Using Virtual Reality as Learning Tools on Chemistry: Advantages and Challenges

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Abstract: This research aims to elucidate the potential benefits and inherent challenges of employing Virtual Reality (VR) technology as an instructional tool in contemporary educational settings. With an emphasis on understanding teachers' perceptions, the study investigates the difficulties faced during traditional oral teaching and the potential advantages that VR-based pedagogy may bring to the educational environment. The participants of this empirical investigation included 20 educators (11 males and 9 females), who provided their insight on a set of 15 questions specifically designed and later analyzed via Rasch measurement. The Rasch model's assessment provided comprehensive insight into the teaching difficulties experienced by educators and the potential benefits accrued from the application of VR as a teaching aid. The findings indicate that the majority of educators face challenges while instructing through oral methodologies without appropriate pedagogical tools. Conversely, the integration of VR in teaching methods was found to foster students' knowledge acquisition, comprehension, and application in novel situations, augmenting their analytical and evaluative capabilities. VR application was also found to bolster student engagement, motivation, and attention in the learning process. However, despite these promising findings, several obstacles were identified, most notably the cost of VR technology and the requisite technical skills needed for its implementation by educators. The results of this study bear significant implications for future research, particularly as a teaching tool in chemistry. It also prompts a discussion on educators' capacity-building to seamlessly integrate VR technology into existing teaching methodologies.

INTRODUCTION

Virtual Reality (VR) has a rich history spanning over three decades, garnering much research interest (Loureiro et al., 2020). The first attempt at a VR system, Sensorama, was introduced by Morton Heilig between 1960-1962, featuring a pre-recorded color film with immersive elements like sound, scent, and wind. In 1965, Ivan Sutherland proposed the initial concept of VR, including features such as interactive graphics and force-feedback (Grabowski & Jack, 2021; Stec & Shanmugam, 2020). Several innovations followed, including the creation of a force-feedback system at the University of North Carolina in 1971, and Myron Krueger's Videoplace in 1975, an Artificial Reality system (Giri & Pandey, 2016). Further advancements included
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The mid-1980s saw the production of popular VR devices like the DataGlove and Eyephone HMD by the VPL company. Fake Space Labs then introduced BOOM in 1989, a device offering immersive VR experiences. The same decade witnessed the development of an architectural walkthrough application at the University of North Carolina, supplemented by various VR devices. In the early 1990s, NASA Ames developed the Virtual Wind Tunnel, enabling detailed flow-field studies. Lastly, in 1992, a VR system known as CAVE was introduced, which used projected stereoscopic images instead of an HMD (Berkman, 2018; Franchi, 1994).

In recent years, the application of Virtual Reality (VR) technology in educational contexts has grown exponentially (Izard et al., 2017). Regarded as a pedagogical and didactic tool (Roman & Racek, 2019; Sari et al., 2021; Haase et al., 2014), VR offers unique characteristics, such as being attractive (Polechoński et al., 2020), interactive (Amador et al., 2020), evocative (Zhang et al., 2017), and fun (Lin et al., 2018). Numerous studies have explored its benefits in learning contexts, indicating that VR can enhance students' achievements, motivation, interest, attention, and engagement (Akman & Çakır, 2023; Al Amri et al., 2020; Falah et al., 2021; Araiza-Alba et al., 2020; Bogusevchi et al., 2020; Ho et al., 2019; Liagkou et al., 2019; Makransky & Lilleholt, 2018; Ogbuanya & Onele, 2018; Villena Taranilla et al., 2022). Leveraging the ability of VR to create immersive 3D environments (Liagkou et al., 2019), users can experience a sense of presence in virtual spaces ranging from classrooms and laboratories to beaches and markets (Amador et al., 2020). This immersive quality uniquely positions VR as a potentially revolutionary tool for instruction in subjects like chemistry, which heavily rely on three levels of representation: macroscopic, sub-microscopic, and symbolic (Broyer et al., 2021; Sari et al., 2021). VR not only facilitates a more comprehensive and engaging learning experience but also provides a practical solution for conducting chemical experiments that involve dangerous or costly materials.

Despite these apparent advantages, educators' experiences and challenges in implementing VR technology in classrooms remain less studied. Thus, this research seeks to uncover the difficulties, advantages, and challenges associated with VR use in teaching, guided by the following research questions: (1) What are the teaching difficulties experienced by the teachers?; (2) What are the advantages of using VR as learning tools?; and (3) What are the challenges of using VR as learning tools?

This study's novelty lies in its unique participant pool consisting of teachers involved in the VR Ambassador Program. These teachers offer a rare perspective as they have firsthand experience of creating VR scenes and implementing them in their classrooms. This study, therefore, not only contributes to the growing body of research on VR in education but also provides new insights into the real-world application and challenges of VR technology from the perspective of educators involved in the VR Ambassador Program.

METHOD

This study adopts a survey-based methodology, involving a group of teachers participating in the VR Ambassador Program. The participant demographics comprise 11 male and 9 female teachers. Upon the completion of the VR Ambassador program, participants are administered an online questionnaire via Google Forms.
This study employs a questionnaire thoughtfully designed as the primary tool for data collection. The questionnaire is intended to glean comprehensive insights into two main areas: the challenges faced by teachers and the potential benefits they discern in implementing Virtual Reality (VR) Technology as an integral part of their pedagogical methods. These insights are uniquely valuable as they are derived from the teachers' firsthand experiences, thus offering a pragmatic viewpoint on the application of VR technology in the classroom setting.

The questionnaire is divided into two distinct sections, each focusing on a specific research question. The initial section comprises six items (numbers 1-6) designed to delve into the various challenges teachers encounter during their teaching process. The second section incorporates nine items (numbers 7-15), each highlighting the potential advantages of integrating VR technology into the educational environment.

### Table 1. Participant Demographics

<table>
<thead>
<tr>
<th>No.</th>
<th>Participant</th>
<th>Coding</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Female teacher</td>
<td>F01</td>
</tr>
<tr>
<td>2</td>
<td>Male teacher</td>
<td>M01</td>
</tr>
<tr>
<td>3</td>
<td>Female teacher</td>
<td>F02</td>
</tr>
<tr>
<td>4</td>
<td>Male teacher</td>
<td>M02</td>
</tr>
<tr>
<td>5</td>
<td>Male teacher</td>
<td>M03</td>
</tr>
<tr>
<td>6</td>
<td>Male teacher</td>
<td>M04</td>
</tr>
<tr>
<td>7</td>
<td>Female teacher</td>
<td>F03</td>
</tr>
<tr>
<td>8</td>
<td>Female teacher</td>
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</tr>
<tr>
<td>9</td>
<td>Female teacher</td>
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<tr>
<td>10</td>
<td>Male teacher</td>
<td>M05</td>
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<tr>
<td>11</td>
<td>Male teacher</td>
<td>M06</td>
</tr>
<tr>
<td>12</td>
<td>Female teacher</td>
<td>F06</td>
</tr>
<tr>
<td>13</td>
<td>Female teacher</td>
<td>F07</td>
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<tr>
<td>14</td>
<td>Male teacher</td>
<td>M07</td>
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<tr>
<td>15</td>
<td>Male teacher</td>
<td>M08</td>
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<tr>
<td>16</td>
<td>Male teacher</td>
<td>M09</td>
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<tr>
<td>17</td>
<td>Female teacher</td>
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<tr>
<td>19</td>
<td>Male teacher</td>
<td>M10</td>
</tr>
<tr>
<td>20</td>
<td>Male teacher</td>
<td>M11</td>
</tr>
</tbody>
</table>

Data from respondents’ feedback are used to assess person reliability, item reliability, and also Cronbach's alpha coefficient, to ensure the internal consistency of our scale. Teachers' responses are converted into binary code for ease of analysis. This data is initially compiled using Microsoft Excel before being imported into the WINSTEPS software (version 4.4.5) for further examination.

The Rasch model analysis (Purwanto et al., 2020; Sumintono & Widhiarso, 2015) is subsequently employed using WINSTEPS to investigate the challenges faced by teachers and the benefits of using VR technology as educational tools. The...
general research procedure is graphically represented in Figure 1.

Figure 1. The Research Procedure

RESULT AND DISCUSSION

The questionnaire was completed by the teachers, after which we applied Rasch analysis to interpret the results. The obtained scores were employed to assess person reliability, item reliability, and the Cronbach's alpha coefficient of the instrument, as depicted in Figure 2. As Figure 2 demonstrates, the person reliability values are 0.87 and 0.88, indicating that the person reliability falls within the good category. Concurrently, item reliability scores are 0.84 and 0.84, likewise suggesting that item reliability is within the good category. Moreover, the quality of interaction between individuals and items, demonstrated by the Cronbach's Alpha value (KR-20) of 0.89, falls within the strong range.

Figure 2. Summary Statistics on Rasch Analysis
Teacher Difficulties and the Advantages of Using VR

The outcomes of the analysis, which evaluated teacher difficulties and the advantages of using VR as educational tools, are displayed in the form of a Wright Map as seen in Figure 3. On the left-hand side of the Wright Map, the placement of the respondents higher up or lower down represents the degree to which they acknowledged the items; those higher up agreed more, while those lower down agreed less. The right-hand side of the Wright Map features the items; those placed higher are less frequently agreed upon, whereas those lower down are more commonly agreed upon.

Figure 3. The Score of Teachers in Wright Map

In reference to Figure 3, it is evident that the majority of teachers face difficulties when teaching solely through verbal explanation without the aid of appropriate educational tools (DF3). There is only one exception to this, as represented by Teacher M02, who reportedly did not experience any significant difficulty while teaching. The consensus among all participants is that the use of VR as a learning tool significantly aids students in gaining knowledge (AD1), enhancing understanding (AD2), applying their knowledge to new situations (AD3), improving analytical skills (AD4), and boosting their ability to evaluate (AD5). Furthermore, VR also appears to effectively enhance students’ engagement (AD7), motivation (AD8), and attention span (AD9) in a learning context.
The Challenges of Implementing VR as a Learning Tool

Despite its clear advantages, the implementation of VR in the learning process introduces its own set of challenges. These primarily concern the cost and the technical capability of teachers to effectively utilize VR technology. Commercial VR systems, sophisticated enough to offer complex models and diverse functionalities, are associated with considerable costs (Bricken, 1991). If teachers were to create their own VR scenes, they would require computers with high specifications to prevent any performance issues during the process. Such high-specification computers, similar to the smartphones needed as VR viewers, carry a relatively high price tag. In the same vein, other requisite components such as a VR box (as depicted in Figure 4) also involve significant costs. These financial constraints represent a considerable challenge to the wider adoption of VR technology in educational settings.

Figure 4. VR Box

The second challenge pertains to the teachers' proficiency with VR technology. For instance, Unity 3D has emerged as a popular engine for designing and constructing virtual environments (Drori et al., 2020; Tredinnick et al., 2017). Other software programs used to create VR encompass Unreal and MultiGen Creator (Chen et al., 2017; Frevert & Di Fuccia, 2019; Haase et al., 2014; Kourtesis et al., 2020; Lu et al., 2011; Martinez-Gonzalez et al., 2020; Rukai, 2019; Wu et al., 2021). These tools typically necessitate a certain level of computer programming skills and coding prowess, which poses a significant challenge for teachers who may not possess these technical abilities.

Nevertheless, more accessible and user-friendly alternatives are starting to emerge. A case in point is Millea Lab's VR creator engine. This innovative tool simplifies the process of creating VR learning tools by eliminating the need for programming skills or coding knowledge. Its intuitive interface operates on a "drag and drop" principle, where a user simply drags the objects into the scene area, making the creation of VR learning environments a straightforward process. An example of the Millea Lab VR creator can be seen in Figure 5.

This development presents a promising shift in the accessibility of VR technology for educational purposes, potentially allowing more teachers to harness its benefits without needing extensive technical skills. However, despite these advancements, additional training and resources may still be necessary to ensure teachers can effectively use and incorporate these tools into their teaching practices.

This emphasis on the challenges tied to cost and technical proficiency underscores the importance of addressing these issues in order to make VR technology more viable and attractive for educational settings. The resolution of these challenges may well play a key role in the wider adoption of VR technology in the education sector.

Figure 5. Millea Lab Creator
Millea Lab creator requires a computer/laptop with the minimum specifications outlined in Table 3. This requirement ensures that the program can be installed and run seamlessly without any technical issues. Once a scene is created by the teacher, it's uploaded to a virtual class. Each virtual class comes with a unique code.

| No | Component       | Computer/Laptop  | Smartphone     |
|----|-----------------|------------------|----------------|----------------|
| 1  | Processor       | Intel Core i3/i5 or equal | Hexa-core 4 x 1.4 GHz |
| 2  | RAM             | 2 GB             | 2 GB           |
| 3  | OS              | Windows 7/8/10 - 64 Bit | Android Lollipop |
| 4  | Free Storage Space | 2-5 GB         | 500 MB        |
| 5  | Graphic Card    | Internal or External Graphic Card | Adreno 510 or equal |
| 6  | Sensor          | -                | Gyroscope, Accelerometer, and Magneto Sensor |

In this way, both teachers and students are required to have access to certain hardware and software to use the Millea Lab VR learning tools. While this might present some challenges, it also brings a level of interactivity and immersion to the learning experience that traditional methods may not offer. The ability for students to virtually explore their subjects could enhance their understanding and engagement with the material. It's an innovative step towards a more interactive and immersive form of education.

Millea Lab offers an intuitive platform for teachers, enabling them to design VR scenes specifically tailored for chemistry lessons. Teachers can leverage its user-friendly interface to create VR content, entirely bypassing the need for advanced computer programming and coding skills. Millea Lab boasts a comprehensive library of 3D objects, thus allowing educators to exercise their creativity in generating captivating and educationally rich chemistry learning scenes. Three distinct modes are supported on the Millea Lab viewer: VR mode, camera 360° mode, and non-gyro mode. These options ensure an immersive learning experience adaptable to various educational contexts and student preferences. Millea Lab's extensive collection of 3D objects and animated 3D objects facilitate the creation of diverse, engaging scenes that encompass a broad range of subjects. An illustrative example of a chemistry learning scene created with Millea Lab is presented in Figure 6.

![Chemistry laboratory scene](image1.jpg)  
(a) Chemistry laboratory scene

![Classroom scene](image2.jpg)  
(b) Classroom scene

**Figure 6. Chemistry Learning Environment**
Please note that while Millea Lab makes the creation and viewing of VR learning environments more accessible, there may still be challenges for some teachers and students in meeting the necessary technical requirements. This highlights the need for continued efforts to improve the accessibility and affordability of VR technology for educational purposes.

The adoption of Virtual Reality (VR) as a learning tool in chemistry education offers exciting prospects for enhancing both teaching and learning experiences. VR technology has the potential to transform traditional classroom instruction by providing immersive, interactive, and engaging educational experiences (Falah et al., 2021). In terms of the benefits of using VR technology in chemistry, one of the significant advantages is that it provides an interactive learning environment. Through VR, complex and abstract chemical concepts can be visualized and manipulated in three-dimensional space, thereby aiding students' understanding. For instance, visualizing molecular structures, understanding chemical reactions at a microscopic level, and virtually experimenting with different chemical compounds becomes possible. The interactive nature of VR can help to increase students’ engagement, motivation, and attention, which can lead to improved learning outcomes (Al Amri et al., 2020; Grabowski & Jach, 2021; Roman & Racek, 2019).

Furthermore, VR in chemistry education allows for safe experimentation (Broyer et al., 2021; Falah et al., 2021). In traditional chemistry labs, students are often exposed to potentially harmful substances. With VR, students can experiment in a safe virtual environment, which reduces the risk of accidents and increases the opportunity for learning through trial and error.

Despite the numerous advantages, the implementation of VR in chemistry education is not without challenges (Broyer et al., 2021; Falah et al., 2021). One of the major hurdles is the cost of VR technology. The sophisticated VR systems that offer complex models and diverse functionality are often expensive. This extends to the necessary hardware such as high specification computers and smartphones, and VR viewers, which may not be readily available or affordable for all educational institutions or students. Another significant challenge lies in teachers' technological proficiency. The successful integration of VR technology into chemistry education requires teachers to possess certain technical skills. Although tools like Millea Lab have simplified the process of creating VR learning environments, some teachers might still find it challenging to navigate these tools effectively.

CONCLUSION

An investigation has been conducted to ascertain teachers' opinions regarding the challenges of teaching and the advantages of implementing Virtual Reality (VR) in learning activities, based on their personal experiences. The Rasch analysis was employed to elucidate the difficulties faced by teachers and the benefits of using VR as a learning tool. The results indicate that most teachers encounter difficulties when teaching solely through oral methods without adequate learning tools. Almost all teachers agree that the utilization of VR as a learning tool can assist students in gaining knowledge, understanding, applying their knowledge to new situations, developing analytical skills, evaluating abilities, and VR can also help to enhance students’ engagement, motivation, and attention. The use of VR in the learning process presents challenges, such as the cost and teachers' capability to use VR technology. The
challenge of cost can be overcome by teachers creating their own VR environments using the Millea Lab creator. Looking towards the future, it's crucial to address these challenges to fully exploit the benefits of VR in chemistry education. Efforts should be focused on making VR technology more affordable and accessible, and providing the necessary training and support for teachers to enhance their technological competencies. As VR technology continues to evolve, there's a promising future for its use in chemistry education and other scientific domains. With continual research, refinement, and investment in VR technology, more immersive, engaging, and effective learning experiences can be achieved.

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