

New Norms: Enhancing Biology Achievement, Creativity, and Student Innovation Post-Covid-19 Through Virtual Science Inquiry-Based Learning and Augmented Reality Applications

Norma Baharu: Meningkatkan Pencapaian Biologi, Kreativiti dan Inovasi murid Pasca Covid-19 melalui Pembelajaran Berasaskan Inkuiri Sains secara maya dan Aplikasi Augmented Realiti

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ABSTRACT

The COVID-19 pandemic opened a new chapter to digitalise learning strategies, especially in Biology education. Integration of an inquiry-based approach with technology, including Augmented Reality (AR), has become prevalent, allowing students to master the skills needed in 21st-century education. Hence, this study aims to identify the need to develop inquiry-based learning and the use of Augmented Reality (AR) applications in teaching activities and learning. This research uses quantitative and qualitative methods. A total of 303 Form 4 Biology students from 13 national secondary schools were selected for this study. The instruments used in this study included questionnaires to determine the level of difficulty in biology learning topics, diagnostic tests, semi-structured teacher interview protocols and questionnaires to analyse the level of student agreement with the module requirements. The data was then analysed through descriptive statistics, namely percentage and frequency, by SPSS software and thematic analysis. At the end of this preliminary study, it was found that the topic of Cellular Respiration was the main focus. The results of the diagnostic test showed that the student's level of understanding of the concept of Cellular Respiration was low. From the interviews conducted, three themes were identified. Thus, there is potential to improve the teaching and learning process in Biology through this research. The findings of this study indicated the need to develop a module based on inquiry-based Science education and the use of Augmented Reality (AR) in the teaching and learning process of Biology to contribute to the Industrial Revolution (IR 4.0).

Keywords: Biology, Science Inquiry-Based Learning, Augmented Reality (AR), Cellular Respiration

ABSTRAK

Pandemik COVID-19 membuka lembaran baharu untuk mendigitalkan strategi pembelajaran, terutamanya dalam pendidikan Biologi. Penyepaduan pendekatan berasaskan inkuiri dengan teknologi, termasuk Augmented Realiti (AR), telah menjadi berleluasa, membolehkan murid menguasai kemahiran yang diperlukan dalam pendidikan abad ke-21. Justeru, kajian ini bertujuan untuk mengenal pasti keperluan untuk membangunkan pembelajaran berasaskan inkuiri Sains dan penggunaan aplikasi Augmented Realiti (AR) dalam aktiviti pengajaran dan pembelajaran. Penyelidikan ini menggunakan kaedah kuantitatif dan kualitatif. Seramai 303 orang murid Tingkatan 4 Biologi dari 13 buah sekolah menengah kebangsaan telah dipilih untuk kajian ini.

Instrumen yang digunakan dalam kajian ini termasuklah soal selidik untuk menentukan tahap kesukaran dalam topik pembelajaran biologi, ujian diagnostik, protokol temu bual guru separa berstruktur dan soal selidik untuk menganalisis tahap persetujuan murid terhadap keperluan pembangunan modul. Data tersebut kemudiannya dianalisis melalui statistik deskriptif iaitu peratusan dan kekerapan menggunakan perisian SPSS dan analisis tematik. Di akhir kajian awal ini, didapati topik Respirasi Selular menjadi fokus utama. Keputusan ujian diagnostik menunjukkan tahap kefahaman pelajar terhadap konsep Respirasi Sel adalah rendah. Daripada temu bual yang dijalankan, tiga tema telah dikenalpasti. Justeru, terdapat potensi untuk menambah baik proses pengajaran dan pembelajaran Biologi melalui penyelidikan ini. Dapatan kajian ini menunjukkan keperluan untuk membangunkan modul berasaskan berasaskan inkuiri Sains dan penggunaan Augmented Realiti (AR) dalam proses pengajaran dan pembelajaran Biologi untuk menyumbang kepada Revolusi Industri (IR 4.0).

Kata kunci: *Biologi, Pembelajaran Berasaskan Inkuiri Sains, Augmented Realiti (AR), Respirasi Sel*

INTRODUCTION

The outbreak of the COVID-19 pandemic in the early 21st century precipitated a seismic shift in the world of education. Traditional classrooms were replaced by virtual spaces, while educators were tasked with reimagining their teaching methods to meet the challenges of remote learning. As the dust began to settle and the world adapted to a new normal, it became evident that the integration of digital technologies and innovative pedagogical approaches held the potential to transform education in profound ways. This study ventures into the realm of this "New Norm" in education, where digital learning, science inquiry-based teaching and augmented reality converge to redefine the landscape of biology education (Pacheco, 2021). The global pandemic forced global educational institutions to embrace digital learning as a primary mode of instruction. While this transition was born out of necessity, it catalysed a re-evaluation of traditional teaching methodologies and paved the way for innovative approaches to pedagogy. In response to the evolving demands of education, a paradigm shift towards science inquiry-based learning emerged. This pedagogical approach encourages students to become active participants in their learning journey, fostering curiosity, critical thinking and problem-solving skills. As one of the most promising candidates for next-generation mobile platforms, augmented reality (AR) has the potential to revolutionise the ways people perceive and interact with various digital information (Kim, 2021).

In the meantime, recent advances in display and optical technologies, together with the rapidly developing digital processors, offer new development directions to advancing near-eye display systems (Zhan Toa, 2020). In the sphere of science education, particularly biology, academic achievement remains a central goal (Xiaoming Zhai & James W. Pellegrino, 2023). Achieving success in biology not only entails mastering core knowledge but also cultivating the ability to apply scientific principles to real-world scenarios. Education's role extends beyond academic proficiency; it should also stimulate creativity and innovation. Nurturing creativity enables students to generate novel ideas, while innovation empowers them to translate these ideas into practical solutions. This statement is especially true in the field of biology, where solving difficult problems requires creative thinking. In the context of biology education, this study investigates the convergence of digital learning, science inquiry-based teaching and augmented reality applications. It attempts to investigate how these interrelated components can raise biology achievement, spark imagination and encourage students to think creatively and innovatively.

In essence, this study embarks on a journey into the future of education, where the convergence of digital tools, innovative pedagogies and immersive technologies ushers in a "New Norm." Further, it delves into the intricate tapestry of biology education, seeking to understand how this holistic approach can reshape the learning landscape, redefine achievement and inspire the next generation of creative and innovative thinkers in the post-COVID-19 era (Diana Evawati, 2023). Biology, often hailed as the "science of life," forms the foundation of human understanding of the natural world and the living organisms inhabiting it. In Blueprint Education, we embark on an exciting journey into the captivating realm of biology, where we explore the intricacies of life, from the tiniest cells to the grandeur of entire ecosystems.

This subject is designed to ignite your curiosity, deepen your knowledge and equip you with the fundamental principles necessary to comprehend the diverse and interconnected web of life on Earth. "The Malaysian Blueprint for Education 2013-2025 emphasises the importance of modernising biology education to equip students with the latest scientific knowledge and skills necessary for addressing environmental challenges and contributing to the nation's sustainable development.". The study of biology is no longer confined to rote memorisation. Digital learning, coupled with inquiry-based approaches, equips students with the critical thinking and problem-solving skills needed to excel in biology and apply their knowledge in practical scenarios (Agbi, A., & Yuangsoi, P. 2022).

BACKGROUND

Following the COVID-19 epidemic, the educational landscape underwent a profound upheaval that required educators to reconsider and modify their methods of instruction. As the use of digital platforms in education has grown, educators have looked into creative ways to keep instructions entertaining, effective and in line with students' changing requirements. This research explores the dynamic field of digital learning in the post-COVID-19 age, concentrating on the intersection of augmented reality (AR) applications in biology education and science inquiry-based learning. The study investigates the ways in which this comprehensive strategy can improve biology performance, ignite imagination and encourage students' ingenuity.

By transforming passive learning into an immersive experience, augmented reality encourages students' creativity and ingenuity. Beyond academics, education is crucial in developing these abilities. Students are empowered to innovate and think creatively owing to the "New Norms" approach, which also gives them the confidence to take on challenging biological problems. Through the integration of digital technology, inquiry-based learning and augmented reality, this progressive education prepares students for a world that is changing quickly. It paves the road for biology education that transcends boundaries and equips the next generation of scientists, inventors and creative thinkers as humans embrace the digital world, pique interest and capitalise on AR's immersion. This path takes advantage of change to fully realise the potential of education in our changing environment.

Augmented reality has emerged as a cutting-edge technology that enhances learning experiences by blending digital elements with the physical world (Mayilyan, H. 2019). In biology education, AR can offer immersive experiences, enabling students to visualise complex biological processes and structures. Achieving academic success in biology involves acquiring knowledge, mastering scientific principles and performing well in assessments. Effective teaching methods and tools should contribute to improved biology achievement outcomes. In addition to academic success, education should stimulate creativity and innovation. In short, creativity involves generating novel ideas, while innovation involves applying these ideas to solve real-world problems (Yustina, 2020).

PROBLEM STATEMENT

The integration of digital learning methods, including science inquiry-based learning and augmented reality applications in biology education in the post-COVID-19 era, presents a compelling opportunity to enhance student achievement, foster creativity and stimulate innovation. However, several key challenges and uncertainties surround the successful implementation of this multifaceted approach. The goal of the KSSM Biology curriculum (Standard Secondary School Curriculum) is now to provide students with science and technology knowledge and skills besides enabling them to solve problems and make decisions in daily life based on scientific attitudes and moral values (Ministry of Education Malaysia, 2013). Statistical data from the Ministry of Education and Culture also showed that pupil enrolment in Biology is ranked as the lowest, compared to Physics and Chemistry, hence indicating Biology subject as the least popular among Biology students. In addition, TIMSS 2019 data also illustrated that 25% of Malaysian students have not yet reached the international benchmarking level in the topic of Biology, with an average score of 399 or below (TIMSS, 2019).

Biology is a critical knowledge discipline in the 21st century where the mastery of knowledge in Biology can produce many technological innovations and discoveries in the field of science and technology, contributing to the development of society and the country (Campbell et al., 2018). Among the topics contained in Biology, it was shown that the topic of cell respiration is a difficult topic for students to understand (Norliza, 2017). This topic forms the basis of Biology in the fourth grade, which will be used when students study other topics in the fifth grade and when they continue their studies at a higher level. If this basic topic is not mastered, it might make it easier for students to better understand other topics. Creativity is the main focus of the country in the field of educational development, especially in the field of Biology (Park, 2012; Chumo, 2014). Apart from that, the need to finish the syllabus and more emphasis on test achievement (Manm, 2005; Neill, 2003; Rahimah, 2012) are among the factors causing PdPc to encourage less creativity.

Based on the results of Sirajudin's (2021) study, the students' creativity varies between low and medium, while the answers to the creativity test demonstrated results that were lower than expected. As digital learning becomes more prominent, ensuring equal access to technology and online resources remains a concern. Many students may lack the necessary devices or reliable internet access, potentially exacerbating educational disparities. The effective use of digital tools and innovative pedagogies requires educators to acquire new skills and adapt their teaching methods. According to Parama Kwangmuang (2021), most teachers are focused on developing and innovating teaching methods instead of learning innovation that stimulates students' self-learning skills, which can increase the search for information from the media or through independent ideas. The solution to the problems should be discussed, while the construction of an online module based on science inquiry-based learning needs to be built to improve student achievement in the topic of cell respiration, creativity and innovation in the fourth-grade Biology subject. Addressing these multifaceted challenges is vital to unlocking the full potential of digital learning, inquiry-based learning and augmented reality applications in Biology education. By tackling these issues, educators and policymakers can create a more inclusive, engaging, and innovative learning environment for Biology students in the post-COVID-19 era.

OBJECTIVE

To identify the need to develop a module based on inquiry-based science education and the use of Augmented Reality (AR) in improving students' achievement, creativity and innovation in Biology.

LITERATURE REVIEW

The new Biology Secondary School Standard Curriculum (KSSM) consisting of grades 4 and 5 is organised under five themes, namely Basic Biology, Human and Animal Physiology, Physiology of Flowering Plants, Ecosystem and Sustainability, as well as Inheritance and Genetic Technology. Each theme is divided into several learning areas, as shown in Table 1.

Table 1 Themes and Fields in KSSM Biology Form 4

Forms	Theme	Theme Level of Learning Area
Four	Fundamentals of Biology	<ul style="list-style-type: none"> • Introduction to Biology and Laboratory Rules • Cell Biology and Cell Organisation • Movement of Substances Across the Plasma Membrane • Chemical Composition in Cells • Metabolism and Enzymes • Cell Division • Cell Respiration

continued

Human and Animal Physiology	<ul style="list-style-type: none">• Respiratory System in Humans and Animals• Human Nutrition and Digestive System• Transport in Humans and Animals• Human Immunity• Coordination and Response in Humans• Homeostasis and the Human Urinary System• Support and Movement in Humans and Animals• Sexual Reproduction, Development and Growth
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Cellular Respiration Topic

Biology is one of the subjects that requires memorisation and understanding of concepts. According to Nor Asniza Ishak's (2021) study, the title Cellular Respiration is based on the matriculation program semester exam report at one of the matriculation colleges in northern Malaysia as one of the most difficult topics for Biology subjects at the pre-university level. This topic is also found to be of less interest to students. At the same time, Mohd Adnan Khan's study (2014) found that the results of the survey confirmed that cellular respiration is a difficult topic, and students cannot explain the concept of cellular respiration accurately and correctly. From the findings of Muhamad Shakir Saad's study (2018), it was found that at a higher level, students have failed to master the topic of Cellular Respiration; therefore, this topic needs to be given attention at the secondary school level again, as it is the basis for students to learn the topics such as the photosynthesis process. In the KSSM Biology syllabus, the topic of Cell Respiration is the fourth-grade Biology topic. The students who study this topic are students who take the fourth grade Biology subject.

Achievement in Cellular Respiration Topic

The average achievement of Biology around the world is falling; for instance, in Nigeria, reports have shown the persistently poor achievement of Biology students in SSCE administered by WAEC (Chief Examiner's Report, 2015–2017). According to the Chief Examiner's report (2016), students only performed better in practical Biology (paper 3) and performed poorly in Biology objectives (paper 1) and essays (paper 2). E.Ibe's study (2019) demonstrated that audio visual technology content had been integrated and tried in the teaching and learning process to increase student achievement, where teachers should try using audio visual materials during Biology teaching and learning. In Malaysia, the achievement of Sijil Pelajaran Malaysia (SPM) subjects for the years 2018 to 2019, especially Biology, still failed to show a significant improvement (Malaysian Examinations Board, 2019). In this regard, some researchers suggested the use of innovative methods that will improve student achievement and facilitate their interest in Biology (Aniweze, 2014; Onochie, 2010; Ezikwu and Eze, 2007).

Creativity in Biology

Every person has the potential to be creative; it is a gift from God. Still, not everyone can be inherently creative without developing their gift. In order to uncover students' ideas, creativity and innovation abilities must be continuously cultivated in students. Innovation and creativity are related to one another. They interact in the framework of education to make sure that both can be used in the process of teaching and learning. The reason that Biology courses and creativity are related is that everyone aspires to be highly creative, but especially the next generation of leaders of the nation. Fostering creativity in Biology classes might indirectly present students with opportunities.

Therefore, creativity skill needs to be nurtured in students to make the country highly innovative and advanced. According to Shi et al. (2017), various countries around the world also practice creativity in the community, in line with the rapid development of the era of science and information technology today. Creativity is a priority for education and is the core of the 21st-century learning discourse in the six elements (6C) found in PAK21. The concept of creativity in PAK 21 is the process of generating ideas, producing material innovation, as well as new, unique, useful and quality projects. The study by

Fachrunnisa (2020) using 25 students showed that students find themselves facing difficulties in expressing the fluency and elaboration found in the elements of creativity. In addition, they also displayed enthusiasm to learn more about teaching strategies in Biology subjects implemented in the classroom environment.

Innovation in Biology

In today's digital era, teachers need to innovate modern learning, including biological learning. Several studies have shown that learning innovations are developed to promote creative and critical thinking by applying theoretical principles into practice, combined with multimedia features and online learning (Hwang et al., 2018; Lee et al., 2004, 2021; Prahani et al., 2020; Saïdo et al., 2018; Strycker, 2020;). Parama Kwangmuang's study (2021) indicated that students who experience learning innovation have a higher average score than before learning, especially in analytical thinking, creative thinking and critical thinking. In today's digital era, teachers need to innovate modern learning, including biological learning. The paradigm that some students view Biology as a memorisation paradigm and that learning innovations are more modern and responsive to the latest technological developments should be eliminated. With the Industrial Revolution 4.0, which now involves the use of digital technology and the Internet for All (Internet of Things), innovation in biological learning can be done in various ways.

The important thing to note is how to change the old paradigm of biological learning in the era of Industrial Revolution 4.0; What is learning innovation? What does the era of Industrial Revolution 4.0 have to offer? Industrial Revolution 4.0 is about cyber-physical systems that can connect the digital world, such as humans through the Internet. Industrial Revolution 4.0 involves a two-way relationship between humans and electronic equipment that makes humans part of technology. This preparedness needs to be paid attention to, especially with the application of technological elements across innovation to the students.

Science inquiry-based learning

Inquiry-based Science Education (IBSE) is a constructivist approach often discussed and suggested for use in science subjects, including Biology, which has been implemented in most curriculum documents in Education around the world (Ramnarain and Hlatswayo, 2018). This science inquiry-based learning is very relevant to PAK21 and Education 4.0 as in PAK21, collaborative skills, creativity, critical thinking and communication are emphasised. Based on Kong Suik Fern's (2020) , inquiry-based learning can improve TIMMS and PISA scores or results through active learning by involving students directly. There are three main elements in science inquiry-based learning, which are questions, explorations and conclusions. Teachers will pose questions to the students about a concept, while the students will be asked to conduct exploratory activities and then draw conclusions based on the answers to the questions that arise.

Learning based on science inquiry is very important to give students the opportunity to think analytically, creatively and innovatively. These skills are very necessary in the era of the 4th industrial revolution and "digital disruption". The results of this learning can be applied by the students when faced with the world of work in the future where a workforce with skills like this is very much needed now and even more so in the future.

Augmented Reality (AR) Technology in Biology

Changes in the education system need to be made by giving exposure to students from primary school to university about Industrial Revolution 4.0. If early exposure to Industry 4.0-related technologies can be given and encouraged, a skilled workforce can be created according to market needs. Based on Mohd Razali Abd Samad (2022) shows that students give a positive perception towards the use of technology and can reduce the use of traditional learning methods. One of the uses of technology in education is the use of Augmented Reality in the teaching and learning process. Augmented Reality (AR) enables interactive experiences with the real world where objects in the real world are enhanced by computer-

generated perceptual information. This technology has positively influenced various fields, such as education, industry, entertainment, medicine and tourism, among others. According to Mohd H. A. Kalana (2020), the use of AR in Biology learning is very innovative compared to normal learning. AR technology can apply a culture of innovation in teaching that can make PdPc more interactive and improve quality in the field of education (Rohaila & Fariza, 2016).

Augmented Reality technology is a solution that can help make observations easier, since it is able to depict 2D objects in 3D. The 3D forms used in this module are objects and pictures related to the topic of Cellular Respiration, including mitochondrial organelles. Apart from that, to make it easier for students to remember the word equations in Cell Respiration, the equations are shown in AR form so that students can easily understand and remember them. To attract students' interest in the topic of Cellular Respiration, virtual practice using AR technology is also used in this module. Students can try aerobic experiments using AR. The use of AR in the world of education is no stranger as it has become an intermediary between the world of reality and the real world. Students will feel immersive in the AR simulation game; that is, they feel as if they are interacting with the virtual environment created, like running a virtual practice. So, it is not surprising that AR has the potential to bridge the gap between formal and informal learning as it can stimulate high motivation and create passive learning.

According to Hakan (2022), materials based on animation and AR increase student achievement and motivation, as well as having a more positive attitude. Based on Bautista's research (2022), it has been proven that the use of AR in Biology significantly increases learning achievement as it was demonstrated that post-test scores were higher than pre-test scores, thus showing that the teaching intervention through the use of AR helps in increasing the respondent's score. This finding is also supported by the study of Azidah Abu Ziden (2022) stating that the use of AR can help in achieving an effective learning process. The results of the research presented a significant difference in student achievement when using AR. According to Mystakidis (2022), the use of AR makes it easier for students to acquire skills, especially in courses with a high three-dimensional visualisation component, besides passively affecting various aspects of the learning process, such as motivation, satisfaction or autonomous learning. AR is also an educational technology tool used for higher education in health science, which improves the teaching-learning process by influencing it in a multidimensional way. So, the use of AR at the secondary school level may help students when continuing their studies at a higher level, especially in the field of health.

MATERIALS AND METHODS

This research employs quantitative and qualitative approaches. A total of 123 Form 4 students from national secondary schools in Pulau Pinang were selected in this study. In addition, three Biology teachers were interviewed to explore how they implemented the teaching of Biology in the classroom. The instruments comprised a need analysis questionnaire to determine the level of difficulty in Biology learning areas, a diagnostic test and a teacher interview protocol. The need analysis questionnaire was adapted from that by Nor Tutiani Ab. Wahid (2019). The questionnaire consisted of four sections, namely the demographics of the respondents, the students' consensus level questions on the module requirements, difficult topics in the Form 4 KSSM biology subjects and open-response questions. The students were still learning from home while this research was conducted. Hence, this questionnaire was given to students through Google Forms. After identifying one learning area to be focused on in this study, a diagnostic test was conducted. Diagnostic tests carried out at the beginning of this study aimed to identify titles that pupils could not answer well and poorly. The purpose of this diagnostic test is to help the teacher identify the cause of the student's failure to master a title. The implementation of these diagnostic tests can help teachers design teaching methods or techniques that are specific to an individual or group more accurately and systematically. A semi-structured interview containing 13 questions was constructed based on a review of the literature to gauge the extent to which the e-ReSP-AR module needs to be built based on the Biology syllabus. Researchers interviewed three expert teachers to obtain a response on the difficult titles in the Form 4 syllabus and the challenges in teaching them.

RESULTS AND DISCUSSION

Results of the Diagnostic Tests

As a result of the results of the Biological Diagnostic Test for 123 Form 4 students based on the assessment range shown in Table 4.5, it was found that the achievement of the students ranged from good to weak. Table 4.5 shows the overall diagnostic test results with only 3 pupils (2.4%) scoring at excellent levels (90-100 marks), 17 pupils scored well (75-89 marks), 17 pupils scored moderately (65-74 marks), while the majority of 67 pupils scored weakly (40-64 marks) and 19 failed (0-39 marks). The conclusion of the results explained that more than half of pupils have poor levels of achievement in Biology.

Table 1.0 Diagnostic Test evaluation range

Grade	Range	Scores Matter
A	90-100	EXCELLENT
B	75 – 89	GOOD
C	65 – 74	MEDIUM
D	40 – 64	WEAK
E	0 - 39	FAILED

Table 2.0 Summary of Overall Results of Form 4 Biological Diagnostic Tests

Grade	Total Pupil	Percent%
A Excellent	3	2.4%
B Good	17	13.8%
C Medium	17	13.8%
D Weak	67	54.5%
E Failed	19	15.4%
Total	123	100%

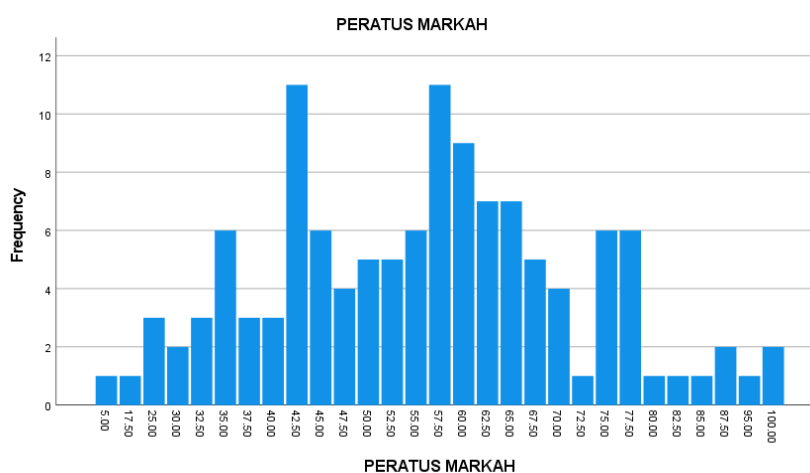
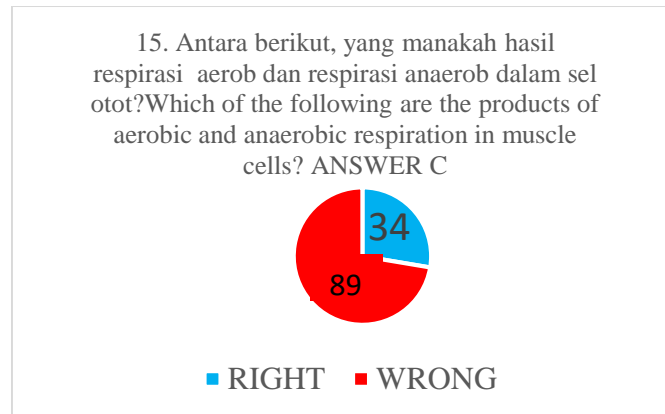


Figure 1.1 Normal distribution of Form 4 Diagnostic Test results

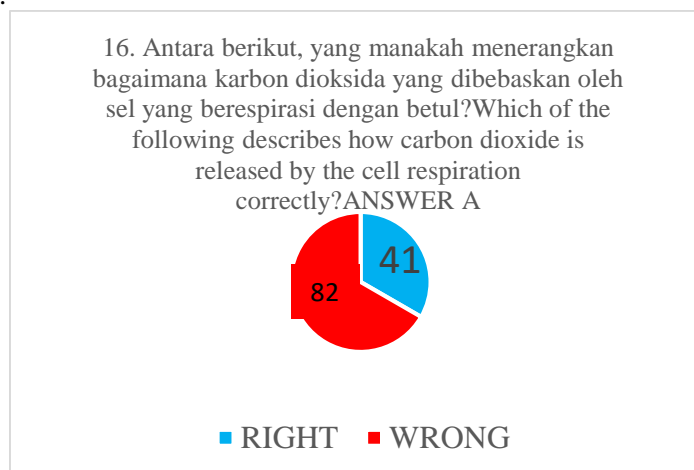
Within the biological diagnostic test, three questions pertained to the topic of cell respiration, specifically questions numbered 15, 16 and 19 (as found in Figures 1.2, 1.3 and 1.4). The analysis of the students' responses revealed that, for Question 15, 34 individuals responded correctly, while 89 were unable to provide the correct answer. Regarding Question 16, only 41 respondents answered accurately, whereas 82 struggled to do so. Similarly, for Question 19, a total of 48 students managed to respond

correctly, while 75 encountered difficulties in providing an accurate response. This collective evidence suggests that students have not yet fully grasped the concepts related to cell respiration, as indicated by their performance on these questions.



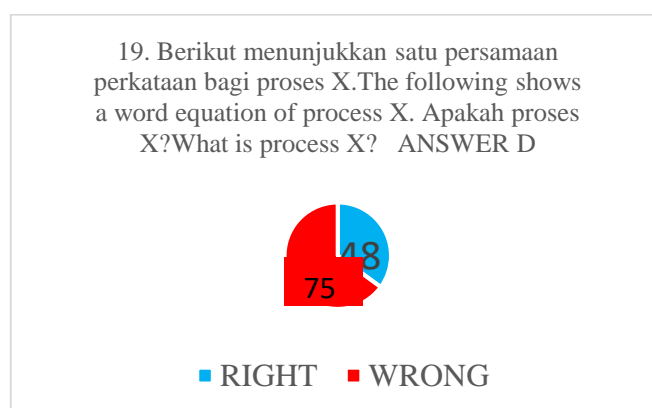
Figures 1.2

For this question, 15 students were able to answer the question correctly, while 89 students were unable to answer accurately.



Figures 1.3

Referring to Question 16, 41 people answered correctly, while 82 students were unable to answer correctly.



Figures 1.4

Referring to Question 19, 48 students were able to answer this question accurately, while 75 students were unable to answer correctly.

Needs Analysis Questionnaire Analysis

The results of feedback from respondents through a needs analysis questionnaire distributed online using a Google form to students taking Biology subjects throughout Penang by their teachers were analysed to obtain frequencies, percentage values, mean values and standard deviations to allow data analysis to be made. Among the information contained were gender, race, science achievement during PT3, Biology achievement in Level 4 Final Examination, school name and state. Table 3.0 shows the findings of the Needs Analysis based on the questions given as follows:

Findings of Needs Analysis based on questionnaires

16) Analysis of the Level of Student Agreement on Module Requirements

In this section, the researcher has expressed 25 statements to respondents regarding the construction requirements of the e-ReSP-AR module. The findings can be summarised as shown in Table 3.0 below.

Table 3.0 Student agreement on module requirements

Bil	Items	Scale				
		1	2	3	4	5
2.	A learning approach based on scientific inquiry helps the achievement of Biology subjects.	0.6% (1)	1.1% (2)	-	71.1% (128)	27.2% (49)
14.	I always thought, “I can’t do it”, when the biology assignment given was quite difficult.	6.1% (11)	35.6% (64)	-	47.2% (85)	11.1% (20)
15.	I think it is important for me to have knowledge about Biology to get a good job.	1.7% (3)	-	-	71.1% (128)	27.2% (49)
16.	The biology teachers know the situation when I have problems with my assignments.	1.7% (3)	8.9% (16)	-	79.4% (143)	10.0% (18)
20.	I like to use learning by using 'online' modules (online).	6.7% (12)	28.3% (51)	-	50.6% (91)	14.4% (26)
21.	Teaching modules using technology, for example, Augmented Reality @ Augmented Reality (AR), need to be increased to help students in Biology subjects.	1.1% (2)	7.2% (13)	-	72.2% (130)	19.4% (35)

continued

22.	The use of Augmented Reality @ Augmented Reality (AR) method helps students' PdP activities.	1.1% (2)	6.7% (12)	-	7.3.3% (132)	18.9% (34)
23.	The use of technology helps my achievement in Biology subjects.	0.6% (1)	3.3% (6)	-	68.3% (123)	27.8% (50)
24.	I like using Augmented Reality (AR) elements in PdP.	2.2% (4)	9.4% (17)	-	66.1% (119)	22.2% (40)
25.	I like it when teachers use technology to teach.	1.1% (2)	1.7% (3)	-	63.9% (115)	33.3% (60)

Note:

- 1: Strongly Disagree
- 2: Disagree
- 3: Disagree
- 4: Agree
- 5: Strongly Agree

Table 3.5 shows the mean for each item presented to students. The overall student response showed a positive response to the needs of the module construction. Item no 25 (I like it when teachers use technology to teach) demonstrated the highest mean value of 4.27. It shows that the use of technology is an element that is very much preferred by students. This statement is supported by the 2nd item (Scientific inquiry-based learning approach helps the achievement of Biology subjects), which has a mean value of 4.23. It was shown that when the use of technology is combined with science inquiry methods, students will be interested in learning the topic of Cellular Respiration. On the third highest item, which is Item 15 (I think it is important for me to have knowledge about Biology to get a good job), studying Biology using this method will increase the student's knowledge of Biology, which in turn increases achievement and makes it easier for them later to look for job opportunities, as the 23rd item (The use of technology helps my achievement in biology subjects) yielded a mean value of 4.19. The 22nd item showed that students strongly agreed that the use of AR can help students' PdP activities, with a mean value of 4.02.

Difficult Topics in KSSM Biology Form 4

Below is an analysis of difficult topics presented in the requirements analysis questionnaire.

Table 4.0 Difficult Topics in Form 4 KSSM Biology Subjects

Bil	Items	Scale					Mean
		PM	M	SS	S	PS	
1.	Introduction to Biology and Laboratory Rules	46.7% (84)	40.6% (73)	8.3% (15)	4.4% (8)	-	1.71
2.	Biology and Cell Organisation	6.1% (11)	50.0% (90)	37.2% (67)	3.9% (7)	2.8% (5)	2.47
3.	Movement of Substances Across a Plasma Membrane	3.3% (6)	33.3% (60)	55.0% (99)	7.2% (13)	1.1% (2)	2.69

continued

4.	Chemical Composition in a Cell	3.3% (6)	26.7% (48)	57.8% (104)	10.6% (19)	1.7% (3)	2.81
5.	Metabolism and Enzymes	3.9% (7)	31.1% (56)	46.1% (83)	16.7% (30)	1.7% (3)	2.81
6.	Cell Division	1.7% (3)	27.2% (49)	48.9% (88)	18.9% (34)	3.9% (7)	2.97
7.	Cellular Respiration	6.0% (1)	20.0% (36)	50.6% (91)	25.0% (45)	3.9% (7)	3.12
8.	Respiratory System in Humans and Animals	3.3% (6)	33.3% (60)	51.7% (93)	11.1% (20)	1.1% (2)	2.74
9.	Nutrition and Human Digestive System	3.9% (7)	27.2% (49)	50.6% (91)	15.6% (28)	2.8% (5)	2.86
10.	Transport in Humans and Animals	1.1% (2)	23.9% (43)	52.2% (94)	18.9% (34)	4.4% (8)	3.02
11.	Immunity in Humans	4.4% (8)	31.7% (57)	47.8% (86)	14.4% (26)	3.3% (6)	2.82
12.	Coordination and Response in Humans	1.7% (3)	20.0% (36)	53.3% (96)	18.9% (34)	6.7% (12)	3.09
13.	Homeostasis and the Human Urinary System	3.9% (7)	17.2% (31)	47.2% (85)	24.4% (44)	7.2% (13)	3.14
14.	Support and Movement in Humans and Animals	2.2% (4)	20.6% (37)	56.1% (101)	17.2% (31)	3.9% (7)	3.00
15.	Sexual Reproduction, Development and Growth in Humans and Animals	3.9% (7)	24.4% (44)	46.1% (83)	17.2% (31)	8.3% (15)	3.02

PM: Easiest

M: Easy

SS: Moderately Difficult

Q: Difficult

PS: The most difficult

The results of the analysis of difficult topics in Biology subjects guided by Table 4.0 showed that the topic cellular respiration has a mean value of 3.12; according to Murniza Muhamad et al. (2012), topics that obtain an average mean of more than 3.0 are considered difficult by students and teachers. This finding is supported by the study of Rafiza Rosli et al. (2022), showing the results of a needs analysis conducted to assess difficult topics in Biology subjects; for the title Cellular Respiration, the mean value obtained was 3.12. This finding is also supported by Saidatul Ainoor Saharim's (2023) study of the difficult topic test, which obtained a mean of 4.18. Therefore, the topic of Cellular Respiration needs to be paid attention to, as the analysis of SPM biology questions demonstrated that the topic of cell respiration is a topic that is frequently asked every year. Apart from that, the selection of the cellular respiration topic was based on the quality of SPM 2018 biology answers provided by the Malaysian Examinations Board. Apart from that, the title of cellular respiration is also the basic title of Form 4 Biology.

Expert interview and analysis

During this needs analysis phase, expert interviews were conducted with the aim of identifying the challenges students encounter in the Cellular Respiration topic. A semi-structured interview approach was employed and adhered to a specific interview protocol. These interviews were conducted individually with three biology expert teachers in Penang.

Theme 1 Teacher's views on difficult topics in Biology subjects

Analysis of the Cell Respiration chapter, which is an important chapter for students to learn and master, found that all three respondents agreed that this chapter is important. The RS2 teacher explained in an interview:

.....this chapter is important because it is still on the basic theme of Biology, which is considered the basis for students to learn more deeply about other themes in Forms 4 and 5....

(RS 2/TB1/86)

The RS3 teacher also agreed by stating that students can learn the types of cell respiration and the processes that occur in aerobic and anaerobic respiration (fermentation). Supported by the teacher, RS1 also agreed that chapter 7 is important as it is the basis for other chapters; students need to know how glucose is obtained to produce energy since there is a connection between chapter 9, which is about Assimilation, and chapter 12 where students need to know where the energy comes from for the 'fight or flight' action. The RS1 teacher emphasised that this chapter is very important for students to master to enable them to learn the next chapters, including photosynthesis.

Theme 2 Strategies used by teachers in teaching this chapter

All three teachers lack experience and skills in using AR. When asked about a suitable platform for students to learn AR, they unanimously agreed that smartphones are the appropriate choice. This underscores the significance of the Cellular Respiration chapter as a foundational concept for subsequent topics. Expert interviews have revealed a consensus among experts, emphasising the necessity of developing a dedicated module on Cell Respiration and incorporating supplementary AR elements as educational tools to enhance students' comprehension of this subject.

Theme 3 Technology will make it easier for teachers to teach this topic

When discussing the integration of technology into teaching and learning sessions, the typical teacher primarily relies on 'PowerPoint slides' and subsequently engages students through group discussions by posing questions. Enhancements in technology utilisation are limited to the inclusion of 3-dimensional videos or clear videos, aiming to facilitate student comprehension by simulating movement. For the question of whether the use of AR technology helps in making it easier for teachers to teach this topic, the RS1 teacher responded:

.... the use of AR in this topic is very helpful to the students; they will see more clearly, see the simulation, see that the matter is more 'real' and help them understand more in a subtopic....

(RS1/TB/58)

The findings from expert interviews indicate that Cellular Respiration serves as a foundational chapter that students must grasp to facilitate their understanding of subsequent topics. Experts unanimously agreed on the necessity of developing a module centred around Cell Respiration and incorporating additional augmented reality (AR) elements to enhance students' comprehension of this subject.

CONCLUSION

The promising potential of augmented reality in biology education, particularly in the context of cellular respiration lessons, has been demonstrated by this study. The outcomes have yielded a framework for creating inquiry-driven, augmented reality-based biology learning modules. Biology students' interests are piqued when they see Biology presented in an augmented-reality setting. Moreover, it puts scientific knowledge in context. The interest and comprehension of the students may rise using this strategy. More teacher preparation is advised to carry out these modules efficiently. All things considered, combining augmented reality, digital learning and inquiry-based teaching in Biology education has shown an intriguing new path in the rise of COVID-19. It demonstrated how cutting-edge instruction and technology can enable learning to occur outside physical constraints. Students may engage with complex ideas and learn biology in novel ways thanks to the additional dimension brought by augmented reality. This examination of "New Norms" has revealed the potential benefits of augmented reality.

By transforming passive learning into an immersive experience, augmented reality encourages students' creativity and ingenuity. Beyond academics, education is crucial in developing these abilities. Students are empowered to innovate and think creatively due to the "New Norms" approach, which also gives them the confidence to take on challenging problems in Biology. Through the integration of digital technology, inquiry-based learning and augmented reality, this progressive education prepares students for a world that is changing quickly. Besides, it paves the road for Biology education that transcends boundaries and equips the next generation of scientists, inventors and creative thinkers as people embrace the digital world, pique interest and capitalise on AR's immersion. This path takes advantage of change to fully realise the potential of education in the ever-changing environment.

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