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Spatial Ability and Digital Literacy Profiles: Preceding Survey on the Need of Augmented Reality Media in Chemistry Instruction

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Abstrak

Siswa dituntut dibekali dengan tingkat multiliterasi yang memadai untuk melakukan Keterampilan Abad 21 yang meliputi kemampuan spasial dan literasi digital. Kemampuan spasial sangat dibutuhkan untuk memecahkan masalah dalam pelajaran kimia. Selain kemampuan spasial, literasi digital juga dibutuhkan untuk menghadapi industri 4.0. Penelitian ini bertujuan untuk menganalisis kemampuan spasial dan keterampilan literasi digital serta media yang dapat membantu mengembangkan kedua keterampilan tersebut. Metode penelitian yang digunakan adalah metode deskriptif kualitatif menggunakan survei untuk mengumpulkan data. Penelitian ini dilakukan pada 922 siswa SMA dari empat sekolah dan 35 guru. Uji Visualisasi Spasial Purdue (PSVT), kuesioner skala Likert, dan kuesioner tertutup digunakan sebagai instrumen. Hasil penelitian menunjukkan bahwa 98% siswa memiliki kemampuan spasial kategori rendah sedangkan yang menunjukkan kategori sedang dan tinggi masing-masing hanya terdiri dari 1%. Namun, dalam hal indeks literasi digital, siswa umumnya mendapat nilai yang biasa-biasa saja. Hasil dari media membutuhkan angket pembelajaran kimia untuk menunjukkan bahwa media berbasis Augmented Reality sangat dibutuhkan baik oleh guru maupun siswa. Oleh karena itu, untuk membantu meningkatkan kemampuan spasial dan literasi digital siswa, diperlukan media ajar yang memvisualisasikan objek baik abstrak maupun konkret.

Kata kunci: *Augmented Reality, Kemampuan Spasial, Literasi Digital*

Abstract

Students are demanded to be equipped with a sufficient level of multiliteracy to perform 21st Century Skills which include spatial ability and digital literacy. Spatial ability is needed to solve problems in chemistry lessons. In addition to spatial ability, digital literacy is also required to face industry 4.0. This research is aimed to analyze both spatial ability and digital literacy skills along with the media that could help develop the two skills. The research method used is descriptive qualitative method uses a survey to collect the data. This study was carried out on 922 senior high school students from four schools and 35 teachers. Purdue Spatial Visualization Test (PSVT), Likert-scale questionnaire, and closed-ended questionnaire were used as the instruments. The results indicate that 98% of the students are of low category in spatial ability while those showing mid and high category each only consists of 1%. However, in terms of the digital literacy index, the students generally score mediocre. The results from the media need a questionnaire on chemistry instruction to indicate that Augmented Reality-based media is needed both by teachers and students. Therefore, to help improve the students' spatial ability and digital literacy, a teaching media that visualizes both abstract and concrete objects is needed.

Keywords: Augmented Reality, Spatial Ability, Digital Literacy

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1. INTRODUCTION

Twenty-first is signified with the rapid information and technology advancement. Hence education is expected to catch up with this progression by providing the students with the necessary skills: the 21st Century Skills. The 21st Century Skills are organized into (1) ways of thinking: creativity and innovation, critical thinking, problem-solving, and decision making; (2) ways of working: communication and collaboration; (3) tools for working: information literacy and ICT literacy; (4) living in the world: citizenship – local and global, life and career, personal and social responsibility – including cultural awareness and competence (Griffin et al., 2012). Two components of the 21st Century Skills; problem-solving and digital literacy (or ICT literacy), however, seem to be underdeveloped in many Indonesian Classrooms (Perdana, 2019; Rahayu & Mayasari, 2018). This raises a concern as we are fast approaching Industry 4.0 and to take part in it, an individual needs to acquire a certain level of digital literacy. One effort that the government has carried out in the last few years is through the nationwide digital literacy movement in many facets; family, school, and society.

Twenty-first-century teaching also needs digital instructional media. Digital instructional media as a tool to help improve digital literacy is increasingly important in education as it provides easy access to information and limitless access to knowledge for the students (Dewanti et al., 2021; Gan et al., 2015; Suwartono & Aniuranti, 2019). Digital technology as instructional media can be in the forms of social media, games, mobile learning, augmented reality (AR), and virtual reality (VR) (Chandrasekera & Yoon, 2018; Dwivedi et al., 2021). The use of digital media in teaching can facilitate students, hence, the learning process can be more fun, meaningful, creative, and innovative and in turn, improve the students' understanding of abstract concepts through the use of animation or three-dimensional visualization using AR or VR technologies (Cai et al., 2020; Ritter, 2012; Vagg et al., 2020). Augmented Reality is a technology that combines digital information and the real world that enables its user to interact with virtual objects and also enable the user to see the object with the help of tools such as a digital camera on cell phones, tablets, or smart eyeglasses (Blevins, 2018; Kusdiyanti et al., 2020). Systems required in an AR application should have three characteristics; (1) possess interface that can combine virtual objects and real-world objects; (2) computer systems that produce interactive graphics to respond to input from users in real-time; and (3) tracking system to find the user's poaint of view and enable a virtual image to stay on display (Billinghurst et al., 2014). Integration of AR as media has been effectively applied and successfully improve the students' interest and motivate the students to be actively involved in the learning process (Chen & Liu, 2020; Irwansyah et al., 2019; Peterson et al., 2020b). This eventually improves the students' understanding of the complex concept (Al-nawaiseh, 2020; Huh et al., 2020; Peterson et al., 2020a; Sahin & Yilmaz, 2020; Schmid et al., 2020), raise the students' interest in science (Chen & Liu, 2020; Sahin & Yilmaz, 2020), improve critical thinking (Suryanti et al., 2020), develop higher-order thinking skills (Weng et al., 2020), eliminate misconceptions (Sirakaya & Cakmak, 2018) and create enthusiastic learning environment (Celik et al., 2020). The use of AR-based instructional media may also improve spatial awareness (Habig, 2020; Sung et al., 2020), spatial intelligence (Del Cerro Velázquez & Méndez, 2021; Kodiyah et al., 2020), mental rotation for the students, and reduce the cognitive load (Keller et al., 2021).

Chemistry instruction in SMA/MA should not only be done as a mere transfer of knowledge and skills but also need to nurture higher-order thinking skills (analysis, synthesism, critical, creative, and innovative) through scientific work experience (Irwanto et al., 2018). Classroom scientific work activities could help students face challenges in the future. Chemistry seeks to find answers to natural phenomena related to composition, structure and energy changes. For a better understanding of these abstract concepts, their three representations (macroscopic, sub-microscopic, and symbolic) need to be met (Barke et al., 2008). Many abstract chemical concepts involve the ability to visualize three-dimensional forms of their respected two-dimensional forms, molecule rotation and reflection and drawing a variety of forms of organic chemical compounds (Harle & Towns, 2011). Some examples of these abstract concepts are chemical bonds, geometrical molecule forms using VSEPR theory and organic compound structure (Rahmawati et al., 2021). The skill that supports visualization of two-dimensional molecule structure into three-dimensional is spatial ability.

Studies show that the students' spatial ability correlates to their understanding that forms the basic representations in chemistry (Bodner & Guay, 1997). Spatial ability is one of the nine multiple intelligences proposed by Gardner. Spatial ability is defined as a persons' ability to produce, understand forms and position, and manipulate abstract visual images (Carlisle et al., 2015; Harle & Towns, 2011). In addition to that, previous research defines spatial ability as the ability to imagine and rotate an object; visualize certain configurations where some parts of the object are moving; understand and manipulate three-dimensional objects; change and reconfigure images with spatial patterns (Flores-Amado et al., 2020). Someone who has spatial intelligence likes buildings, decorations, designs, and floor plans as well as effective in creating and reading charts, maps colour coordination, creating forms, sculpture and other three-dimensional objects (Musfiroh, 2014). Spatial ability is an important component in the teaching of science, technology, engineering, and mathematics to solve problems (Kiernan et al., 2021). There are also researchers are debating whether spatial ability can be improved through specific training or innate. However, many studies show that spatial ability develops throughout life and may be improved through intervention (Harle & Towns, 2011). According to the finding, it is necessary to develop AR-based chemistry instructional media that integrates digital information as well. Digital information that is added into textbooks using AR technology could improve the interest and motivate students to learn (Kljun et al., 2020). This development in modules and books, however, is still limited (Arici et al., 2019).

Spatial ability is needed in chemistry learning because it will help students understand abstract and complex concepts at the sub-microscopic level. Digital literacy skills are a prerequisite for exploring sources of knowledge in the digital era. The urgency of this research is because if students have these two abilities, the learning objectives of chemistry can be more easily achieved. Based on this, it was found that there was a correlation between the use of AR learning media, spatial abilities, and students' digital literacy. So, the purpose of this research is to analyze the students' spatial ability, digital literacy, and the need for AR-based learning media in chemistry learning which will be used as data to develop AR-based chemistry learning media.

2. METHODS

The research method used is descriptive qualitative method uses a survey to collect the data (Sugiyono, 2018). The data is taken from 922 students from four schools and 35 teachers from Sukabumi. The respondents' profile is provided in Table 1 and Table 2.

Table 1. Students' Respondents Profile

No	Respondent Classification		Number
1.	Sex	Female	744
		Male	176
2.	Class	X - IPA	442
		XI - IPA	203
		XII - IPA	324

Table 2. Teachers' Respondent Profile

No	Respondent Classification		Number
1.	Sex	Female	18
		Male	17
2.	Teaching Experience	>10 years	18
		7 – 9 years	3
		4 – 6 years	2
		1 – 3 year(s)	2

The instruments used are (1) Spatial ability test using Purdue Spatial Visualization Test, (2) Digital literacy questionnaire, and (3) questionnaire on Augmented Reality-based teaching media needs for teachers and students using Google Form. The test used is the spatial ability test (PSVT-R & D: Purdue Spatial Visualization test -Rotation and Development). The test consists of 24 questions which comprise of 12-question Visualization of Rotations test that is used to survey the students' capability to visualize three-dimensional objects' rotation and a 12-question Visualization of Development test that taps into the students' capability to transform two-dimensional objects into their three-dimensional counterparts (Bodner & Guay, 1997). The sample question of Visualization of Rotations test is show in Figure 1.

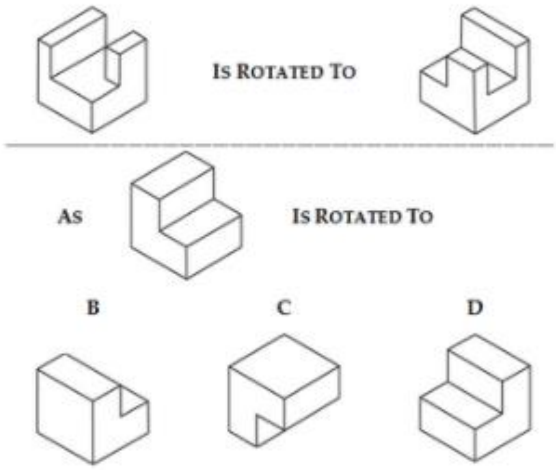

Figure 1. A Sample Question from PVST- Rotation Test

One point is awarded for each question answered correctly. The student's score is obtained from the total score in the maximum value section then multiplied by 100. The result is then categorized into high, mid, and low (Rahmawati et al., 2021). The test score convention used refers to the scoring reference as provided in Table 3.

Table 3. Students' Spatial Ability Test Score Reference

No	Score	Category
1.	75 - 100	High
2.	66 – 74	Mid
3.	0 – 65	Low

The student's digital literacy skills are measured using a questionnaire that is based on *"A Global Framework of Reference on Digital Literacy Skills"* which was adopted by the Ministry of Communication and Information. The students respond to 28 statements constructed of 4 sub-index and 7 competence areas as show in Table 4.

The data is analyzed on a Likert's scale where negative statements very disagree = 1, disagree = 2, not sure = 3, agree = 4, very agree = 5. The data from the questionnaire is then analyzed on SPSS to determine the response frequency of each indicator. The score from each indicator was then averaged to get the score for each sub-index. Then, the result is categorized into low, mid, and high. The test score result is using the reference provided by the Ministry of Communication and Information as shown in Table 5.

Table 4. Digital Literacy Index

No.	Sub-index	Competence Area	Indicator
1.	Information and Data Literacy	Information and Data Literacy	a. Browsing, searching, and filtering data, information, and digital content b. Evaluating data, information, and digital content
		Critical Thinking	a. Managing data, information, and digital content
2.	Communication and Collaboration	Communication Skills	a. Interacting through digital technologies b. Sharing through digital technologies c. Engaging in citizenship through digital technologies d. Collaborating through digital technologies
		Ethics in using technology	a. Netiquette b. Managing digital identity
3.	Digital content creation	Digital content creation	a. Developing digital content b. Integrating and re-elaborating digitalcontent c. Copyright and licenses d. Programming
4.	Safety	Device Safety	a. Protecting devices
		Privacy	a. Protecting personal data and privacy b. Protecting health and well-being c. Protecting the environment

Table 5. Digital Literacy Skill Score Reference

No	Score	Category
1.	4 - 5	High
2.	3 - 4	Mid
3.	0 - 3	Low

The closed questionnaire used is composed of 14 questions for students and 12 questions for teachers which tap into their perception of chemistry instruction, the use of molymod and animation as instructional media to describe molecular geometric forms, organic molecular compound structure, and the integration and disintegration of bonds in the chemical reaction. The need for AR-based media in chemistry instruction is also a part of the questionnaire.

3. RESULTS AND DISCUSSION

Results

The spatial ability of the 257 students was analyzed using the PSVT Test. The result is shown in Figure 2.

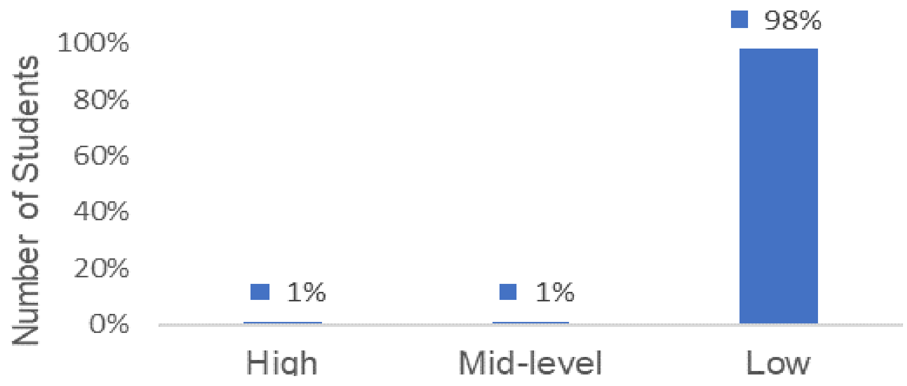

Figure 1. Students' Spatial Ability Category

Base on Figure 2 the graph shows that only 1% of the students display high spatial ability and another 1% shows mid-level spatial ability (three students each) while 98% (251) of the students demonstrate low spatial ability. The result of the digital literacy of 372 students is provided in Figure 3.

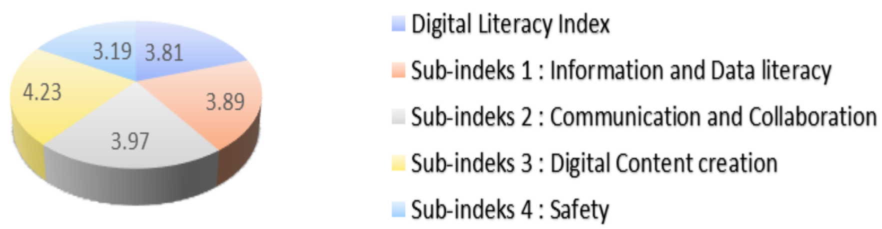

Figure 3. Students Digital Literacy Index

Base on Figure 3 the graph shows that for sub-index 1, 2, and 4, the students' digital literacy appears to be on the mid-level, while a high level is reached for sub-index 3 – Safety. Moreover, the questionnaire on AR-based Chemistry Instruction Media Needs was given to 332 students from three schools and 35 teachers in Sukabumi. The questionnaire reveals that approximately 83% of the students consider the process of integration and disintegration of bonds in chemical reactions as a challenging concept to understand. Eighty-six percent of the students also have trouble visualizing two-dimensional molecule forms in their textbooks into their three-dimensional forms. The teachers use molymod and animation as media to explain the concept. Approximately 86% of teachers use molymod to visualize molecule forms and the process of integration and disintegration of bonds in a chemical reaction. Only about 60% of teachers use animation as media.

Discussion

Both students and teachers share a similar view that some parts of chemistry concepts such as atoms, molecules, and chemical interactions are abstract. The results of interviews with teachers also show that teachers had difficulty in visualizing atomic particles or molecular geometric shapes at a sub-microscopic level that students cannot sense when teaching in class. Helping students understand this concept can be done by using two-dimensional images of molecular shapes and molymod media that can represent three-dimensional shapes of molecules. However, in reality, students still find it difficult to visualize the 2D shape of the molecule into a 3D shape. This difficulty arises from the disparity between students' understanding of 2D visualization on paper and the 3D molecule traits. Students also have difficulty in visualizing molecular structures at the submicroscopic level and relating them to other chemical representations (Rahmawati et al., 2021). This problem must be addressed immediately because students' ability to visualize molecular geometric shapes into 3D forms in chemistry can affect their understanding (Tamami & Dwiningsih, 2020). Another problem faced by students is the concept of chemical reaction equations. Students only understand that chemical reactions result from breaking and joining bonds to form new compounds without imagining the process in the three-dimensional form of the molecules of the compounds involved. The statement is in line with the study's results that it is hard for the students to visualize how molecules can interact with one another and create a novel chemical compound (Ewais & Troyer, 2019).

The ability to visualize two-dimensional molecular structure into three dimensions in chemistry learning is spatial ability. It is because chemistry is closely related to the ability to visualize molecules, especially information perception and spatial relationships in molecule representations (Antonoglou et al., 2014). The study shows that 98% (251) of the students demonstrate low spatial ability. The students who demonstrate low spatial ability may find it difficult to visualize molecular structure at the sub-microscopic level and relate it with other chemical representations (Rahmawati et al., 2021), as well as solve scientific problems (Wu & Shah, 2004). One causing factor could be that the teachers provided less than sufficient in-class explicit training which results in misconception. Another factor that should be taken into account is time constraints that force the teacher to simplify spatial information in a complex and abstract chemistry concept (Carlisle et al., 2015; Rahmawati et al., 2021; Wu & Shah, 2004). Hence, there is a need to improve spatial ability. This could be done through relevant classroom activities that are guided and designed specially to improve the students' external representation understanding (Carlisle et al., 2015). One technology that can help train spatial skills is Augmented Reality media in learning (Guntur et al., 2020). AR integration in teaching helps improve students' understanding of complex chemistry concepts by visualizing the concepts in 3D (Abdinejad et al., 2020). From the questionnaire, it is also found that the majorities of the teachers have not used AR as media and hope that this media is available to help them improve the students' understanding of abstract and complex chemistry concepts.

The survey results of students' digital literacy skills show that overall, of students' digital literacy appears to be at mid-level and requires improvement to face Industry 4.0. It is in line with previous study entittle "pedagogy in Industrial revolution 4.0". The researcher found that students are facing the problem of inability to select information and that technology addiction results in the shift of character and traits (Robandi et al., 2019). This result also added by other researcher that analyse affect of digital literacy for students. The result of study state that digital literacy turn into challenges for teachers to help and provide the students with opportunities to develop their digital literacy skills in the context of current and future technology needs (Blevins, 2018).

Implication of this study trying to provides an overview of the relationship between the use of AR learning media, spatial abilities, and students' digital literacy. This is because spatial ability is needed in learning chemistry because it will help students understand abstract and complex concepts at the submicroscopic level. The limitation of this study are limited to the scope of chemistry topic and test which in this study was analyzed using only the Rotational Visualization test which was used to survey students' ability to visualize the rotation of three-dimensional objects and the Visualization test. So it is hoped that the next researcher will be able to provide a more in-depth analysis that covers more topics in chemistry lessons related to digital literacy and spatial ability.

4. CONCLUSION

The students' spatial ability is still in the low category. This affects students in understanding complex and abstract chemical concepts at the submicroscopic level. Augmented Reality-based chemistry learning media is still rarely used in the classroom. Most teachers use molymod media to help visualize molecular geometric shapes and animations that can describe the process of breaking and forming bonds in chemical reactions. Although students' digital literacy skills are already at mid to good level, it is hoped that the use of Augmented Reality-based chemistry learning media is developed to train spatial ability and improve students' digital literacy skill.

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