 1, science is introduced with simple hands-on, minds-on, and hearts-on classroom activities. The number and complexity of these activities increases substantially based on the cognitive demand as stipulated in the syllabuses. At Years 5 and 6, the teaching and learning of science in the primary classroom depends very much on note-copying and drilling in preparation for the National Standardized “Primary School Evaluation Test” or its acronym UPSR (Ong, Mesman, & Yeam, 2014). Because of the limited time, the teachers take a shortcut by explaining the outcomes of science experiments verbally, rather than allowing the students conduct the experiments.

On the other hand, various initiatives for the development and improvement of science education quality (such as Smart School policies) do not always deliver the expected results when technology transfer occurs too slowly (Akçayır & Akçayır, 2017; Sumintono, 2015). Meanwhile, the decline of interest in science among students makes it difficult for the country to reach the target. Although various strategies and policies have been formulated and adapted to arrest the situation, identifying barriers responsible for the gap between technology and practice is still needed (Halim & Meerah, 2016; Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich, 2017). Reinhold, Holzberger, and Seidel (2018) stated that lack of structural school-level factors such as material resources designed for STEM subjects can potentially reduce the quality of STEM teaching, thus affecting students’ orientation about the subject. Previous research (e.g., Gopalan, 2016; Mahadzir & Phung, 2013; Mat-jizat, Osman, Yahaya, & Samsudin, 2016; Vongkulluksn, Xie, & Bowman, 2018; Weng, Bee, Yew, & Hsia, 2016) investigated the usefulness of VR and AR in different learning situations among primary school students. However, the perspective of these studies was limited to the feasibility of VR and AR applications for promoting a certain usage behavior. This led us to examine the following questions:

1. What are the challenges that hinder teachers’ utilization of VR and AR in the classroom?
2. What are the prospects of utilizing VR and AR in teaching science subjects?

It is anticipated that outcomes from this study would help decision makers in developing countries to understand the prospects of using AR and VR in teaching science. This include understanding how these technologies can be used to develop new forms of interaction and exploration to support students’ science inquiry in a seamless learning environment. It is also

hoped that the educational policy makers will take note of the challenges posed by certain environmental factors to effectively utilize AR and VR.

3. Method

Figure 1 shows the research procedure of this study. The present study data were collected through qualitative approach using interview. A semi-structured interview was used to gather data from primary school teachers about the challenges and prospects of utilizing VR and AR technologies in teaching science subjects. Ethical clearance was obtained from the review board of our university. In addition, we obtained written informed consent of the respondents prior to the interviews.

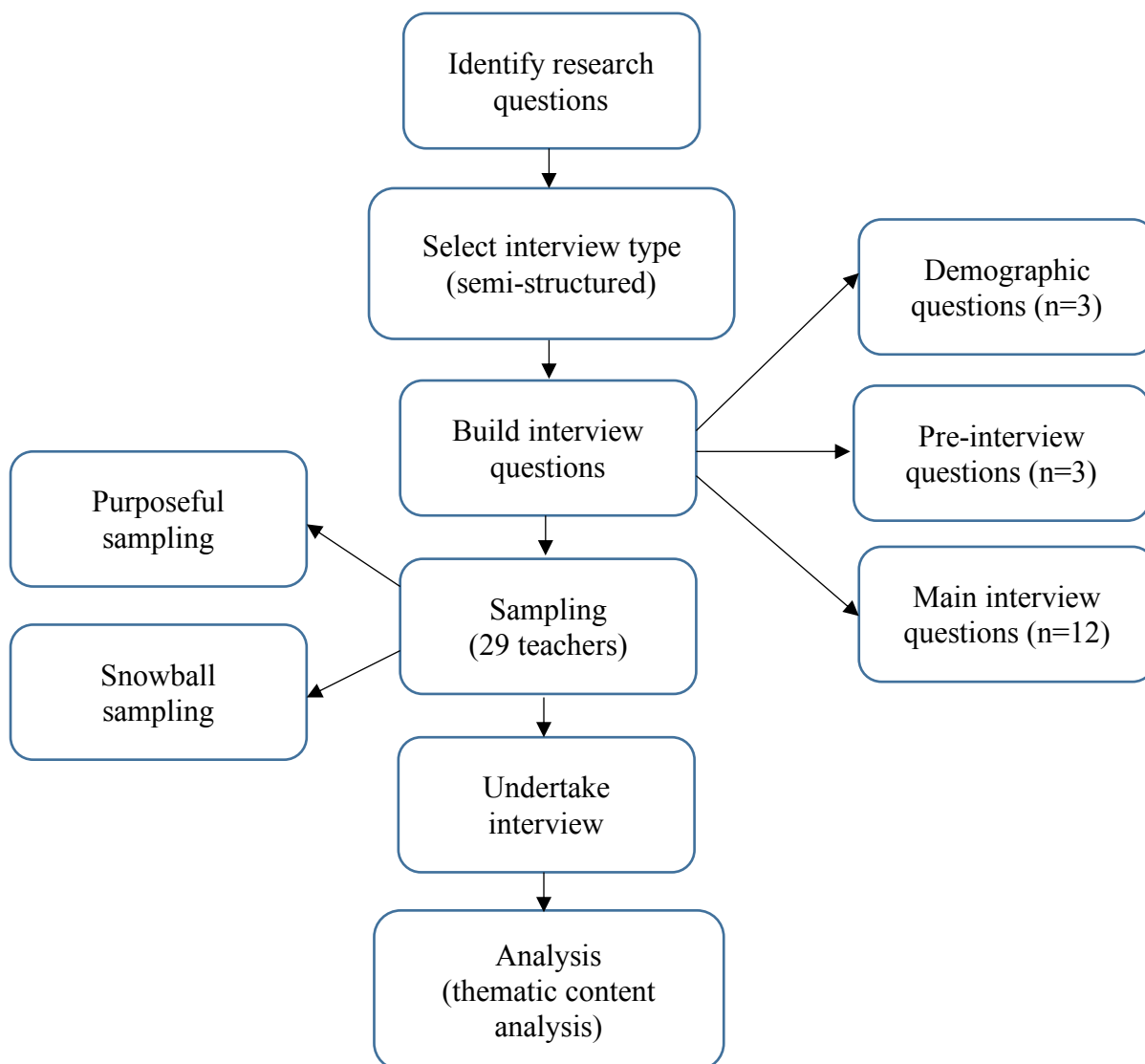


Figure 1. Research procedure

3.1 Sampling

Only science teachers from different primary schools were invited to participate in this study. In this study, we used purposeful sampling method in combination with the snowball sampling technique, as recommended by Patton (1990), in order to recruit teachers who were board-certified in science teaching. Since the sample size for conducting a qualitative study should be large enough to obtain feedback that can lead to the attainment of saturation

(Glaser & Strauss, 2017), the sample data was collected from 29 participants and analyzed until the sample had been saturated, as evidenced by repeating themes or concepts. This number of participants is considered sufficient for qualitative-based research. All the schools in this study have been using virtual learning environments for teaching science subject on limited basis, while AR has been rarely used. All the participants were familiar with VR and AR technologies with a fundamental understanding of its components, regardless of whether it was from class or personal experience. They were briefed and guided throughout the interview session. The interviews were scheduled over eight weeks.

3.2 Instrument

In this study, the semi-structured interview was used because it provides our need for communication with the teachers to a higher degree in comparison with a structured interview. In the semi-structured interview, the number of open-ended questions was more than that of closed questions. This is because closed questions may not provide in-depth understanding of the participants' thoughts or perceptions (Patton, 2005). The instrument consisted of three demographic questions (gender, age, and teaching experience) and pre-interview questions (consisting of level of level of technology use, experience with VR and AR field trips, and status of school's financial aid) to assist in understanding the association of these data to the challenges and prospects of utilizing VR and AR. This was followed by 12 semi-structured questions, which were primarily designed to focus on teachers' overall perception of VR and AR in teaching science subjects (see Appendix). These questions included different aspects related to teachers' perceptions of these technologies as assistive tools for teaching science subjects. This included the suitability of VR and handheld AR for teaching primary school students, students' preferences and their likelihood of utilizing these tools, teachers' confidence about the usefulness of these tools, and their potential for addressing certain learning difficulties. In addition, other questions focused on the key challenges that impact the use of these tools by teachers for teaching science, which included current environmental settings (e.g., location, internet connection, technical support, and hardware availability). Finally, three questions focused on the potential opportunities that VR and AR may provide for the current teaching and learning of science subjects.

3.3 Data collection procedure

We interviewed 29 school teachers to address the current challenges and prospects of VR and AR technologies for teaching science subjects. All face-to-face interviews were recorded for transcription purposes. To ensure participants' confidentiality, consent was obtained before starting the interview session. After clarifying all doubts and questions, participants were asked to describe their understanding of VR and AR. This was essential for preventing any misunderstanding about the comprehension of these technologies before further interaction. The assessment showed that all teachers were knowledgeable and familiar with VR and AR applications. A mobile device was used for recording video and voice. After each interview, the recorded files were labeled accordingly and saved in a repository. In addition, two copies were created for each file to prevent data destruction.

3.4 Data analysis procedure

In this study, the thematic content analysis was used in order to unpick and capture the emergent categories or themes from the interviews. The data analysis procedure is shown in Figure 2. The data from the interviews were typed in Word documents in the language of conversation and then translated to English using the back-translation technique. In order to ensure the validity of the English translation, all responses were translated into their original language by bilingual experts. Minor grammatical errors in the responses were corrected to

comprehend the meaning of phrases. Then, the translated responses were translated again into English and the end product was similar in syntax and meaning to the original. In addition, the face validity of the interview questions was confirmed by the authors in collaboration with three heads of schools from the selected provinces. Audible behavior, such as sounds and pauses, was not transcribed. The time allocated for transcription was based on the length of the interview. After each transcription, separate folders were created. Each folder contained a transcription in a Word document and was named in such a manner that it was linked to its corresponding subject. After all interviews were transcribed, pseudonyms were assigned to each participant. Then, every transcription was reviewed twice to obtain an overview of the message conveyed. Inductive content analysis was applied, where relevant categories were identified through careful examination and constant comparison of text (Zhang & Wildemuth, 2009). The analysis started with open coding of each pattern determined through computer software for qualitative analysis (ATLAS). Responses that were determined to be interesting and appealing were coded. Then, refined codes were categorized into broader higher order categories, where the codes to be placed in the same category were determined. Next, the consistency of the coding was rechecked by referring to the final codebook. Finally, a frequency analysis on each category was conducted and presented in a tabular form.

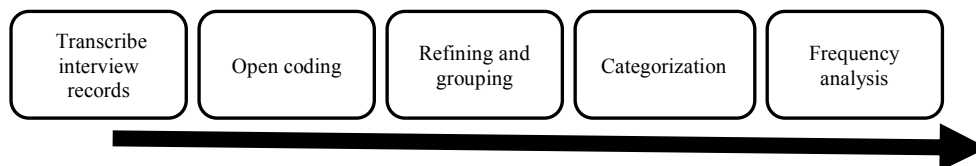


Figure 2. Data analysis procedure

4. Results

The responses from the interview transcriptions are classified into the following four primary categories: *challenges of VR* (CVR), *challenges of AR* (CAR), *prospects of VR* (PVR), and *prospects of AR* (PAR) in science education.

4.1 Demographic background

Nine male teachers and 20 female teachers participated in this study. The unbalanced ratio of male/female gender can be due to the numerical domination of female teachers in the primary school, which may give the impression that primary teaching is 'women's work' (Chan, 2011). The ages of the participants ranged between 26–38 years, and teaching experience ranged between 5–9 years. The majority of the participants declared that they often (n=16) used the technology in the classroom. In addition, 10 out of 29 participants stated that they sometimes used the technology in the classroom. Some participants (n=22) have carried out field trips on AR and VR. Table 1 provides more information about the demographic background of the participants.

Table 1: Demographic background results

| Questions | Frequency | Percentage |
|---|-----------|------------|
| Gender | | |
| <i>Male</i> | 9 | 31% |
| <i>Female</i> | 20 | 69% |
| Age | | |
| 26-29 | 5 | 17% |
| 30-33 | 11 | 38% |
| 34-38 | 13 | 45% |
| Teaching experience | | |
| 5-7 | 10 | 34% |
| 8-9 | 19 | 66% |
| Level of technology use in the classroom | | |
| <i>Never</i> | 0 | 0% |
| <i>Rarely</i> | 3 | 10% |
| <i>Sometimes</i> | 10 | 35% |
| <i>Often</i> | 16 | 55% |
| Field trips on technology-related programs. | | |
| <i>Yes</i> | 22 | 76% |
| <i>No</i> | 7 | 24% |
| Financial aid for teaching science | | |
| <i>Yes</i> | 5 | 17% |
| <i>No</i> | 24 | 83% |

4.2 Challenges of VR (CVR)

Even though the majority of teachers agreed that VR may suit the requirements of students, they went on to place conditions around its suitability. A total of 21 teachers stated that VR is suitable if it is provided to upper primary students only because lower primary students are too young to use it. As one teacher stated, this technology is for “*those students who are skillful in technology and communication and those that already know how to use a computer.*” Moreover, “*this technology can be used to assess students’ participation based on activity logs. If we provide a learning tool that suits the abilities of different students, then there should be no problem.*” Three teachers expressed that “*If the government provides VR with its environmental elements, then it should be possible to engage learners in active knowledge construction.*” Others expressed their concern over the content of the technology; for example,

In VR, students have the freedom to access anything. However, we do not want them to access unrelated topics. This made us question the extent to which VR developers have knowledge of what they design.

Five teachers concluded that VR is a tool for independent learning. Most students could not use VR properly.

The student must be a strong self-initiated learner. Otherwise, he/she will get bored easily. Suppose there is a museum in VR. I think students may not have the ability to explore it, particularly when low-achievement students use VR. For example, I found that all comments written by students in the VLE forum were irrelevant. They could not grasp the primary ideas in learning.

Authentic experience and interaction with an actual environment were the concerns raised by three science teachers. A participant expressed her opinion on the suitability of VR. She was not convinced about teaching science using this technology. According to her, the reason for this was “*the requirement to have an authentic experience to help students memorize for longer periods. If you watch something on a television and/or a digital computer gadget, there is no actual interaction.*” Another participant expressed that

The materials used to teach students in VR are similar to cartoons. Students would like to observe actual situations. Thus, if you show a virtual world, students will question its feasibility.

Eight participants expressed other concerns related to health risks for students, such as addiction to the technology. As noted, “*if our health is affected by addiction to mobile phones, students’ health is also at risk when they look at computers for a long period.*” Based on this, the majority of teachers were in favor of conventional teaching. They valued VR as a good technology; however, they would not use it for all science lessons. A participant believed that worksheets assist her students in learning correctly because she assumed that students will talk casually in a VW, which is typically not permitted by her and her colleagues. She stated that

We have to provide exercises and writing assessments. We cannot just depend on a virtual environment to teach complex concepts to our students. We require students to express. I observed that currently, students are poor at expressing. They talk to others in an informal manner. For others to accept your teaching method, it must have formal language.

The study found that time constraint was another concern that prevents teachers from using VR regularly. The majority of participants stated that they teach science two to four times a week. They were concerned that they could not finish the syllabus. This was expressed by a participant, who stated that “*with four lessons devoted to science weekly, we are concerned that we cannot finish the syllabus. Hence, maybe we can use it occasionally. We cannot use it continuously.*” In addition, other hardware and software requirements were addressed by the participants. The overall opinion was that VR required an equipped environment to be used effectively in their schools. The majority of the participants reported that the internet connections in their schools do not provide a stable bandwidth to effectively use VR. For example, only laboratories and school offices have a limited Wi-Fi connection. This is problematic when the entire class uses VR simultaneously.

It is impossible to use VR in every lesson. We have to compete with other teachers to borrow computer labs and use them in turns. The lab contains a few places for the students to use. Only certain areas have an internet connection.

4.3 Challenges of AR (CAR)

The results of the interview revealed various challenges associated with handheld AR utilization among school teachers. We found that the key challenge was the bring your own device (BYOD) policy, which is not yet implemented in all primary schools. A few participants mentioned that the policy at their schools does not allow students to bring digital devices to the school. To gain further insights, participants were asked to enrich the understanding of the primary reason for not allowing students to bring their own devices. Only 7 of the 29 teachers interviewed stated that parents could not afford mobile phones. Furthermore, “*parents and school administrators are concerned that students may lose their devices*” and “*we do not have time to secure and check students’ belongings. Personally, I want each of them to have one device.*” Another participant stated that “*if the school provides handheld phones in the lab, it enables us to use AR efficiently for learning purposes.*” Another participant narrated her experience of mobile phone utilization in the classroom.

I tried to ask the pupils to bring the gadgets to the classroom last year in one of my lessons. I received complaints from teachers and parents. I wanted to try different methods with students, allow them to try a few online quizzes, and ask them to save my blog address for future communication. Besides, I noticed that pupils failed to control themselves. I gave Y6 D three chances and I

deliberately passed by several times to observe whether students are playing with the gadgets in other lessons.

Even though most of the teachers expressed that the use of AR is suitable for primary students, a teacher opted for VR instead of AR because she expected that AR is a gimmick and it could only retain students' interest for a short period. Students may get used to it and may find it less interesting later. She predicted that *“after a while, they will know what is included. They will find it interesting at the beginning. However, in the long term, they may lose interest in it.”* Another participant supported this assumption and stated the following: *“We tested AR with our students aged between three to nine years. They were interested in it for a few days.”* On the contrary, the other participant stated that he had used it before and it generates interest among students. However, they continue their learning through textbooks because of the following:

I used AR to teach at school before. Students were interested in exploring the materials. However, subsequently, we require them to use textbooks because the learning culture here is yet to reach an individualized learning atmosphere.

The use of textbooks is a norm for the teachers, who rely on textbooks for teaching because the government provides science textbooks every year. The textbooks contain the syllabus to be covered.

Definitely, there are teachers willing to use it for developing a new method of learning science subjects. However, the majority of teachers depend on textbooks. If you ask new teachers to use AR, they will think that you are placing them under stress and trying to make them busier.

The participant further shared her experience of not using textbooks to teach. She insisted on minimizing the use of textbooks.

Last time I used EPM [software] to teach a poem. The content is the same as that in the textbook. Thus, I skipped teaching that page. The students told me that the teacher did not teach. I was considerably upset. [I said] that I already opened it for you to see. All students think that if you did not open the textbook, you did not teach them. This problem shows that in addition to teachers, students should need to transform, and parental support must be increased. I think that if AR provides a part of this, then it should be used as a supplement.

Several categories were identified from the interview data, which were used to answer the proposed research questions. The transcriptions were coded and analyzed using qualitative analysis software (ATLAS). Then, the codes were divided into subcategories to identify the categories that were common to the challenges of VR and AR (see Table 2).

Table 2
Challenges of VR and handheld AR

| VR | | |
|------|------------------------------|--|
| Code | Primary category | Description |
| CVR1 | Lack of competency | Refers to the lack of VR functionalities to ensure the competency of students. A suitable platform may not be available for accommodating the learning requirements of different students. For example, it is assumed that VR is more suitable for computer literate students, matured or self-initiated learners, and upper primary students. The majority of teachers agreed that immature students may not find it interesting. |
| CVR2 | Limited instructional design | Refers to the limited materials offered in VR, which may or may not suit the learning goals of students. For example, teachers stated that currently, VR does not provide suitable learning materials in accordance with local syllabus and context. |

The majority of teachers stated that VR provides a broad area of learning that lacks meaningful explanations and assessments.

| | | |
|------|---------------------------------|---|
| CVR3 | Lack of focused attention | Refers to the state of students when they are not focusing on a learning task for a continuous period without being distracted. VR may distract students, particularly when they explore a virtual world and chat with other students simultaneously. |
| CVR4 | Lack of time | Refers to the lack of time for students to learn all materials. The primary concern in this case was that students may require more time to master VR. |
| CVR5 | Limited environmental resources | Refers to the insufficient number of computers, poor internet connection, coverage, and speed, lack of spacious classrooms, lack of technical support, restricted internet settings, and computers with low specifications. |
| CVR6 | Lack of guidelines | Refers to limited instruction about using VR in learning, which negatively effects students' willingness to use VR in future. |
| CVR7 | Lack of practice | Refers to the skills required to promote a positive learning experience in VR. Most teachers consider this as a challenge because they do not use VR frequently. |
| CVR8 | Health impairment | Refers to the negative impact of using VR for long periods. In addition, teachers' opinions on poor communication by students and their addiction to VR were highlighted. |
| CVR9 | Lack of parental support | Refers to parental resistance to the use of technology for learning school subject matter. |

AR

| <i>Code</i> | <i>Primary category</i> | <i>Description</i> |
|-------------|---------------------------------|---|
| CAR1 | Lack of competency | Refers to the lack of AR functionalities for promoting the competency of students. For example, it is assumed that AR is more suitable for computer literate students. |
| CAR2 | Limited instructional design | Refers to the limitation of AR in providing an extension of knowledge that may or may not suit the learning goals of students. For example, teachers stated that currently, AR does not provide students with learning materials in accordance with local syllabus and context. |
| CAR3 | Lack of focused attention | Refers to the use of digital handheld devices for purposes that are not related to learning tasks. For example, students use the device to explore other applications and take photos of their friends. |
| CAR4 | Lack of time | Refers to the time required by each student to be able to run AR. |
| CAR5 | Limited environmental resources | Refers to the limited resource provided by schools, such as digital handheld devices and lack of technical support. Internet problems were not included in this category because AR applications can be used without internet. |
| CAR6 | BYOD policy restriction | Refers to the current policy restriction on not allowing students to bring their own devices to school. In addition, some students do not own personal phones or cannot afford them. Teachers foresee this as an unnecessary move. |
| CAR7 | Lack of long-term engagement | Refers to the lack of long-term engagement by students when using AR. Students do not remain interested for long periods because AR lacks exploratory features and users can predict the content. |

Eight common categories were identified among the VR and AR categories. Five of these were related to CVR and CAR, which included 1) lack of competency, 2) limited instructional design, 3) lack of focused attention, 4) lack of time, and 5) limited environmental resources. Three categories were related to PVR and PAR; these were 1) promote exploratory behavior, 2) promote perceived usefulness, and 3) develop positive attitude.

The frequency analysis of the coded inductive categories for challenges is presented in Table 3 and Table 4. The results for categories under CVR showed that all participants agreed upon the role of limited environmental resources (100%), followed by lack of competency (62.5%), limited instructional design (50%), lack of time and practice (43.75%), health impairment (37.5%), lack of focused attention (31.25%), lack of parental support (25%), and lack of guidelines (18.75%).

Table 3
Category frequencies for CVR

| Code | CVR | Frequency (%) | Number of participants (%) |
|------|---------------------------------|---------------|----------------------------|
| CVR1 | Lack of competency | 32 (19.16) | 62.5 |
| CVR2 | Limited instructional design | 16 (9.58) | 50 |
| CVR3 | Lack of focused attention | 8 (4.79) | 31.25 |
| CVR4 | Lack of time | 17 (10.18) | 43.75 |
| CVR5 | Limited environmental resources | 61 (36.53) | 100 |
| CVR6 | Lack of guidelines | 4 (2.40) | 18.75 |
| CVR7 | Lack of practice | 8 (4.79) | 43.75 |
| CVR8 | Health impairment | 13 (7.78) | 37.5 |
| CVR9 | Lack of parental support | 8 (4.79) | 25 |

In the case of CAR, results revealed that the BYOD policy restriction was the most notable challenge (50%). With this regard, teachers emphasized that a student should be responsible for the upkeep and maintenance of his/her own devices. Some teachers added that most parents are opposed to the BYOD policy of making mobile or laptop use mandatory. In addition, this study found that limited environmental resources and lack of long-term engagement may significantly contribute to the limited utilization of handheld AR among school teachers. Three participants were concerned about limited instructional design and lack of time, while 12.5% of the participants were mostly concerned about lack of competency and lack of focused attention. Some teachers linked the lack of competency among students to the need for restructuring of training programs on technology use to help students improve their skills when learning with technology.

Table 4
Category frequencies for CAR

| Code | CAR | Frequency (%) | Number of participants (%) |
|------|---------------------------------|---------------|----------------------------|
| CAR1 | Lack of competency | 3 (5.77) | 12.5 |
| CAR2 | Limited instructional design | 6 (11.54) | 18.75 |
| CAR3 | Lack of focused attention | 4 (7.69) | 12.5 |
| CAR4 | Lack of time | 6 (11.54) | 18.75 |
| CAR5 | Limited environmental resources | 7 (13.46) | 31.25 |
| CAR6 | BYOD policy restriction | 15 (28.85) | 50 |
| CAR7 | Lack of long-term engagement | 11 (21.15) | 31.25 |

The categories that were common to VR and AR were compared (see Figure 3). From the perspective of functionality to promote learning, 62.5% of teachers said that the functionality

of VR was a challenge, especially when teaching large groups. 50% of the participants were concerned about limited instructional design in VR, as compared to 18.75% of the participants in the case of AR. They further elaborated that poor instructional design can result in ineffective learning and exploratory behavior, inefficient activities, and unmotivated learners—a consequence that can lead to varied serious long-term effects. Five out of 29 participants (31.25%) stated that VR may not necessarily ensure learners' focused attention, as compared to other participants in the case of AR. This is attributed to that VR can construct multi-sensory virtual environments which may not fulfill students' learning needs. The experience emerged from this reality may shift students' focus away from the task and impact their ability to move forward in the learning process. Approximately 43.75% of the participants had a negative perception about the time required to use VR, as compared to 18.75% of the participants in the case of AR. Some teachers reasoned that the time needed for students to explore the functionalities of the VR environment and understand the link between the materials and the VR concepts is one of the key challenges that need to be overcome in order to see wider deployment of this technology. Notably, findings concluded that most participants were in agreement about the role of limited environmental resources in hindering efficient utilization of VR, as compared to 31.25% of the participants in the case of AR.

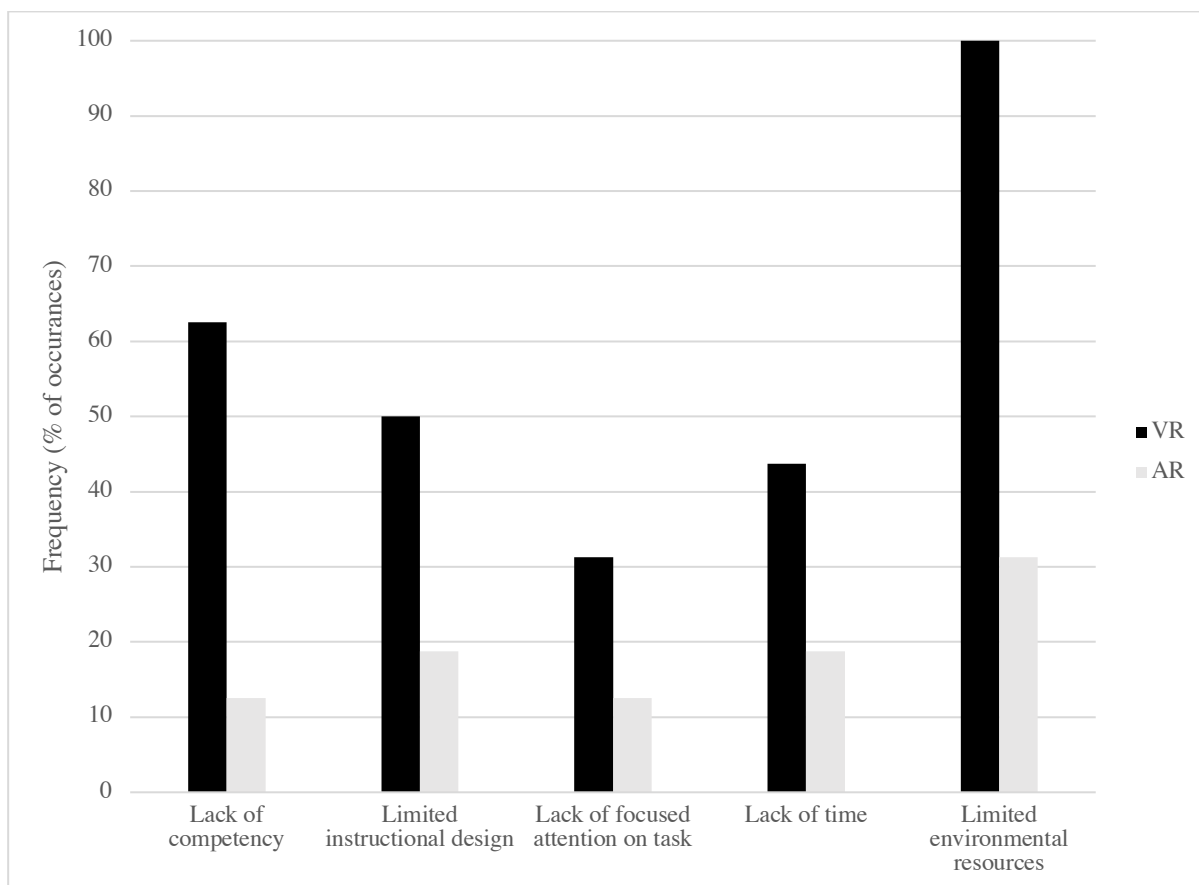


Figure 3. Common categories for challenges of VR and AR

4.4 Prospects of VR (PVR)

The participants were questioned about the suitability of utilizing VR in the context of primary schools. The majority of participants expressed that VR is suitable as a method for assisting students' learning of science subjects. Two participants stated that this technology is

acceptable because today's children are digital learners, as *“currently, children are very good at exploring. The practice of using computers is considered as a norm in our country.”* Moreover, *“currently, students [are] excellent at using technology. They are able to use tablets and iPhones; hence, I think VR is more suitable for primary school level.”* We noticed that the majority of participants valued VR as a good teaching tool because they believed it could stimulate students' interest by explaining abstract concepts. One participant stated that *“AR can be suitable for teaching science. Several things in science are difficult to experience. This could let students observe actual situations.”* When considering the use of VR, *“it may promote students' positive experience by creating the feel and look of adventure and add novelty value, which drives them to feel excitement.”* In addition, the participants considered VR as a tool that could provide opportunities to students for understanding the learning concept by providing a wide range of learning resources. *“If they learn fast, then their [achievement] would be significant.”*

The majority of the participants were in agreement about the usefulness of VR for promoting positive learning experiences in science. They confirmed that students would be interested in VR and this may motivate them to learn. Moreover, findings indicated that most teachers were interested in teaching science subjects using VR in future. This was considered as an opportunity to implement VR in primary schools. Teachers expressed that students may appreciate VR more than handheld AR because of a large number of exploration and gaming elements.

AR may not necessarily convince students about the learning concept. I want to use VR because we do not know what will happen in a virtual environment. AR is considerably predictable.

VR is more attractive because students can explore things themselves. They can decide where to explore, as compared to AR. In AR, they can view the contents provided by [marker-based] textbooks only.

4.5 Prospects of AR (PAR)

The majority of teachers interviewed recommended the use of handheld AR as a supplementary tool for explaining complex concepts. The first reason for the considerable support for handheld AR compared to VR is the conveniences that it could provide to teachers and students. In the aspects of teaching convenience, *“handheld AR is more practical. When students use it, they can understand more about the learning aspects in an interactive manner that allows for self-observation and reaction. We could also observe the students. However, in VR, only students could observe themselves. We cannot monitor them.”* *“I prefer handheld AR. I think that VR is extremely ‘broad’. It cannot maintain students' interest.”* Another participant added the following:

I prefer AR because it is easier for me to manage; however, for students, VR is more suitable because they can find and explore detailed information about the topic that was taught. I want to use both technologies. However, if I had to select between them, I would prefer to use AR to support my teaching methods.

In addition, another reason that AR is preferred is that mixed reality design could provide learners with hands-on experience. *“It is considerably dynamic, and I feel that an actual object is there, and it is easy to control.”* In addition, AR resolves the argument on authentic learning.

This is considerably better because everything is not virtual. Thus, [it is] better for students to use AR. Even though the pop-up objects are 3D, they are more solid. At least, they can move.

AR is simpler than VR in terms of hardware and software requirements. It requires only a portable device with a downloadable AR application and marker-based paper. This prerequisite increases the teachers' willingness to use AR. One teacher added the following:

As AR requires less hardware equipment compared to VR, it is more convenient. Most students at my school do not have computers at home; however, most of them have mobile phones. With AR applications, they could use it anytime and anywhere.

Accordingly, it is anticipated that the majority of teachers are in favor of teaching with AR as compared to teaching with VR.

The codes were divided into subcategories to identify the categories that were common to the prospects of VR and AR in school teaching practice (see Table 5).

Table 5
Prospects of VR and handheld AR

| VR | | |
|-------------|------------------------------|---|
| <i>Code</i> | <i>Primary Category</i> | <i>Description</i> |
| PVR1 | Promote exploratory behavior | Refers to the state where VR can adapt to the manner in which students respond and navigate through an environment. Terms such as students' exploratory nature, digital learning, digital users, and eagerness to use were included in this category. |
| PVR2 | Promote perceived usefulness | Refers to teachers' confidence in the usefulness of VR for their teaching and its benefits for students' learning by enabling them to gain more control of a learning task. VR was found to enhance knowledge, understanding, and academic performance, motivate students, provide a positive learning experience, stimulate interest, improve visualization, attract and retain attention, explain abstract concepts, encourage collaborative learning, and reduce the burden on teachers. |
| PVR3 | Develop positive attitude | Refers to the potential of VR in promoting the development of positive feelings among students, which encompasses terms such as 'happy', 'grateful', 'interesting' and 'good'. |
| AR | | |
| <i>Code</i> | <i>Primary Category</i> | <i>Description</i> |
| PAR1 | Promote exploratory behavior | Refers to the state where AR can be used to promote students' learning of a task by providing cognitive resources for stimulating a positive exploratory experience. |
| PAR2 | Promote perceived usefulness | Teachers' opinions about PAR2 are similar to those about PVR2. |
| PAR3 | Develop positive attitude | Teachers' opinions about this category are similar to those on PVR3. |
| PAR4 | Overcome facility shortage | Refers to the benefit of AR in terms of providing the environmental resources required for running applications. It consists of terms related to simple configuration, lightweight devices, and offline features. |
| PAR5 | Create convenience | Refers to the usefulness of AR in enabling teachers to fulfill the teaching objective and provide instructions. |

The frequency analysis of coded inductive categories for the prospects of VR and AR is shown in Table 6 and Table 7, respectively. The result showed that 93.75% of the participants agreed that VR has potential for promoting exploratory behavior and developing a positive attitude, whereas 81.25% of the participants stated that AR could increase perceived usefulness. Both technologies were seen to provide multiple forms of sensory feedback that can be manipulated to enhance the learning experience of the students.

Table 6
Category frequencies for PVR

| Code | PVR | Frequency (%) | Number (%) of participants |
|------|------------------------------|---------------|----------------------------|
| PVR1 | Promote exploratory behavior | 45 (21.53) | 93.75 |
| PVR2 | Promote perceived usefulness | 106 (50.72) | 81.25 |
| PVR3 | Develop positive attitude | 58 (27.75) | 93.75 |

In addition, the study confirmed that 93.75% of the participants agreed upon the role of AR in promoting perceived usefulness and developing a positive attitude among students, followed by promoting exploratory behavior (68.75%), creating convenience (68.75%), and overcoming facility shortage (56.25%). Some teachers elaborated that AR is a promising platform for learning where students can freely interact with the materials placed in real scenarios required to facilitate scientific inquiry.

Table 7
Category frequencies for PAR

| Code | PAR | Frequency (%) | Number (%) of participants |
|------|------------------------------|---------------|----------------------------|
| PAR1 | Promote learning behavior | 28 (12.73) | 68.75 |
| PAR2 | Promote perceived usefulness | 91 (41.36) | 93.75 |
| PAR3 | Develop positive attitude | 51 (23.18) | 93.75 |
| PAR4 | Overcome facility shortage | 22 (10) | 56.25 |
| PAR5 | Create convenience | 28 (12.73) | 68.75 |

Figure 4 shows the comparison between the categories common to PVR and PAR. Results found that 93.75% of the participants expressed that VR is more appreciated for promoting exploratory behavior among students, as compared to 68.75% of the participants in the case of AR. VR provides the motivational elements necessary to engage students in positive exploratory behavior. It also increases the realism of the choice environment compared to lab setups. However, 93.75% of the participants perceived AR to be useful, as compared to 81.25% of the participants in the case of VR. This was reasoned to that AR enables students to display different kinds of visualization elements (such as animations and information features) for realization of which it is necessary to stimulate learners' curiosity to the augmented world. The majority of the participants (93.75%) agreed that VR and AR could be used in schools for developing a positive attitude.

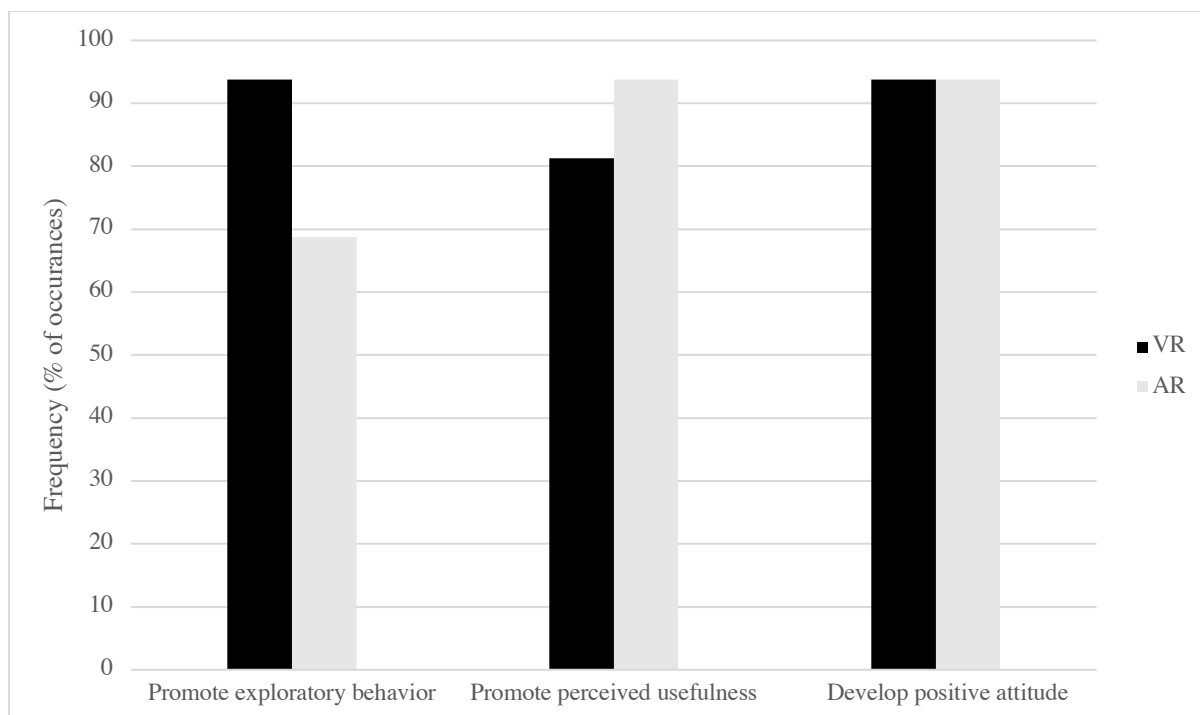


Figure 4. Common categories for prospects of VR and AR

5. Discussion

The literature on improving science teaching and learning practices have shown the needs for identifying techniques and resource material to tackle concerns in the education of science (Chien, 2018). Science teaching requires teachers be able to select and implement advanced technologies that support the development of student learning and discovery, thus improving the current state-of-practice.

The key contribution of this study is in revealing the major factors that would hinder the use of AR and VR in school settings. The results emphasize the importance of certain environmental dimensions and encourage policy makers to include these dimensions into their decision-making processes, thereby helping schools cope with the failure to use these technologies in the classroom. The following subsections discuss the challenges and prospects of AR and VR utilization among school teachers.

5.1 Challenges faced in using VR and AR among school teachers

5.1.1 Challenges of VR in school teaching practice

There were a number of challenges teachers faced when delivering science subjects with VR. These challenges were mostly related to lack of competency, limited instructional design, lack of focused attention, lack of time, limited environmental resources, lack of guidelines, lack of practice, health impairment, and lack of parental support. For example, this study found that limited environmental resources, in the form of instructional materials, were hindering the use of VR in the science curriculum of primary schools. The interview results also showed that students' low level of practice with the technology, coupled with the limited technical support, can lead students to overestimate the benefit of technology in learning science. This is in line with the work of Lim, Nonis, and Hedberg (2006), who stated that using VR for learning science implied that more time is required for learning a given topic compared to the chalk-and-talk method. Therefore, the designers of VR environments are required to follow design-based and development-based theories to create a learning atmosphere relevant to science subjects (Hanson & Shelton, 2008). In addition to this, the lack of time required for science practice prevents teachers from allowing students to explore

and master VR. The lack of active participation in VR was found to minimize its effectiveness among teachers, which can be reasoned to their limited skills of operating it. This can be reasoned by the fact that average teachers may find themselves not inclined to develop 3D VR models because they lack the required skills (Ab Kadir, 2017). The lack of focused attention was also found to be one of the key challenges in which students may be off task while navigating through VR. This includes exploring other websites or applications through the device. Teachers' general belief that VR could impair a user's health is another obstacle to its utilization. Students who spend more time on in-world activities than real-world activities are considered to be addicted to VR. This is supported by Boellstorff (2015) who stated that a few Second Life residents may spend several hours to acquaint themselves with other people there. In addition, VR has potential for resulting in eyestrain and cyber sickness (Park et al., 2017).

5.1.2 Challenges of AR in school teaching practice

On the other hand, science teachers reported seven challenges of using AR in primary schools, among which five challenges were common to AR and VR technologies (see Figure 5). The study showed that challenges of utilizing AR were primarily related to the BYOD policy restriction, limited environmental resources, lack of long-term engagement, lack of instructional design, lack of time, lack of competency, and lack of focused attention. However, some students may not be able to buy devices, whereas some families do not allow their children to use their own devices in the classroom. Teachers also expressed concern over the issue of device loss and misuse. Previous studies, for example, Mohamad and Woollard (2012) addressed parents' worries regarding the use of mobile phones by their children in the classroom. The authors claimed that aspects related to cyber bullying, health, communication, domestic, damage, loss and theft can be the main factors affecting the utilization of mobile phones in mainstream schooling. Dyson, Wishart, and Andrews (2017) also supported this claim by arguing that schools normally fear of loss or damage when the devices are misused by students. The students, therefore, cannot use them for their homework or for informal learning in their spare time, such as browsing the Web for topics of personal interest.

Furthermore, most teachers stated that the lack of instructional design might negatively affect their willingness to use AR properly. This is because of the rigidity of the content in AR systems, which restrict teachers from making any change according to the national curriculum, for it to accommodate learning requirements. This is somehow consistent with previous studies, wherein the content of AR could not be modified based on teachers' preference (Wang, 2017). In addition, some teachers stated that students may experience short-term engagement in AR because of its structure and that the content is limited and can be predicted. This is possibly because experiences emerged from using mixed reality applications may tend to lack the depth necessary to have a last impact on learning skills (Akçayır & Akçayır, 2017). According to Bower, Howe, McCredie, Robinson, and Grover (2014), the challenges associated with the use of AR applications are provision of information and lower order thinking capabilities in which learning with AR may limit the cognitive development of students.

In addition, the lack of time and competency were argued to hinder AR utilization in learning science subjects. Teachers were primarily concerned about the computer literacy skills of students for using AR and the extra time required to reflect on and understand a learning task. This is supported by Ariso (2017) who stated that users need to learn how to develop new epistemic skills in order to integrate and employ AR in a way that can meet certain learning goals.

Students who use AR applications frequently are likely to experience cognitive overload due to the vast amount of time and attention they would have to invest in order to understand the learning materials (Baragash, Al-Samarraie, Alzahrani, & Alfarraj 2019; Wu et al., 2018). Thus, an AR environment should be specifically designed to clearly link skills with specific learning needs placed in the physical world (Alzahrani, Al-Samarraie, Eldenfria, & Alalwan, 2018).

In addition, more efforts are needed to overcome the lack of focused attention while using AR. According to FitzGerald et al. (2013), there is a potential that students' focused attention could be shifted to other environmental and technical aspects such as charging batteries or being attracted to the novelty of AR. Radu (2014) claimed that AR need to be developed to keep students' attention focused on learning by making the content more relevant (such as pointing at geometric shapes or patterns in the physical space) to their immediate surroundings.

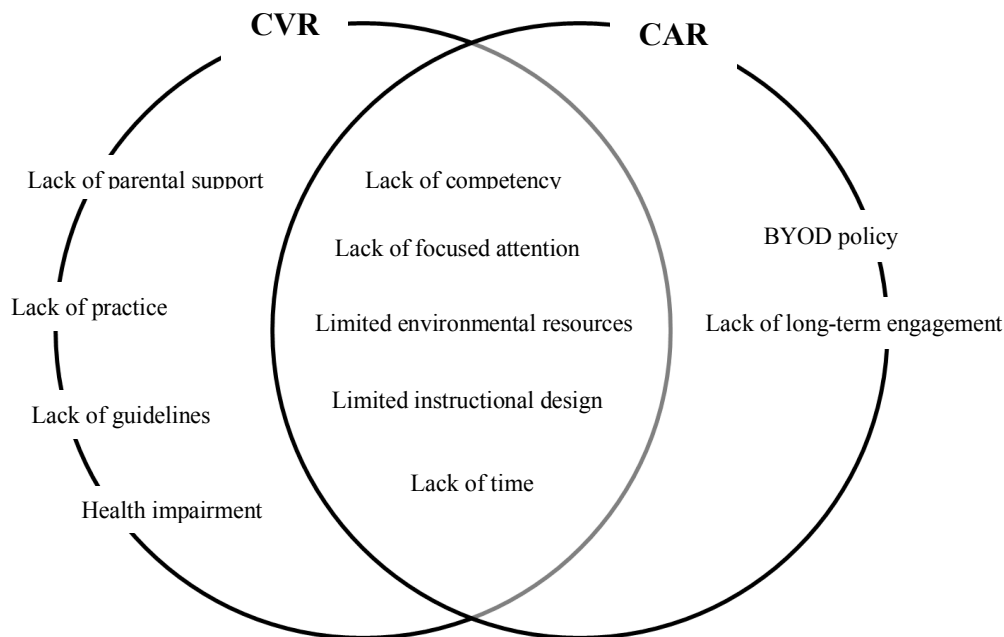


Figure 5. Challenges faced in using VR and AR among school teachers

5.2 Prospects of VR and AR in school teaching practice

To a certain extent, the recent technological shift in schools and in society seem to be limited to certain environments. Understanding how technologies are used (and adapted) in these environments can support students' learning, which is one aspect for developing science education. Hence, identifying the prospects of using AR and VR in science teaching would unlock the potential of these underutilized technologies and provide the basis for major developments in key areas of science and the next generation of infrastructure that will enable it. Teachers' views of VR and AR prospects lead us to assume that both technologies could be used to promote exploratory behavior, perceive usefulness, and develop a positive attitude. This is because of telepresence, immersive experience, a sense of being there, and accommodation of students' learning behavior (Christopoulos, Conrad, & Shukla, 2018; Rovira & Slater, 2017; Velez & Zlateva, 2017). Students could navigate using their favorite avatar and reach objects or act in a manner that is impossible in the real world. In addition, this study confirmed that both technologies could play a key role in increasing a teacher's perceived usefulness and developing a positive attitude about technology for teaching science subjects (Carbonell Carrera & Bermejo Asensio, 2017; Huang & Liaw, 2018; Liu, Li, Cai, &

Li, 2018). This finding is supported by Ozdamli and Karagozlu (2018) who reported that AR may potentially support pupils in the use of technology and it also draws their attention to the lesson, while helping preschool teachers teach about different characteristics of objects.

Teachers' perception of AR usefulness was reported to be higher than VR usefulness. This perception can be associated with the fact that AR generally provides user-friendly features that require less time for users to master. In addition, handheld AR was considered to provide an easy method for primary school students to learn science, as compared to VR, which typically requires more special hardware and software setup. This study also found that AR could be used to overcome internet facility shortage because it can function without an internet connection whereas VR could be used only when the internet was available.

As internet availability and speed were the major concerns raised by teachers, AR would certainly facilitate the teaching and learning process by enabling students to access learning material without being connected to the internet (Carbonell Carrera & Bermejo Asensio, 2017; Chaczko, Alenazy, Carrion, & Tran, 2014). Moreover, a smartphone, which is required to run AR, is comparatively cheaper and more affordable than a laptop or desktop, which is required to VR to run properly. It can be inferred that AR would be more convenient for teachers. Most of them emphasize on the importance of convenience because they are too busy to carry out daily teaching using conventional methods. For instance, if teachers use AR in a science lesson, it can facilitate the teaching process and allow for easy accomplishment of teaching objectives. By utilizing AR, it is believed that teachers and students would not need to relocate their classroom to search for a network, use computer laboratories, and waste transit time (see Figure 6).

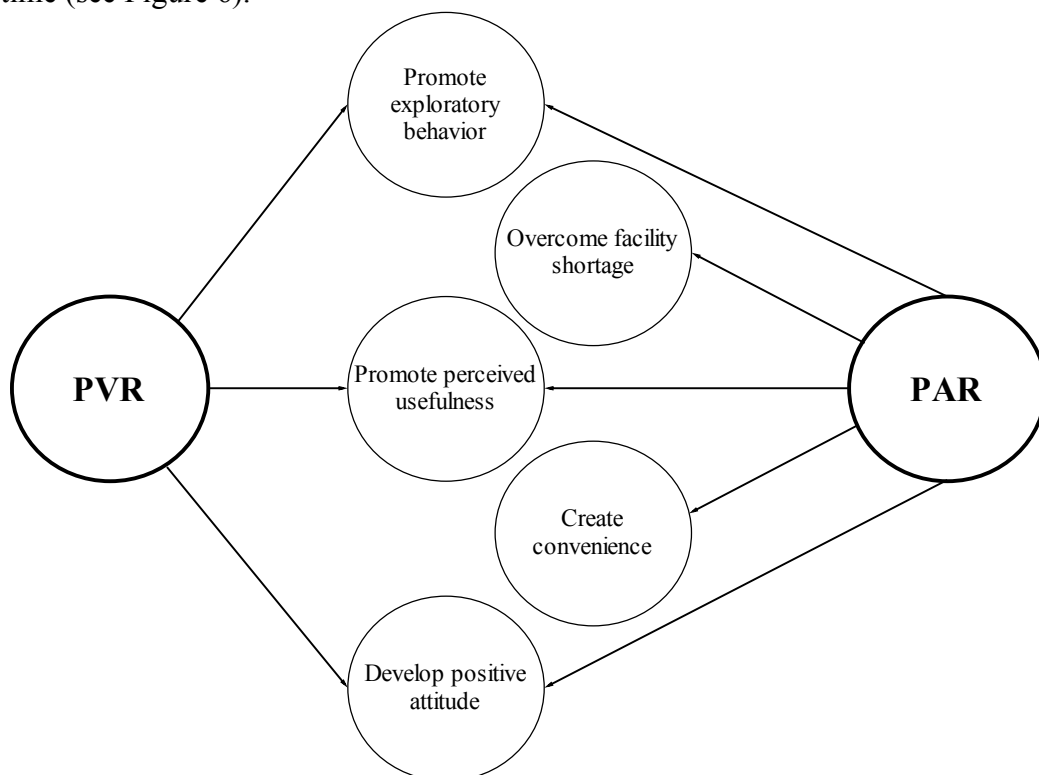


Figure 6. Prospects of VR and AR in school teaching practice

6. Implications and recommendations

This study showed that VR and AR have several common challenges and prospects. The educational decision makers may need to consider the shared aspects of VR and AR to effectively utilize them in schools. For instance, teachers' perceptions on requirements for effectively using VR were considerably more difficult to comply with, as compared to those

for AR (Baragash, Al-Samarraie, Moody, & Zaqout, 2020; Baragash & Al-Samarraie, 2018). In addition, primary schools may attempt to encourage parents to allow their children to bring their own devices to school for learning. If parents resist educational technology, students would have lesser exposure to VR. School administrators could also be informed of this, and they could further explain the benefits of VR to parents. Understanding the challenges of using VR and AR in teaching science subjects would ultimately provide the means for educational policy makers to suggest the necessary measures to effectively reflect upon the current trends, experiences and practices to support and build capacity for educational change.

This study offers suggestive evidence for the lack of practice among teachers to master VR technology. It indirectly reflects that teachers must be updated and trained on various educational technology practices. It further implies that state education departments, district education offices, and schools should offer more related courses to refine teachers' VR skills and knowledge. Information on technology should be disseminated in a manner that could benefit teachers and students. In addition, the lack of guidelines in VR, lack of long-term engagement in AR, lack of instructional design, lack of competency, and lack of focused attention in VR and AR can lead us to understand that VR and AR instructional and application designs are the most important factors for ensuring their usability in the education system. Severe monitoring must be performed to ensure that this is carried out correctly.

This study is of the view that AR could be implemented in an effective manner. Even though a large number of people do not favor this policy, it is difficult to stop technology from being utilized in such a context. It affects how we learn and live. However, the digital divide between urban and rural school students might increase. Thus, the ministry may consider supporting rural school students by bridging this gap. The study appears to offer new evidence on the role of VR and AR in promoting students' exploratory behavior and perceived usefulness and in developing a positive attitude based on teachers' opinions. According to this, both technologies have high likelihoods to be well accepted by school teachers. It was found that the process of applying science practices in the classrooms often lack laboratory equipment and trained staff to operate it, which makes it difficult for students to reflect their practice of science experiments and relate it to their daily lives. Since the use of VR and AR has been introduced to in the current teaching of anatomy and physiology at some universities, there is an additional benefit to students if primary schools can take on this technology. This may help and imitate the styles of learning in high schools and tertiary institutions.

7. Limitations and conclusions

The limited understanding of how these technologies (AR and VR) can be used to improve the learning and teaching of science makes it difficult for educational policy makers to apply additional measures in order to deal with the difficulties associated with the availability of equipment and trained staff. This study showed that both technologies can benefit students' learning by developing a positive attitude among teachers, thus promoting technology utilization in the classroom. Outcomes from this study might provide insights for administrators and policy makers to set priorities for using VR and AR to carry out various reflective practices and exploration tasks. However, there are few concerns regarding these technologies were reported in terms of lack of functionalities for supporting students' competency, which may not provide a suitable platform for accommodating different abilities. The limited learning materials offered in these environments may not necessarily suit students' learning goals in accordance with the standard local syllabus. In addition, students can be distracted when engaging in a learning activity with limited monitoring

facilities. Moreover, the study stressed that the lack of parental support for using technology to learn about school subject matter is an unresolved issue.

There are still some limitations that need to be addressed. First, this study only examined the challenges and prospects of using VR and AR from the perspective of science teachers. This study was also limited to teachers from certain schools. Therefore, future study can be conducted to consider larger sample size from different regions to acquire a better view about the challenges and prospects of VR and AR. In addition, future study may also look at the potential of other technologies in learning complex science topics, which can be carried out through experimental design.

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