Analysis of teenagers' preferences and concerns regarding HMDs in education

Jie GUO¹, Dongdong WENG¹,², Yue LIU¹,², Qiyong CHEN³, Yongtian WANG¹,²

¹. Beijing Engineering Research Center of Mixed Reality and Advanced Display, School of Optics and Photonics, Beijing Institute of Technology, Beijing 100081, China
². AICFVE of Beijing Film Academy, Beijing 100088, China
³. Vive Immersive Lab, Beijing 100084, China

* Corresponding author, crgj@bit.edu.cn
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Abstract  Background Virtual reality (VR) has become a powerful and promising tool for education, and numerous studies have investigated the application and effectiveness of VR education. However, few studies have focused on the expectations and concerns of teenagers regarding head-mounted displays (HMDs), which are used for this purpose. Methods In this paper, we aim to explore the current problems and necessary advancements required in VR education based on a survey of 163 senior high school students who experience VR educational content for 1h. The usability and comfort of the HMD system, the physical and psychological effects on the students, and their preferences and concerns are investigated.
Results The results show that HMDs increase students' interest, concentration, and enthusiasm for learning. However, isolated virtual environments make students feel nervous and afraid. The immersive environment also makes them worry about VR addiction and confusing the physical world with the virtual one. Conclusions VR has great potential in the field of education, but the issue of safety needs to be considered in the future.

Keywords Virtual reality; Education; Preferences and concerns

1 Introduction

Virtual reality (VR) leverages computing technology to create three-dimensional (3D) scenes for users to navigate and interact in a virtual environment (VE)⁵. Through the use of a communication media, highly immersive VEs can provide a feeling of presence to make the users feel their existence in a virtual world⁶. This sense of "presence" is helpful for users in that it helps them process their memory and induce emotions⁷. Unconscious memory processing and emotional induction can change cognition and behavior of users⁸, which helps them transfer the learning and training outcomes in VEs to the physical
environment\([6]\). In addition, the VE is rendered by the computer to make the learning progress controllable and to personalize the learning task\([7]\). The students can immerse themselves in the VE to learn and train anywhere and anytime, making them active learners\([8]\). In addition, immersive VEs can keep learners highly motivated and engaged in learning and training and enhances their ability of spatial knowledge representation\([9]\). In addition, the visualization of an abstract concept in VR is beneficial for improving learning performance. Abstract concepts such as "force" and "solar system" can be appropriately expressed in VEs to increase the learners' understanding of the concepts\([10]\). These features therefore endow VR with great potential in the field of education.

As a promising tool in education, VR has been effectively explored in the recent years. However, few studies have investigated the effects of head-mounted displays (HMDs) on teenagers. The expectations and concerns from the perspective of teenagers are not widely investigated. In this paper, we investigate the expectations, preferences, and concerns of students regarding HMDs. Participants were made to experience three types of VR educational content (guide-based educational content, video-based educational content, and game-based educational content) for an hour. A survey on the comfort and usability of current HMDs, the physical and psychological effects on the students, and students' preferences and concerns about VR education was designed to explore the effects of VR on the education of teenagers. We believe that the findings obtained in this study are meaningful and will support future research on VR education.

2 Related work

2.1 VR in education

Numerous studies have investigated the effectiveness of VR in education since the 1990s\([11]\). Lee investigated the effects of desktop VR on learning performance, and the results showed that the representational fidelity and the controllable immediacy of VR could indirectly influence the learning outcomes\([12]\). VR functions by using the presence, motivation, cognitive benefits, control, active learning, reflective thinking, and other psychological factors of the learning experience. Ibanez used a mixed-reality environment based on VR for learners to learn Spanish as a foreign language\([13]\). Their results indicated that VR as an auxiliary learning tool had positive effects on students' motivation and improved the learning outcomes. To investigate the impact of learner characteristics (i.e., perceptual and psychological variables) on chemistry-related learning achievements, Merchant examined a model of 3D desktop VR in an introductory college chemistry class\([14]\). The results showed that VR could indirectly support the development of spatial ability, enhancement of self-efficacy levels, and improvement of learning concepts. Hwang also indicated that the collaborative VR learning environment had a positive influence on learning achievement\([15]\). Furthermore, VR has proven to be effective in learning basic courses such as art\([16]\), anatomy\([17]\), and physics\([18]\). VR has also been demonstrated to be useful for training in various fields such as software engineering\([19]\), safety training\([20]\), and simulator training\([21]\).

The effects of VR context on learning outcomes have also been explored. Jensen concluded that VR could be used for the acquisition of cognitive, psychomotor, and affective skills\([22]\). Iwan explored the effects of visually complex materials on learning outcomes\([23]\). Their results showed that positive correlations existed between presence, perceived affective quality, and perception of learning. Viegas investigated the influence of teachers in VR education and explored the difference between basic and advanced courses\([24]\). Their results showed that VR was highly useful for teaching basic courses, and that the students benefited greatly from this technology in this regard. Rau explored the effects of reading speed on VR or AR, and their results showed that the students needed more time (approximately 19%) to make choices in VR and AR environments as compared to that on a desktop computer\([26]\). Marin used VR to develop an emotion recognition system for affective states in the field of education\([25]\).
2.2 Physiological and psychological effects of VR

Numerous studies have investigated the physiological effects of VR. Simulator sickness is a type of motion sickness experienced by VR users; it impacts user comfort and can also be a safety issue, as it may lead to injuries or decreased capacity. Simulator sickness can give rise to a number of symptoms such as nausea, vomiting, dizziness, headache, and fatigue. A mismatch between the observed and expected sensory signals, self-motion, visual display characteristics, and gameplay experience may lead to this illness. In addition to the symptoms stated above, visual fatigue is another common issue experienced by HMD users. Factors such as disparity, blur, luminance, and color influence visual fatigue. The conflict between the eyes' vergence and accommodation caused by the inconsistency of the imaging plane and the focus plane is also an important factor that affects the visual fatigue when the disparity is less than 1°. Furthermore, Fernandez investigated the effects of radiation from VR on young people. Their results showed that young eyes and brains absorbed substantially higher local radiation as compared to adults.

In addition to exploring the physiological effects of VR, several researchers have investigated the psychological effects of VR. Annerstedt et al. indicated that virtual nature environments can activate the parasympathetic nervous system to help users recover from stress. Tarr et al. explored the effects of virtual humans on social closeness and loneliness in VEs. Kim et al. investigated the effects of different VR technologies (desktop VR, HMDs, and CAVE systems) on emotional arousal and task performance.

3 Materials

3.1 Hardware

The HTC VIVE Focus was used in our experiment. It is a standalone VR device that provides six degrees of freedom without the need for external sensors or lighthouses. The display of this HMD uses low-persistence AMOLED technology that provides a resolution of 2880×1600 pixels and a refresh rate of 75Hz. It provides a view of 110° on nominal horizontal and vertical fields. The VIVE Focus device is equipped with a gyroscope, an accelerometer, and a magnetometer to track the head position. It also provides a built-in front camera for additional position tracking.

3.2 Virtual scenarios

To investigate the effects of VIVE Focus on senior high school students, we chose three types of educational content in our experiment. The first type was the guide-based educational content. In this type of content, the students experience educational scenarios as physical, chemical, and astrophysical spaces and can view and understand simulated phenomena. The guide is usually in the form of a voice and text. We used the VR content, "Space Says" and "Universe Lesson," as our guide-based content, as shown in Figure 1. In "Space Says," a model of space is shown to the students, as illustrated in Figure 1a. The students can walk through the solar system to view the different stars and even control them. They can observe different astrophysical phenomena and learn about astronomy. In "Universe Lesson," various physical phenomena are shown, as shown in Figure 1b.

The second type of content was the video-based educational content. The teaching methodology in this type of content is similar to that adopted by traditional methods; in other words, the students are provided with educational videos. However, HMDs can provide more immersive content via the panoramic videos. In this paper, we chose an app called Veer via which the students can watch panoramic videos. This app
was created by Beijing Fastweb Technology Co., Ltd.

The last type was the game-based educational content. This type of content enhances learning outcomes by making learning more fun. There are two types of games: first-perspective and third-perspective. In this paper, we chose a first-perspective game called Wonder Glade and a third-perspective game called Spark of Light for the experience (Figure 2). Wonder Glade can teleport users to an ever-growing theme park where they can enjoy carnival-themed classic games. They can play five minigames and earn tickets that can be redeemed at Wonder Wheel. The Spark of Light, which was developed by Pillow's Willow VR Studio, is a casual puzzle game in which the students can control a young lad and help him find the light.

4 Experiment

4.1 Participants

A total of 163 participants (120 males and 43 females), aged from 15 to 18 years, participated in this experiment. They reported that in their daily lives, they spent 6.97±3.461h on a daily basis watching content on different kinds of displays. Among these displays, 96.4% of the participants reported that they used smartphones more frequently, 2.5% reported that they mostly used TV, and the remainder of the participants said they mostly used the iPad. When using displays, 17.2% of them reported that they frequently suffered from carsickness and seasickness, and the rest reported that they seldom or never suffered from motion sickness. Among these participants, 59.5% had used HMDs once before the experiment, and 91.2% had spent less than 1h in total on HMDs. None of the participants suffered from motion sickness when they immersed themselves in the VE. During their VR experience, 46.6% of them reported that they used HMDs to experience different scenarios, 37.4% used it to watch videos, 33.7% used it to play games, and only 9.2% used HMDs for studying. It was also confirmed that a month before participating in the experiment, the participants had regular sleep and work-rest schedules. They did not have any auditory or visual impairment, mental retardation, history of ocular diseases, or brain injuries that
could affect the outcome of the study.

### 4.2 Experimental procedure

The experience lasted 70min, and the participants had a 10min rest period after 30min of experience. The participants experienced all three types of content. First, they were asked to choose one of the guide-based contents: the space sway content or the universe lesson content. Then, they were asked to watch a panoramic video. Afterward, they were asked to experience a VR game, thereby completing all the surveys.

### 4.3 Measurements

The physical effects, psychological effects, preference, and subjective evaluation of the hardware were tested to explore the effects of VIVE Focus on young people. Comfort and usability were evaluated using a hardware evaluation questionnaire (HEQ), presence questionnaire (PQ), and system usability survey (SUS). The simulator sickness questionnaire (SSQ) was used to test the physical effects of VR, and the positive and negative affect survey (PANAS) was used for the psychological effects. The preference and concern survey (PCS) was designed to explore the expectations and concerns of young people in the education domain.

#### 4.3.1 Hardware evaluation questionnaire

HEQ is a 5-point Likert scale used to measure the subject's subjective assessment of the HTC VIVE Focus. This questionnaire includes 11 items, each of which has 5 levels. Level 1 represents "not at all," and Level 5 represents "completely." The higher the score, the better the performance. These 11 items can be divided into 3 categories: comfort of hardware, comfort of wearing, and quality of the display. The HMD's light weight, breathability, shading, and moveable freedom are included in the comfort of hardware. The comfort of wearing includes adjustment difficulty, head fit, and tightness. Image distortion, chromatic aberration, resolution, and refresh rate are included in the quality of the display.

#### 4.3.2 Presence questionnaire

PQ was designed based on Usoh's presence questionnaire\(^{[34]}\) to evaluate the subject's sense of "being there." This questionnaire consists of eight items. Each item has seven levels, in which level 1 represents the state of "none" and level 7 represents the state of "completely." The eight items include Q1: the sense of being in the VE, Q2: the familiarity with the VEs, Q3: the memory of the VEs, Q4: the environmental awareness of the VE, Q5: the sense of myself in the VE, Q6: the sense of position in the VE, Q7: the control of the VE, and Q8: the control of my own body. These items could be divided into two categories: the presence of the VEs and the presence of themselves.

#### 4.3.3 System usability scale

SUS was designed by Brooke\(^{[35]}\) in 1996 for the global assessment of system usability. The survey includes 10 items with 5 levels. Level 1 represents the state of "strongly disagree" and level 5 represents the state of "strongly agree." For the positive items (odd-numbered items), the value is equal to the score minus 1, while the value of the negative items (even-numbered items) is 5 minus the score. Then, calculating the positive items' value with the negative items' value determines the total score. The total score multiplied by 2.5 gives an SUS score with values from 0 to 100.

#### 4.3.4 Simulator sickness questionnaire

The SSQ was designed by Kennedy\(^{[36]}\) and is commonly used to assess the discomfort induced by virtual
simulation. This questionnaire includes 16 items, and each item has 4 levels, in which level 0 represents the state of "completely no" and level 3 represents the state of "completely yes." SSQ can test three symptoms of simulator sickness: nausea, oculomotor, and disorientation. The total score of the SSQ is combined with the three symptoms. The symptoms of nausea include general discomfort, increased salivation, sweating, nausea, difficulty concentrating, stomach awareness, and burping. The score for nausea is multiplied by the total score of those items by 9.54, ranging from 0 to 200.34. The score of the oculomotor factor was multiplied by 7.58, ranging from 0 to 159.18. The score of disorientation ranges from 0 to 292.32. The total score of SSQ is the sum score of those three factors multiplied by 3.74, ranging from 0 to 2437.88.

4.3.5 Positive and negative affect schedule

PANAS was designed by Watson\textsuperscript{37} in 1988 to evaluate subjects' positive affect (PA) and negative affect (NA). It is one of the most popular scales in psychology to measure both positive and negative affect in individuals. This survey consists of 20 mood words and every word score on a scale from 1 to 5. Score 1 represents the state of "very slightly or not at all," and score 5 represents the state of "extremely." Ten descriptors were used for each PA scale and NA to define their meanings.

4.3.6 Preference and concern survey

PCS was designed by the authors to investigate the students' acceptance, preference, willingness, and concerns regarding HMDs. It contains the acceptable usage time, preferred educational content and forms, preferred type of HMDs, willingness to own a VR device, and concerns regarding current VR devices.

5 Results

5.1 Evaluation of system performance

5.1.1 Evaluation of hardware

The results of HEQ are presented in Figure 3. This figure shows the performance of the device, the performance of wearing, and the quality of the display. The horizontal axis represents the evaluation indicators of the HMD device. The vertical axis represents the mean score of each indicator. The higher the score, the more comfortable the device. The score of each indicator ranges from 1 to 5 points. One point indicates "uncomfortable," 2 points indicate "less uncomfortable," 3 points indicate "comfortable," 4 points indicate "more comfortable," and 5 points indicate "very comfortable." Therefore, the indicator is considered acceptable when the score is higher than 3 points, while the factor needs to be improved when

![Hardware performance](a)  
![Wear performance](b)  
![Quality of display](c)  

Figure 3 Evaluation of hardware performance.
the score is lower than 3 points.

The results show that the HTC VIVI Focus has a great wear performance ($M=3.48\pm0.699$) and displays ($M=3.60\pm0.616$). However, the weight of the HMD continues to be an issue for the young people ($M=2.62\pm0.731$). Therefore, for long-term use, HMDs need to be much lighter.

5.1.2 Evaluation of virtual environments

The performance of VE was tested by the PQ. The results thus obtained are presented in Figure 4, in which the horizontal axis represents the eight items, and the vertical axis represents the average score of each item. The higher the score, the stronger the feeling. The results indicate that the VEs for this experiment had a moderate spatial presence ($S=4.53\pm1.068$) and self-presence ($S=4.87\pm1.208$). In the virtual world, the participants had the most profound sense of themselves ($S=5.11\pm1.580$) and a deeper sense of being in the VE ($S=5.01\pm1.330$). This means that the participants could feel their own presence in the VE environment when they were immersed in it. However, their familiarity with VEs ($S=3.66\pm1.706$) was the lowest because the virtual world was quite different from their typical physical environment. This unfamiliarity with the VE environment caused the participants to have a low memory score ($S=4.59\pm1.565$) and awareness of the VE ($S=4.58\pm1.675$). The score of VE control ($S=4.82\pm1.639$) and their body control ($S=4.92\pm1.678$) were better than their memory and awareness of VEs. In other words, the participants found the VEs easy to control.

5.1.3 Evaluation of system usability

The score of SUS was 67.83 ± 11.352, which indicated the moderate usability of HMDs. Among the indicators that influence the SUS score, the factor of ease of learning this equipment ($S=4.289\pm0.9175$) showed the best performance. The results also showed that the participants may not use the devices very frequently ($S=3.242\pm1.0178$) even though the devices were easy to use ($S=3.9191.0335$). The participants reported that they needed more information ($S=2.597\pm1.1503$) or guidance ($S=2.644\pm1.12196$) to effectively use the HMDs. These requirements significantly restrict the usability of HMDs. In other words, HMDs are easy to learn and use, but the usability can be improved by providing appropriate guidance to the users.

5.2 Physical and psychological effects

5.2.1 Results of physiological effects

The physiological effect was tested using a simulator sickness questionnaire, as shown in Figure 5. The horizontal axis represents the three symptoms: nausea, oculomotor, and disorientation, and the vertical axis represents the average score of the symptoms. The higher the mean score, the
more severe the symptom. The results indicate that the scores of each of the SSQ symptoms (\(M_{\text{nausea}} = 24.32\), \(M_{\text{scolometer}} = 40.67\), \(M_{\text{disorientation}} = 80.88\)) and that of the total symptoms (\(M_{\text{total}} = 545.57\)) were significantly lesser than the general levels, which means that SSQ symptoms caused as a result of using VE devices are considered acceptable by the young people.

### 5.2.2 Results of psychological effects

The psychological effects, as shown in Figure 6, were tested using a positive and negative affect survey. The horizontal axis represents the positive affect (PA) and the negative affect (NA). The vertical axis represents the average score of each effect. Both the positive and negative affect scores ranged from 10 to 50 points. The higher the score, the stronger the feeling. For the positive effect, a general baseline of 29.7 points indicated a momentary positive affect. A general baseline of 14.8 points for the negative effect denoted a momentary negative affect.

The results indicated that the participants had a higher positive feeling score (\(PA = 29.95 \pm 7.503\)) and a lower negative feeling score (\(NA = 17.86 \pm 5.518\)) after the VR experience. The results also indicated that the participants experienced several momentary positive moods (\(PA > 29.7\)) as well as some momentary negative moods (\(NA > 17.4\)) during their VR experience. Table 1 describes the scores for each mood. This indicates that the participants experienced positive feelings such as interest, attention, excitement, enthusiasm, and activity indicators, which are helpful in studying and training. However, the highest score for negative feelings is nervousness. This means that the VE, which separates from the physical environment, makes the participant nervous, jittery, and even a little afraid. The results show that HMDs have great potential in education, but the safety of VR needs to be considered.

![Figure 6 Results of positive and negative affect survey.](image)

#### Table 1 The score of each emotional indicator

<table>
<thead>
<tr>
<th>Moods</th>
<th>Positive Affect</th>
<th>Negative Affect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Interested</td>
<td>3.50</td>
<td>0.977</td>
</tr>
<tr>
<td>Attentive</td>
<td>3.38</td>
<td>1.023</td>
</tr>
<tr>
<td>Excited</td>
<td>3.27</td>
<td>0.998</td>
</tr>
<tr>
<td>Enthusiastic</td>
<td>3.20</td>
<td>1.115</td>
</tr>
<tr>
<td>Active</td>
<td>3.18</td>
<td>1.059</td>
</tr>
<tr>
<td>Strong</td>
<td>2.91</td>
<td>1.139</td>
</tr>
<tr>
<td>Determined</td>
<td>2.83</td>
<td>1.081</td>
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<tr>
<td>Proud</td>
<td>2.72</td>
<td>1.162</td>
</tr>
<tr>
<td>Inspired</td>
<td>2.59</td>
<td>1.157</td>
</tr>
<tr>
<td>Alert</td>
<td>2.36</td>
<td>1.170</td>
</tr>
</tbody>
</table>

### 5.3 Preferences and concerns

Only 116 data items were included in this part because some of the participants failed to complete the preference questionnaire, while some missed questions.

#### 5.3.1 Acceptable usage age, usage time, and frequency

**Usage age.** The results for usage age are shown in Figure 7a. Among all the participants, none of them...
thought that children younger than seven years should use HMDs. Ten percent of them thought that children aged between 7–10 years can start using HMDs. Most of them (67%) thought that students aged between 11–18 years old can start using HMDs. The rest (23%) thought that people can begin using HMDs when they are older than 18 years. It was therefore concluded that students who are older than 10 years can start using HMDs.

**Usage time.** The results for usage time are shown in Figure 7b. Only 1% of the participants thought that HMDs should be used for less than 15 min at a time. Forty-seven percent of the participants thought that students should use HMDs for 15–30 min at a time. Forty-nine percent of the participants thought that 30–60 min is the best usage time. Only 3% of them thought that HMDs can be used for more than 60 min.

**Frequency.** The frequency results are shown in Figure 7c. All the participants thought that HMDs should be used for no less than once a week. Among them, 14% thought that students should use HMDs once a week. Half of them (53%) thought that HMDs can be used twice or thrice a week. Twenty-two percent thought that HMDs can be used every day, and the others (7%) thought that HMDs can be used with no frequency limitations. The survey indicated a tendency for young adults to use HMDs frequently in the future; this demonstrated the great potential HMDs have in the field of education.

### 5.3.2 Preferred applications

The reasons why participants wanted to use HMDs, and the popular types of educational content are investigated, as shown in Figure 8.

**Advantages.** Figure 8a shows the reason why young adults prefer to use HMDs. The most crucial reason is that they wanted to broaden their horizon and enrich their knowledge base. Some participants wanted to use HMDs for relaxation purposes, while some used them to study educational courses. Cultivating creativity and indulging in imagination were highly desired by the participants. Some participants also believe that HMDs allow them to challenge themselves, and they can safely face situations that they may be afraid to face in real life. Some students also believe that HMDs can make them more open and inclusive.

**Attractive applications.** The most popular application is scene experience, which helps students broaden their horizons. The second most popular application of HMDs is viewing leisure content for relaxation. The third most popular application is viewing educational content for gaining knowledge and developing skills. Content that can help improve intelligence are also welcome.

**Engaging in educational content.** Figure 8b shows the course content that the students preferred. Foreign language learning was found to be the most popular. Students thought that practicing and using a foreign language in a non-foreign environment was challenging. VR can solve this problem by building a pure foreign language scenario to help the users practice a foreign language. The second most popular content was the historical content. China is a country with more than 5000 years of history. Naturally, students find it extremely difficult to learn the historical events from traditional history books. VR can visualize historical scenes and events for learning and understanding history. Geographic content was also
observed to be as popular as historical content. Geography requires spatial thinking and imagination, and VR can be valuable in this regard as it can help students learn geography with ease. VR therefore has great potential in education and can help students with their studies.

5.3.3 Preferred forms

**Purchase factors.** The reasons why the students wanted to purchase HMDs are shown in Figure 9a. The results show that a high price-performance ratio is the first consideration. The second factor is that the students would buy this device when they know enough about it. Moreover, recommendations from their friends are as important as their understanding, while recommendations from experts have little influence on their choice. In addition, few students indicated that they would buy HMDs only when they felt that their experience with the device was good.

**Preferred forms of HMDs.** As shown in Figure 9b, the all-in-one HMD is the most popular among the students (50.9%) owing to its high performance and freedom from line control. Similarly, mobile VR headsets, which have the characteristics of low cost, low weight, and low-power budget, are also attractive (48.3%) to the students. By contrast, the best performing HMDs based on desktop computers in third place. The brand of the HMD was also considered important by a few students. The results show that convenience and portable were the primary considerations. Portable HMDs therefore have great potential for e-learning in the future.

5.4 Concerns

**Concerns.** The students' concerns about VR (Figure 10a) can be discussed in three parts. The first part is its physical influence on users. The most significant concern is the influence on students' perceptions, for example, visual perception, visual discomfort, visual fatigue, or even a decrease in visual acuity. The simulator sickness caused by visual-vestibular conflict may induce a change in motion perception. The second concern is related to the effects on their growth and development. Students worry about the effect
of HMDs on the head, neck, and spine as a result of wearing a rather heavy helmet on their head. Furthermore, some students worry about the addiction that may be caused by the highly immersive VR environments and their weak self-control. There are some students who have indicated that they worry about confusing the virtual world with the real world.

**Constraining factors.** The primary factor that restricts the students from buying an HMD device is an inadequate understanding of VR devices (47.4% of the subjects), as shown in Figure 10b. The second constraining factor was the cost effectiveness ratio (43.1%). Furthermore, 29.3% of students did not want to buy the HMDs owing to health concerns. In addition, being unaccustomed to the virtual scene is another constraining factor.

6 Conclusion

In this paper, the potential and challenges of VR in education were investigated. More than 100 senior students completed a 1h experiment and questionnaires, and the results of this experiment are shown in Figure 2. The results show that the HTC VIVE Focus has an excellent performance in terms of the wearing comfort and displays; however, it needs to be much lighter in the future as its heavy weight is an issue faced by the young people. After 1h of VR experience, the symptoms of simulator sickness showed only slight changes. This means that the students were comfortable with the educational content for 1h. Regarding the psychological effects, the results of PANAS showed that the students experienced more positive feelings and fewer negative feelings after the VR experience. Such positive feelings including interest, attentiveness, excitement, enthusiasm, and activeness are beneficial for studying and training. However, the separated VE made the students nervous, jittery, and even a little afraid. Therefore, the issue of safety in VEs needs to be considered in the future for the better application of HMDs to the educational area. In addition, the presence questionnaire showed that the students could strongly experience the sense of presence in the VE. However, unfamiliar scenes sometimes contributed to their nervousness. Regarding system usability, the students believed that the system is easy to learn and use, but they stated that they could not use this device frequently owing to the absence of a guide or guidance. Therefore, smarter guidance needs to be designed in the future.

The students' acceptance, preference, and willingness to use HMDs was also investigated in this paper. For the accepted usage time, most students believed that children should use HMDs after 10 years of age, and each usage should last no longer than an hour. Only a few students wanted to use HMDs with no limitations in terms of usage frequency. Regarding the preferred content, scenario-based content was found to be the most popular. They also found foreign language learning very interesting. As far as the forms of HMDs are concerned, all-in-one HMDs were determined to be more popular than those based on desktop computers. This indicates that the convenience of using a device is more important than its performance. Interestingly, the lack of understanding of VR devices is the main limitation associated with their purchase,
as compared to the discomfort caused by HMDs. Therefore, the VR market should publicize their products more, so that a greater number of students are aware of the products.

In summary, this paper explored the effects of HMDs on senior students. The advantages and disadvantages of VR in education from the perspective of senior students were investigated. We believe that our findings will be meaningful and important, and will guide the development of VR education in the future.

### Table 2 Experimental results

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Evaluation</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System Performance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HMD device</td>
<td>HEQ</td>
<td>1) HTC VIVI Focus has great performance in terms of wearability and display.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) Weight of HMDs is still an issue for the young people.</td>
</tr>
<tr>
<td>Virtual scenes</td>
<td>PQ</td>
<td>1) VEs for this experiment provide a moderate spatial presence and self-presence.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) Unfamiliarity with VEs causes the participants to have low memory and awareness scores.</td>
</tr>
<tr>
<td>System usability</td>
<td>SUS</td>
<td>HMDs are easy to learn and use, but guidance needs to be provided.</td>
</tr>
<tr>
<td><strong>Human factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physiological effects</td>
<td>SSQ</td>
<td>VEs lead to mild symptoms of nausea, oculomotor, and disorientation.</td>
</tr>
<tr>
<td>Psychological effects</td>
<td>PANAS</td>
<td>1) The participants have a higher positive feeling score than negative feeling scores after the VR experience.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) The participants experienced positive feelings of interest, attention, excitement, enthusiasm, and activeness indicators, which are helpful for studying and training.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) The results of negative feelings show that the separated virtual environments make the participant nervous, jittery, and even a little afraid, which indicates that the safety of VR needs to be considered.</td>
</tr>
<tr>
<td><strong>Preference</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Usage age, usage time, and frequency</td>
<td>PCS</td>
<td>1) Young people between 11–18 years can start using HMDs (67%).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) 30–60min is the best usage time (49%).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) HMDs can be used two or three times or week (53%).</td>
</tr>
<tr>
<td>Preferred applications</td>
<td></td>
<td>1) Experience of VR scenes is the most popular application.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) Foreign language learning is the most popular educational content.</td>
</tr>
<tr>
<td>Factors and forms of HMDs purchasing</td>
<td></td>
<td>A high price-performance ratio is a first consideration when buying an HMD device.</td>
</tr>
<tr>
<td><strong>Concerns</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concerns</td>
<td>PCS</td>
<td>Physical effects of VR on users are the most considered.</td>
</tr>
<tr>
<td>Constraining factors</td>
<td></td>
<td>Primary factor that restricts a student from buying an HMD device is inadequate understanding of VR devices (47.4%).</td>
</tr>
</tbody>
</table>

### Declaration of competing Interest

We declare that we have no conflict of interest.

### References

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