Hayashi, Y., et al. (Eds.) (2017). Workshop Proceedings of the 25th International Conference on Computers in Education. New Zealand: Asia-Pacific Society for Computers in Education

Virtual and Mixed Reality for students: How to Control Human Factors

Hyojeong LEE, Yong-Sang CHO*
Korea Education and Research Information Service, Korea
**zzosang@keris.or.kr*

Abstract: Emerging technologies, such as virtual reality and mixed reality, help teachers as well as students understand educational contents more easily. But we need to consider more deeply. Because most of the devices and contents that released recently are targeted at the game and entertainment market, it may well be doubted whether they are proper for education. Some people have difficulty in health and social aspects after experience virtual or mixed reality. In this paper, we introduce the human factors issues in the virtual and mixed reality area. If we know how to control human factors, virtual and mixed reality could be used more safely in education. We gathered the usage guides, best practices and guidelines about those. We analyze and put the parts commonly mentioned together. But the consideration of hardware itself is excluded. As a result, we propose human factor guideline for users and contents creators using virtual and mixed reality in education.

Keywords: Guidelines, Human Factors, Virtual Reality, Augmented Reality, Education

1. Introduction

Virtual reality (VR) and augmented reality (AR) are emerging around the world. Facebook has announced their plan to pioneer AR and Microsoft has shown an interest in applying VR, AR, and mixed reality (MR) to expand their Windows from monitors onto walls and table surfaces. Google, too, has been lead the popularization of VR and AR technologies with its affordable and efficient things such as Cardboard and platforms like YouTube.

With the Fourth Industrial Revolution (Industry 4.0) underway around the world, attempts are increasingly made to develop and adopt new technologies, such as robotics, VR, and artificial intelligence (AI). K-12 schools are expected to incorporate AR and VR into the classroom in the 2-3 years (The New Media Consortium, 2016). Also, aggregate market size of the educational AR and VR content are expected to $0.7bn by 2025 (The Goldman Sachs Group, Inc. , 2016)..

According to the survey on K-12 teachers in the United States, 85 percent of the participants expect that VR has positive effect to the students (Samsung, 2016). Another survey is conducted on in Germany (Samsung, 2015). It is similarly showed that 74 percent of the participants expect that VR would help keep students motivated better. The experiences such as operability, presence, and immersive learning that AR provides would likely affect the learning effect on students (Bogyeong Gye & Yeongsu Kim, 2008). There were researches that education using VR increase the efficiency of learning more than conventional teaching (Mads T Bonde, etc., 2014).

In using these technologies for more immersive experiences, however, some people experience physical symptoms, such as fatigue in the eyes, and also psychological symptoms including the inability to distinguish between the virtual world and the real world (Changmin Lee, 1999). Particularly, as K-12 students are undergoing critical periods in physical and mental development, it is crucial to consider various issues of human factors before introducing VR and AR into schools.

This study compares and analyzes the existing literature on the involved issues. We propose the human factor guidelines regarding the educational applications of VR and MR technologies. In chapter 2, we introduce some of the recent trends in the educational VR and MR content. In chapter 3, we introduce the human factors of VR and MR. In chapter 4, we analysis of the guides and best practices provided by major head mounted displays (HMDs) manufacturers. Finally, in chapter 5, we present the human factor guideline for using in education fields.

2. VR and MR Trends in K-12 Schools

Contents for education make up only a mere portion of the VR and MR market today. Once devices have been distributed in massive, however, investment in the educational applications of VR and MR will likely increase, leading the growth of the industry as a whole.

Table 1 provides a summary of the key features and functions of the 20 VR apps chosen by the one media as capable of transforming education in the future (The Tech Edvocate , 2017). Among those, almost 60 percent of the apps use VR. The most of these applications can be used on mobile devices (iOS and Android) rather than requiring higher-end devices like HTC VIVE. Similar to the surveys as mentioned earlier (Samsung, 2015, 2016), many of these applications are applied to school subjects, such as science, social studies, and art, that are likely to benefit from incorporating immersive content into their curricula.

In this chapter, we introduce recent trends in the educational applications of VR and MR that could be applied to the K-12 schools.

Table 1: Summary of the 20 VR apps chosen by the Tech Edvocate in 2017.

App	Type 1	Type 2	Operating system	Subject	Function
Start Chart	AR	Image recognition	Mobile devices (iOS)	Science	Mobile camera app that displays constellations and information when projected onto the night sky.
Google Translate	AR	Image recognition	Mobile devices (iOS)	Language	Camera-like scanner that translates texts (in 30 languages).
Cleanpolis	VR	Graphics	Mobile devices (Android)	Science	Game for learning about climate change and carbon dioxides.
Public Speaking VR	VR	360º image	Mobile devices (Android)	Social studies	Practicing giving presentations.
Quiver	AR		Mobile devices (iOS)	Art	Coloring 2D images to view them in 3D.
Boulevard	VR	360º image	Oculus Rift	Art	Virtual tours of six museums.
Unimersiv	VR	360º image and graphics	Samsung Gear VR, Oculus Rift, Daydream, Cardboard, VIVE	Social studies, science	Virtual tours of historic scenes (ancient Greece, the *Titanic*, etc.) and the human anatomy.
Inmind	VR	Graphics	Android (Cardboard)	Science	Virtual tours of the human anatomy
Apollo 11 VR	VR	Graphics	Oculus Rift, HTC Vive, Playstation VR	Science	Virtual tours of outer space.
Earth AR	AR	LBS	Mobile devices (iOS)	Science	Viewing the Earth from new angles.
Cospaces	VR		Mobile devices (iOS, Android)	-	Creative experiences in VR.
TiltBrucsh	VR	Graphics	HTC VIVE, Oculus Rift	Art	3D drawing.
Anatomy 4D	AR		Mobile devices (iOS, Android)	Science	Lesson on anatomy.
Sites in VR	VR	360º image	Mobile devices (Android)	Social studies	Virtual tours (mosques, mausoleums, ancient cities, etc.).
King Tut VR	VR	Graphics	Mobile devices (Android)	Social studies	Virtual tours of the Egyptian Pyramids.
Flashcards-Animal Alphabet	AR	Image recognition	Mobile devices (iOS)	Language	Learning new alphabets /characters and words.
Image-n-o-tron	AR	Image recognition	Mobile devices (iOS)	Language	Learning new alphabets /characters and words
EON Experience	AR/VR		Mobile devices (iOS, Android)	-	VR lectures on a comprehensive range of topics, from physics to history.
Titans of Space	VR	Graphics	Android (Cardboard)	Science	Virtual tours of outer space.
Discovery VR	VR	360º image	Mobile devices (iOS, Android), Oculus Rift, Daydream, VIVE	Social studies	Virtual tours of exotic and hidden natural landscapes.

2.1 VR-Based Contents

Contents using virtual reality can be divided into contents created by 360 images and contents made by 3D simulations. Most of this type is played through HMDs of See-Closed method.

- **Contents created by 360º images**: Panoramic pictures or moving images that capture objects in all the 360 degrees are used. This type is used mainly for the virtual tours of places that are not easily accessed due to locations and time limitation. These can most fruitfully be applied to social studies or science. 360º images contained of actual landscapes can make students feel as if they had been transported into those places. Creators also show only the intended images and thereby maximize the presence of the experiences by fix the target user's vision to the camera. This type has a merit of cost relatively. Also, it is possible to play on common mobile devices.

- **Contents by 3D simulations:** With authoring or graphics tools in computer, we can place 3D objects on virtual simulated spaces. Landscapes that do not exist in reality (ancient cities, future worlds, etc.) could be shown. Creators enable greater freedom in users' eye and body movements. As this tend to be costlier than 360-degree image- contents, there are mostly founded in game and entertainment fields that can generate profits. To play this, computer-based devices with high computational powers are required such as HTC VIVE.

2.2 AR-Based Contents

AR-based contents include marker- or image-recognition, location-based service (LBS), and projection-type. Because these contents overlay the real world with virtual objects, they require the use of mobile device or see-through devices.

- **LBS contents**: By gathering and identifying users' locations using global positioning systems (GPS) and/or gyroscope sensors, image are shown. These are mostly found in advertisements, marketing, and entertainment. A leading example is Pokémon GO. This type requires active movements of users. This technology could be applied to support field trips.

- **Marker or image-recognition contents:** The cameras mounted on the display devices recognized given markers or images to display additional information by overlapping those. Most of these are in the forms of AR cards or AR books. This is used to project onto images not only to show information in textbooks or relics at museums but also help little children learn alphabets and vocabularies.

- **Projection-type contents:** Small projectors are mounted on display devices, it project images directly onto users' retinas or eyeglasses to display the intended images. Since it needs to the high costs for implement the devices required for use, there are few contents have been developed so far. Recently, various companies are investing in the development of these types. It can be used for sharing same contents in classroom or auditorium for many students.

3. Human Factor Issues in VR and MR

Human factors and ergonomics refer to the areas of scientific research required to find theories, mechanisms, and data that are needed to optimize machinery and systems for human use (IEA, 2000). In this chapter, we introduce a number of VR- and MR-related human factor issues across four areas (Yeonghee Lee & Yong-Sang Cho, 2016).

3.1 Health Related Issues

The causes and symptoms of health-related human factor issues can be summarized as follows

- **Discomfort**: In experiencing VR or MR, users can feel unpleasant physical symptoms such as lightheadedness, dizziness, headaches, and nausea. These symptoms are commonly referred to as VR sickness, simulator sickness, motion sickness, and cyber sickness. It is occurred due to the inability of users to react physically to the visual stimuli they experience in virtual environments (Gyeonghun Han & Hyeontaek Kim, 2011).

- **Bad impact on vision**: Since the most of VR or MR devices are close to the users' eyes, excessive use of these can lead to a variety of symptoms affecting the eyes and vision, such as visual fatigue, blurs, double vision (Jeongmin Hwang, Jinhak Lee & Taesu Park, 1999).

- **Irlen syndrome**: Also known as the Pokémon shock or the Nintendo syndrome, the Irlen syndrome causes sudden seizures in users in response to rapidly flickering visual stimuli involving bright lights.

- **Musculoskeletal fatigue**: When using VR and MR devices in the same position for an extended period of time, which, if repeated, can exert duress on the user's musculoskeletal system, leading to fatigue and pain.

- **Hygiene**: Letting multiple users use the same device together or one user using his/her own device repeatedly without taking care to disinfect or clean the device regularly could turn these devices into sources of infectious or communicable diseases.

3.2 Safety Related Issues

Safety issues related to VR and MR is the risks of injuries. Users using see-closed devices that blocked vision to display could fall, trip, or bump into surrounding objects, which increases the risks of their injuries. Even see-through devices that overlay the reality with virtual objects could increase risks of accidents, such as falls and car accidents, by overwhelming users' attention. Also, due to confusion between reality and the virtual world, users may try to sit on chairs or lean against walls those do not exist in reality, thus injuring themselves.

3.3 Social Related Issues

In the social related issues, there are infringe of privacy and over-immersion. Users may (be tempted to) abuse the recording functions of their VR or MR display devices. Users may be too engrossed in the virtual world that they may become unable to distinguish between reality and the virtual world. Further, they could be engaged in violent or self-destructive behavior in reality. Excessive immersive user could think that the outcomes of such behavior could be "undone" or "reset" as in the virtual world.

3.4 Others

There are Accessibility issue that related to whether VR and MR applications and devices can deliver the same beneficial experiences to people with physical disabilities, the infirm and the elderly, and the poor.

4. Analysis of User Manuals, Best Practices and Guidelines

We analyze the user manuals and best practice provided by the major HMD devices makers on the market such as Samsung, Sony, Oculus, Google and HTC. Some organizations, also, has making guidelines.

4.1 Health Related Issues

The amounts of information related health issues differ significantly from manufacturer to manufacturer. Some maker provided quite detailed and thoroughgoing guides, while others provided very simple manuals.

- **Discomfort:** Oculus recommends that the use of independent backgrounds such as sky or broad grassland. When users are running or driving, the usage of the horizon or a fixed background of a single color could provide as if he/she were in a vast "room" and thereby minimize the unpleasant sensation. If fixed positions such as a cockpit or a chair are placed against the virtual backdrop, the user could feel as if he/she were sitting down on such an object even when the surrounding image is moving, and thus feel less displeasure.

- **Warnings against seizures**: Most of the makers advise users who have had seizures such as epilepsy, to consult their doctors before using their devices. Oculus advises users to refer to "ISO/DIS 9241-391.2, Ergonomics of Human System Interaction – Part 391: Requirements, analysis and compliance test methods for the reduction of photosensitive seizures".

- **Interference with medical devices**: Most of the manufacturers indicated that the magnets or other radio wave-emitting parts contained in HMD and mobile devices could interfere with the radio signals of important medical devices, such as hearing aids and cardiac pacemakers.

- **Age restrictions**: There are various in the proper ages at which users may use their devices (Table 2). While manufacturers do not specify the criteria that went into determining the proper ages, some explain that age restrictions are needed particularly in order to protect children, whose visual and physical development is still underway, against possible harms of VR and MR. Most of makers recommend that users be at least 13 years of age in order to use their devices. Some makers even advise parents or adults supervision on over-13 teenagers using these devices.

Table 2: Age Restrictions of Electronic Devices

Device	Details
Mattel View-Master® VR	It is designed for kids 7 and up. Mattel have worked with an ophthalmologist to ensure that View-Master® VR is optically safe for use by children
Sony Play Station VR	The VR headset is not for use by children under age 12.
Samsung GEAR VR	Under 13 restricted
Oculus Rift	13 and older allowed
3D TV	Under 10, it is needed adult supervision
Electronic devices	For 6 to 18 ages, it is recommended less than 2 hours of use per day

- **Pre-use restrictions:** It is advised that users in poor health conditions to avoid using their products. The listed poor health conditions include feeling tired, sleep deprivation, problems with digestion, common colds, influenza, headaches, migraines, ear infections, and other such conditions induced by medications**.**

- **Stopping the use of devices:** Manufacturers advise users to cease using their products immediately upon experiencing any physical symptoms or displeasure, and to take sufficient rest until the

symptoms dissipate. The symptoms developers warn against include feeling tired or pain in any parts of the body, seizures, cognitive dysfunctions, the fatigue of the eyes, nausea, paralysis, and seizures.

- **Warning against hearing impairment:** Manufacturers warn users against the possible hearing impairment that could be caused by using their products at high volumes for extended periods of time.

- **Visual and musculoskeletal fatigue:** Manufacturers warn users against the fatigue of the eyes and musculoskeletal pain they could experience for using their products repeatedly or for extended periods of time. Oculus recommends users to design virtual objects as if they were 0.75 to 3.0 meters away from their eyes. Microsoft advise users to design the virtual images for HoloLens so that those images would not exceed 60 degrees below the horizon, 10 degrees above the horizon, and 45 degrees on either side of the vertical line, as shown in Figure 1.

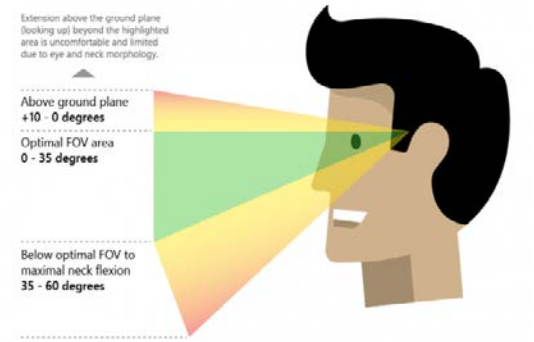

Figure 1. Recommended Angles of Vision to Minimize Fatigue (Oculus Best Practices)

4.2 Safety Related Issues

Safety related issues are summarized as below.

- **User environments:** Developers advise users to secure sufficient spaces free of physical obstacles and other risk factors, and also to use their products while sitting down. The sizes of spaces required differ significantly from device to device.

- **Heat**: Few ever mention the possibility of low-temperature burns from the heat of device. Instead, some makers warn against possible electric shocks or fires that could be caused by using third-party adapters and/or cables.

- **Clashes and falls:** When focusing on virtual object by wearing HMD devices or overlaying devices, peoples could be fall or clash into surrounding objects. Microsoft recommends that users place their HoloLens images 2.0 meters away from their vision in order to minimize the risks of clashes.

4.3 Social Related Issues

Break could be a handling method to social issues due to over-use. Makers recommend that users take breaks of 10 to 15 minutes for every 30 minutes of using their devices. Some makers also advise users to avoid using their products for extended periods of time. Taking breaks is helpful not only to minimize the fatigue on the eyes, but also to prevent users' over-immersion in virtual images.

4.4 Others

Even the content are same, it could differently affect to each users. Oculus advises creators of sensitive contents such as horror to include warning messages in the beginning of their contents. It helps for users test theirs sensitivity to such stories and determines their positions whether go on or not.

4.5 Guidelines proposed by Various Organizations in Korea

Various organization in Korea from government (MSIP the Ministry of Science and ICT) to the academic sector (Barun ICT Research Center), have developing guidelines on the use of VR and MR applications. Each guide is summarized in Figure 2, Tables 3 and 4.

In the guides of the Game Rating and Administration Committee (GRAC), there are many phrases that assumed the game situation. It is because they released just after that Pokemon GO became the topic. It contained personal information security and secret camera attention to reflect the characteristics of using the camera. Also, the phrases that reflect the characteristics that are used while moving (such as dangerous areas and private land access Prohibition, game prohibition during driving, prohibition of use during walking) are stated (Figure 2).

Figure 2. GRAC's AR Game Safety Rules

The MSIT's guideline stresses the human factors of using VR, requiring the minimization of dizziness, and the optimization of other mechanical factors, such as latency and frame rates (Table 3).

Table 3: MSIT's VR and AR Guideline in 2017

	Aspect	Description
Usage	Take a break	Rest of 10 to 15 minutes for every 30 minutes of usage.
	User environments	Make sure that they have secured a sufficient and obstacle-free space for using their devices before starting to use them
	Hygiene	Clean the device before/after use or use with hygienic disposable pads.
	Heat from device	Warnings against possible burns from heated devices should be displayed at the beginning.
VR contents development	Latency optimization	Maintain VR latency below 20ms as much as possible.
	Frame rate optimization	The frame rates of VR applications should be synchronized with the refresh rates of VR HMD devices. Image-based content should maintain 30 FPS or higher, and graphic-based content (games), 90 FPS or higher.
	Virtual camera motion optimization	The frequencies of accelerated motions of virtual cameras (back and front, left to right, zoom-in, rotation, etc.) should be minimized. Virtual cameras should be designed to move at constant speeds.
	Rig structure	The rig systems should be designed so that the real images for 360° VR applications would approximate the no-parallax point.
	Stitching optimization	The location, lens distortion, and synchronicity of the camera should all be optimized.
	FOV(Field of View) coordination	Match the virtual camera field of view (cFOV) to the fixed display field of view (dFOV) as closely as possible.
	Sensory synchronization	VR applications should be designed so as to synchronize the visual and other sensory experiences.
	Motion platform synchronization	The latency between VR input and VR output should be kept at 150 ms or lower.
	UI layout	The UI should be given 3D objects and laid out over a 3D space.
	Sound	The directions of the sounds should change in response to the movements of the user's head.
AR content development	Enhanced reality	The colors, vividness, and light sources of virtual objects should be rendered more optimal and real.

Table 4:. Guidelines for VR users and Commandments of VR guidelines of Barun ICT Research Center

10 Guideline for VR users	10 Commandments of VR guidelines(2015)
Precautions before using VR • Are you in good health? • Do you have enough space to safely use VR? • Are your devices working properly? • Have you read the VR content precautions? **Precautions while using VR** • Stop using immediately if any side effects occur. • Do not use for an extended period of time. • Use under adult supervision **Precautions for using VR in general** • Rest before resuming your daily activities • Do not use while moving around or driving. • Store your VR device with care.	• Thou shalt safeguard against potential physical injuries. • Thou shalt limit VR exposure time. • Thou shalt prevent photosensitive epilepsy. • Thou shalt warn against cybersickness. • Thou shalt provide vibration intensity controls to avert vibration syndrome. • Thou shalt prevent hearing loss. • Thou shalt not use materials that irritate the skin. • Thou shalt provide guidelines for proper posture to avoid muscular and physical fatigue. • Thou shalt improve interface design considering both convenience and comport. • Thou shalt abide by the laws and regulations for consumer safety and protection.

In the guides of Barun ICT Research Center are stated that characteristic of content use to use should be confirmed. However, we didn't take into account that, since the violence and the bad expressions are implicitly excluded in the case of contents purposed for educate. Most of the items in

their guides are designed to output guidance or warning message on the VR device rather than the content design itself (Table 4).

Most of guidelines focused mainly on reducing dizziness in content production. Because they concentrated on the technical side such as the use of the device or the production technique rather than the design of the content itself, it leaves much to be added.

5. Conclusion

Considering of human factor issues, user manuals, best practices and guidelines of other organization, we would like to propose the human factor guideline. It is summarized in Table 5.

Table 5: Summary of Our Human Factor Guideline

	Aspect	Description
Usage	User condition	Check the user's condition before, during, and after using VR.
	Mechanical information	Check the specifications, user's guide, and age restrictions associated with the device before using it.
	User environments	Check the minimum areas or spaces required for using the given VR device/application, and eliminate possible obstacles and risk factors. Use VR while seated.
	Duration	Take frequent breaks while using VR.
	Heat	Beware low-temperature burns from heated devices.
	Refreshing	Refresh the user's attention every now and then to prevent him/her from confusing reality and VR.
	For young users (12 and under)	Parental or adult supervision is required. Do not let children use VR by themselves.
Development	Mechanical information	See guidelines provided by developers.
	Runtime	10 minutes or less.
	Backgrounds	Exclude ethically sensitive backgrounds. Use vast and dark backgrounds for VR images.
	Texts	Minimize the use of texts.
	Colors and sounds	Make appropriate use of colors and sounds
	Sensory synchronization	VR applications should enable users predict or experience sensations accompanying visual stimuli.
	Camera motion optimization	Minimize the accelerated movements of virtual cameras. Maintain them moving at constant speeds as much as possible.
	UI layout	AR applications should be designed with adjustable UIs that users could adjust to fit their vision. UIs for VR applications should be given 3D objects and laid out over 3D spaces.
	Object placement	Virtual objects inserted and placed should be at certain distances from the user's vision so as not to obstruct it.
	Content operation and samples	Provide sufficient tips and examples on how to operate applications' content and help users get acquainted by providing them with samples.

5.1 For Usage

There are 7 aspects for the users consideration.

- **Check the status of users before, during, and after use:** If user is in a seizure-prone group or using medical devices, he/she must consult a doctor or other professionals. Do not use if you have a health problem because it may worsen your symptoms. During use, pay attention to the fatigue caused by hearing damage, photosensitivity seizures, and repetitive movements. If any abnormal symptoms appear, discontinue use immediately. After use, if you have persistent discomfort or abnormal symptom, take a rest and consult your doctor.

- **Check the status, user's guide and the age restrictions of the device:** Make sure the device is not damaged, clean (disinfected), and sufficiently charged before using it. Different devices have different age restrictions and operational requirements. Check these restrictions and requirements in advance in order to ensure safe handling. Since K-12 students are at the stage of physical and mental development, it is recommended that students take an actions as conservatively as possible.

- **Identify the range that can be safely used before use and remove obstacles around it:** As see-Closed devices completely block the user's gaze and see-through devices can confuse the user's eyes, it is possible to cause safety accidents during use. It is necessary to check the surrounding environment in advance and remove obstacles. Also, it is recommended to use in seated position. In particular, when many students are in the same space, be careful about clashes and falls between students.

- **Take breaks often:** When using virtual / mixed reality contents for a long time, somatic side effects such as dizziness, headache, nausea, and eyeball may appear, and mental side effects such as immersion may be experienced. Most manufacturers recommend a 10 to 15 minute break per 30 minutes of use, but it is expected that the continuous use of content on actual training sites will be shorter than 30 minutes.

- **Pay attention to the burn caused by device heat:** Most VR or AR devices are worn on users' bodies or used in close proximity to users' body. If excessive heat is generated in the equipment, it may cause bodily harm such as low temperature burns. The skin of the K-12 students is especially fragile, and in the case of low fever, students are also slow to recognize signs of burns while they are immersed in VR or AR applications.

- **Refresh users' attention after use:** People experienced VR or MR could confuse reality with the virtual world. Especially kids those lack of cognitive ability could confuse more than adults.
- **Do not let young students (age 12 or under) use VR or MR devices alone**: Be sure to observe and supervise by the guardian or guidance teacher. Almost of VR and MR devices have been developed for adult usage, and makers advise children aged 12 and under not to use these devices. Because young children are in critical phases of development, adult supervision and instruction is mandatory in letting them use VR.

5.2 For Contents Create

There are 10 aspects for the contents creators to consider.

- **Check the guidelines provided by the manufacturer of the device you intend to play the content on:** Virtual and mixed reality devices have not yet been standardized, and the driving method and usage method are different for each manufacturer. In particular, referring to the manufacturing guidelines provided by some makers of devices, it may be useful for producing content optimized for the device. In some sensors, the body does not recognize a small child, or a teacher or adult around a child is recognized as a user. If sensors are used, it is needed to design for minimizing these errors.

- **The runtime of each application not be more than 10 minutes:** None of the guidelines surveyed for this study mentioned the proper runtimes of VR or AR applications. Given the experiences of contents creates and young students' age, contents that involve rapid movements of images is suitable for about five minutes, and contents that involve slow-moving images or plots is possible to run for 10 minutes or less.

- **Avoid using ethically sensitive or controversial backgrounds:** Some VR and AR applications have generated controversies by featuring ethically sensitive places as backgrounds. Ethics is considered to be an important factor in education, so caution is needed in selecting the background of learning content. Using vast and dark backgrounds can also help minimize dizziness.

- **Minimize the use of texts**: Many texts are less readable and can cause dizziness. Reduce text, and consider UI design in the form of images or 3D objects.

- **Make appropriate use of colors and sounds**: Bright colors, colors of low chromaticity, and colors that contrast the surrounding backgrounds can catch attention. Further research is needed, however, on the appropriate use of colors. Sound can also capture attention like colors. If eyesight and sounds do not match, the sense of reality may be degraded.

- **Synchronize sensory experiences:** Contents should especially provide situations or expressions that cater to users' expectations or predictions of synchronicity. Using same contents over and over, it reduces dizziness over time. Because it enables the user to predict subsequent situations better.

- **Optimize the movements of cameras**: Abrupt movements of virtual cameras in VR applications can be a major source of dizziness for users. As the vestibular system is sensitive to state changes, camera movement such as forward, backward, left and right movement, rotation, and zooming should be as constant as possible.

- **Adjust of virtual object to the user's eye level:** For VR content, it is recommended for the UI should be 3D objective in virtual space. Deployment of inappropriate UI can cause dizziness. It is better to make it appear only when it is not normally visible, or overlay it on a three-dimensional object.

- **Maintain proper distance when placing virtual objects**: Arranging the objects at a proper distance from the user in the virtual space can prevent the excessive movement of the body as well as securing the view of the user, thereby ensuring the comfort of use. Objects placed at sufficient intervals also appear more natural when they are overlaid on reality.

- **Provide examples and content samples of manipulations**: Even if you experience the same content, your user experience may be different. For safer use, it is advisable to present some of the contents as a sample screen in advance, so that you can get guidance on how to operate and understand the sensitivity of the user.

The contents discussed here are the result of analysis of various papers and data. Although we assumed that the main HMD manufacturer made their manual based on sufficient self-research results, it is needed additional medical research considered the usage environment in the education field.

This guideline should be updated regularly to reflect new trends in the standardization and development of VR and AR technologies. It will also need to gather expert's opinions including education site and developers of traditional educational contents.

Acknowledgements

This work was supported by Institute for Information & communications Technology Promotion(IITP) grant funded by the Korea government(MSIT) (No.2016-0-00327, Technical development for distribution system of educational contents and services platform based on Multi-format Clipped Learning Assets as well as the global commercialization for accompanied growth)

References

Barun ICT Research Center (2016). 10 Guideline for VR users, from http://barunict.kr/?p=6214

Barun ICT Research Center (2015). 10 Commandments of VR guidelines, from http://barunict.kr/wp-content/uploads/2016/05/VR%EA%B0%9C%EB%B0%9C%EA%B0%80%EC%9D%B4%EB%93%9C%EB%9D%BC%EC%9D%B810%EA%B3%84%EB%AA%85.pdf

Bogyeong Gye & Yeongsu Kim (2008). Analysis on correlations among the medium characteristics, presence, learning immersion, and learning effects of AR-based learning. Journal of Educational Engineering 24(4). 193-224.

Changmin Lee (1999). Study on side effects of VR. Korean Journal of Multimedia Studies 3(1).

Designing for Google Cardboard, from https://www.google.com/design/spec-vr/designing-for-google-cardboard/a-new-dimension.html
GRAC (2017). Safety rules for AR games.
Google Cardboard, Product safety information, from https://vr.google.com/cardboard/product-safety/.
Gyeonghun Han & Hyeontaek Kim (2011). Causes of cyber sickness and treatment. Korean Journal of Psychology: Cognition and Biology 23(2). 287-299.
HTC VIVE. Safety and regulatory guide, from http://dl4.htc.com/vive/safty_guide/91H02887-08M%20Rev.A.PDF?ga=2.174671845.632038444.1500280194-1279580701.1499660953.
Hyejeong Lee, Manho Jang & Gijung Ma (2010). Effects of VR images on the eyes. Korean Journal of Optical Science 12(3). 153-162.
Hyeyeong Jeon (2017). VIP report for the renaissance of the Korean Peninsula: Trends and implications of AR and VR industries in and outside Korea 17-14. HERI.
Jeongmin Hwang, Jinhak Lee & Taesu Park (1999). Effects of using HMD devices on the human eyes. Korean Journal of Ophthalmology 40(8). 2267-2275.
LEAP MOTION VR Best Practices Guidelines, from https://developer-archive.leapmotion.com/assets/Leap%20Motion%20VR%20Best%20Practices%20Guidelines.pdf.
Mads T Bonde, Guido Makransky, Jakob Wandall, Mette V Larsen, Mikkel Morsing, Hanne Jarmer & Morten O A Sommer (2014). Improving biotech education through gamified laboratory simulations. Nature Biotechnology 32, 694–697.
Matthew Lynch (2017). 20 top virtual reality apps that are changing education. The Tech Edvocate, from http://www.thetechedvocate.org/20-top-virtual-reality-apps-that-are-changing-education/.
Microsoft., Interaction design, from https://developer.microsoft.com/en-us/windows/mixed-reality/category/interaction_design.
MSIT (2017).VR/AR use and development safety guidelines.
Oculus Best Practices, from https://developer.oculus.com/design/latest/concepts/book-bp/.
Oculus Rift. Health and Safety, from https://static.oculus.com/documents/310-30023-01_Rift_HealthSafety_English.pdf.
Samsung (2016). Is virtual reality ready for the classroom? , from http://www.samsung.com/us/system/b2b/resource/2016/06/29/INFOGRAPHIC_VR_in_EDU_Survey_JUN16AP_1.pdf?redir=VIRTUAL%20REALITY.
Samsung Gear VR. User safety guide, from https://scontent-icn1-1.xx.fbcdn.net/v/t39.2365-6/17640394_1904229119717177_578257461677391872_n.pdf•oh=79802bb236bdd5dfe9cf199fbd611467&oe=5A0FCB7F.
Samsung Newsroom (2017). What do German teachers think of VR in school education? , from https://news.samsung.com/kr/%EA%B0%80%EC%83%81%ED%98%84%EC%8B%A4-%ED%99%9C%EC%9A%A9%ED%95%9C-%ED%95%99%EA%B5%90-%EC%88%98%EC%97%85-%EA%B5%90%EC%82%AC%EB%93%A4%EC%9D%98-%EC%83%9D%EA%B0%81%EC%9D%80.
SONY PlayStation VR (2016). Instruction Manual., from https://www.playstation.com/en-au/content/dam/support/manuals/scee/web-manuals/ps-vr/PSVR_Instruction_Manual_ANZ_Web.pdf/.
The Goldman Sachs Group, Inc. (2016). Equity Research. Virtual & Augmented Reality, from http://www.goldmansachs.com/our-thinking/pages/technology-driving-innovation-folder/virtual-and-augmented-reality/report.pdf.
The Guardian (2016).Pokémon Go: US holocaust museum asks players to stay away, from https://www.theguardian.com/technology/2016/jul/13/pokemon-go-us-holocaust-museum-asks-players-to-stay-away.
The New Media Consortium. NMC/CoSN Horizon Report > 2016 K-12 Edition (2016), from https://www.nmc.org/publication/nmc-cosn-horizon-report-2016-k-12-edition/
Yeonghee Lee & Yong-Sang Cho (2016). Standardization issue report: Educational application and prospects of VR and MR technologies. KERIS.