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Validity and Reliability of The e-ReSP-AR Module for Inquiry-Based Biology Learning on Cellular Respiration

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ABSTRACT - This study aims to evaluate the validity and reliability of the e-ReSP-AR Module developed using the six-step ASSURE Model. The content validity of the module was assessed by nine experts, including lecturers from public universities and specialist teachers with expertise in language, module content, pedagogy, and curriculum. Meanwhile, the module's reliability was obtained from 46 form four students taking Biology. The Cronbach's Alpha score obtained for the module's content validity was 0.89, while for reliability, it was 0.91. Positive feedback was received from respondents regarding the module's reliability, achieving a high reliability value. Overall, the e-ReSP-AR Module demonstrates good content validity and excellent reliability. The Content Validity Index calculation shows that the sessions and activities in e-ReSP-AR are very appropriate and can be used in the study. These findings clearly indicate that the e-ReSP-AR Module has been well developed according to the complete module development procedures and is appropriate for use.

INTRODUCTION

The 4.0 revolutionary era, better known as the 21st century, requires humans to adapt to digitalisation and globalisation. STEM education refers to an educational approach that guides students through four main fields, namely Science, Technology, Engineering, and Mathematics, to strengthen their skills and knowledge in these fields (Jamaluddin et al., 2025). The STEM approach is real-world oriented and suitable for the 21st century; it crosses various fields of knowledge that are broad and interconnected. STEM education is very important as it plays a vital role in producing human capital capable of addressing challenges, competing positively, and possessing high levels of knowledge and skills. This aligns with the country's efforts to advance towards modernisation at the global level (Hasnawati, 2023). STEM skills refer to students' proficiency and competence in exploring, problem-solving, designing, as well as producing products creatively and innovatively (Shamsuddin & Noor Ibrahim, 2021).

Contemporary learning allows students to always have an inquisitive nature in producing innovations in the learning process and subsequently contribute ideas or innovative creations in everyday life applications (PPPM 2013-2025) The goal of the KSSM Biology curriculum (Secondary School Standard Curriculum) now moves to equipping students with knowledge and skills in science and technology, as well as to enabling them to solve problems and make decisions in daily life based on a scientific attitude and noble values (Ministry of Education Malaysia, 2013).

The biology curriculum in Malaysian secondary schools aims to scientifically develop literate students with strong biological knowledge, scientific skills, and positive scientific attitudes, enabling them to apply biological concepts and pursue further studies in STEM-related fields (Ministry of Education Malaysia, 2018).Biology involves complex processes, making the use of overly specific terms difficult to study,

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especially in topics like cellular respiration (Patro, 2008; Rice, 2013). The study by Pérgola and Pérez (2025) also emphasises the topic of Cellular Respiration as among the most important topics in Biology and biochemistry, as it explains the process by which cells produce the energy needed to maintain life functions. Cellular respiration is an important topic in Biology that helps us understand life. Understanding this process also contributes to developments in the fields of medicine, biotechnology, and environmental science using technology (Shuai Yang, 2024). According to the study by Byukusenge et al. (2023), teacher perceptions show that difficulties in understanding certain topics in Biology stem from the abstract nature of concepts and can be taught using 3D models. Using Augmented Reality (AR) in learning can help students build 21st-century skills such as critical thinking, collaboration, and digital literacy (Schmidthaler et al., 2023).

According to Fajarniangtyas and Jefri (2020), success in the context of education does not only depend on academics but also emphasizes the ability to develop new ideas, solve problems creatively, and integrate information with technological skills through innovation. Based on the results of interviews conducted by Sheilla Putri (2023) with Biology teachers at MAN 1 Deli Serdang, it was found that quite a few students still lack creativity. However, at present, facts in the field show that creativity in students remains a problem that is still often faced to this day (Purwaningsih & Supriyono, 2020). Apart from that, in science education, innovation is also greatly needed to foster higher scientific literacy (Obikezie, 2022)

Current literature review shows that although AR is often integrated into active or constructivist pedagogy, assessments of structured pedagogical contexts that affect its long-term impact on student learning are less reported, making understanding the relationship between AR, inquiry approaches, creativity, and student innovation less thoroughly explored (Stanič & Špernjak, 2025). The use of technology would enhance students' understanding of the concepts being taught (Adeosun et al., 2022) In this regard, the e-ReSP-AR module, which integrates Augmented Reality (AR) technology, was developed to enhance students' achievement in the topic of Cellular Respiration, as well as to foster creativity and innovation in the Form 4 Biology subject. Module development studies provide important implications for the design and improvement of instructional modules in Biology education, particularly in enhancing teaching effectiveness and learning outcomes. (Rosli & Ishak, 2024).

Therefore, a study aimed at developing an online module for inquiry-based science learning combined with Augmented Reality technology needs to be developed to improve students' achievement in the topic of Cellular Respiration, creativity, and innovation in the Form Four Biology subject.

RESEARCH METHODOLOGY

The e-ReSP-AR Module was developed using the ASSURE Model, since it incorporates an integrated approach to media and technology in the teaching and learning processes (Smaldino et al., 2015). According to Ahmad (2002), the module activities to be developed must comply with the model or sequence that has been set. At this stage, three steps of the ASSURE Model are involved, namely A - Analyse Learner, S - State Objective, and S - Select Methods, Media, and Materials. The module is developed based on a storyboard draft since it has yet to be evaluated and tested for its effectiveness. Subsequently, the final step in the ASSURE Model, namely E- Evaluate and Revise Instruction, is carried out, in which the draft module prototype is validated by experts, followed by a pilot study conducted with students. The word ASSURE refers to six steps comprising: i) Analyse students, ii) State standards and objectives, iii) Select methods, media, and teaching aids, iv) Utilising media and teaching aids, v) Requiring learner participation, vi) Evaluating and revising teaching aids.

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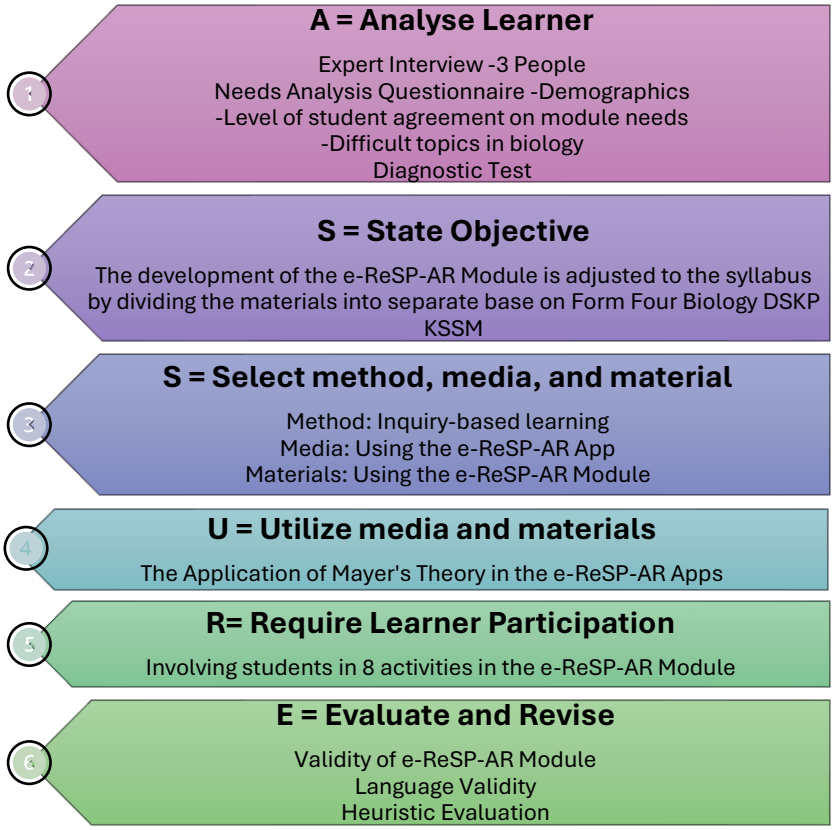
Table 1. Development Steps of e-ReSP-AR



1. Analyze Learner

The first phase involves the process of identifying the characteristics and needs of the learners. In the development of the e-ReSP-AR Module, interviews with three experts were conducted alongside the implementation of a needs analysis questionnaire. The questionnaire focused on the students' demographic background, the level of students' agreement regarding the module's requirements, and identifying Biology topics considered difficult. In addition, diagnostic tests were also conducted to identify the existing knowledge level and learning difficulties faced by the students.

2. State Objective

The second phase emphasizes the setting of clear learning objectives. The development of the e-ReSP-AR Module is aligned with the Form Four Biology syllabus based on the KSSM Curriculum and Assessment Standard Document (DSKP). The module content is systematically divided according to the topics in the syllabus to ensure that the learning objectives are in line with curriculum requirements.

3. Select Method, Media, and Material

At this stage, appropriate teaching methods, media, and learning materials are selected to support the effectiveness of the teaching and learning process. Inquiry-based learning methods are chosen because they can encourage active engagement and critical thinking among students. The e-ReSP-AR application is used as the learning media, while the e-ReSP-AR Module serves as the main material in the implementation of learning activities.

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4. Utilize Media and Material

This phase involves the use of media and materials that have been selected in the teaching process. In the application of e-ReSP-AR, Mayer's Multimedia Learning Theory is applied to ensure that multimedia elements such as text, graphics, animations, and interactive features can help enhance student understanding and reduce cognitive load during the learning process.

5. Require Learner Participation

This phase emphasizes the active involvement of students in the learning process. Students are engaged in eight learning activities provided in the e-ReSP-AR Module. These activities are designed to encourage exploration, interaction, problem-solving, and collaborative learning so that students can understand Biology concepts more deeply.

6. Evaluate and Revise

The final phase involves the process of evaluating the effectiveness of the module and the improvements needed. The evaluation conducted includes the validity of the e-ReSP-AR Module, language validity, and heuristic evaluation. The results of this evaluation are used to make improvements to the module to ensure its quality, usability, and effectiveness in supporting Biology learning.

Overall, the ASSURE model provides a systematic framework in the development and implementation of the e-ReSP-AR Module to ensure that the instructional design developed can meet student needs and enhance the effectiveness of Biology learning.

RESULTS AND DISCUSSION

The developed e-ReSP-AR Module is intended for use by teachers and students as a teaching and learning resource. The module comprises several key components, including the front cover, preface, table of contents, synopsis, introduction, aims and objectives, theoretical framework, module implementation process, instructions for use, lesson plans incorporating elements of science inquiry based, the e-ReSP-AR Apps manual, exercises, answer keys, and references. Examples of the e-ReSP-AR Module are presented in Figure 1.

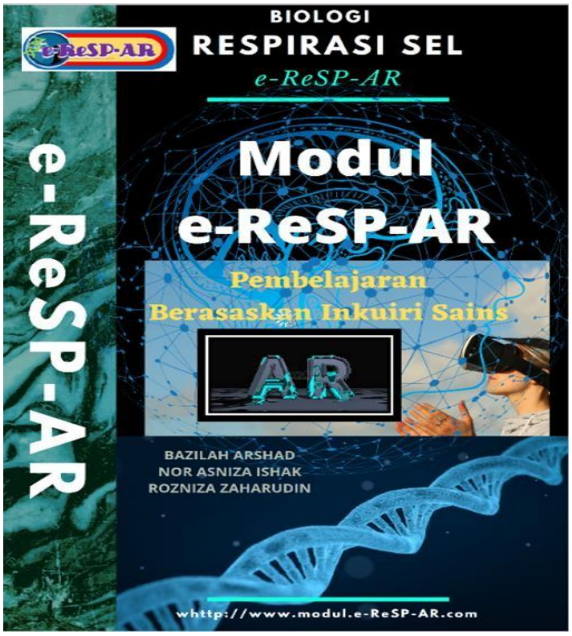

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Figure 1. Cover, Table of Contents, Instructions

Table 2. The Data of the e-ReSP-AR Module Validation Test Reviewed by Experts

Validation Aspects	Findings	Conclusion
Validity of the e-ReSP-AR Module Content	.89	Accepted
Face Validity of the e-ReSP-AR Module	.84	Accepted
Heuristic Evaluation Validity	.87	Accepted
Language Validity of the e-ReSP-AR Module	.94	Accepted

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The results in Table 2 represent the data of the e-ReSP-AR Module validation test reviewed by experts. The findings indicate that the content validity of the e-ReSP-AR Module obtained a value of 0.89, which is considered acceptable. In addition, the face validity of the module recorded a value of 0.84, indicating that the module is appropriate and suitable for use. Meanwhile, the heuristic evaluation validity also displayed a high value of 0.87, demonstrating that the design and usability of the module met the required standards. Furthermore, the language validity of the e-ReSP-AR Module obtained the highest value of 0.94, suggesting that the language used in the module is clear, appropriate, and easily understood. Overall, all validation aspects revealed high scores and were accepted by the experts, proving the validity and suitability of the e-ReSP-AR Module as a teaching and learning resource.

Table 3. *Differences in the Unrevised Version and the Revised e-ReSP-AR Modules*

Before	After
Main Pages	
	
	

Table 3 presents the differences between the unrevised and revised versions of the e-ReSP-AR Module based on expert recommendations. The comparison highlights several improvements made to enhance the usability, design, and effectiveness of the module.

In the unrevised version (Before), the main page of the module displayed a simpler interface with a list of topics arranged vertically, such as *Introduction, Energy, Aerobic Respiration, Let's Do an Experiment, Fermentation, Similarities and Differences,* and *What Are the Differences*. However, the layout appeared less interactive and visually limited.

After revision (After), the main page was redesigned with a more modern and interactive mobile interface. The revised version features a clearer navigation structure, improved graphical elements, and a more attractive visual presentation. The menu options are displayed more systematically, making it easier for users to navigate through the module content. Overall, the revisions were made to improve the user interface, accessibility, and learning experience of the e-ReSP-AR Module, ensuring that it is more engaging and user-friendly for students and teachers during the teaching and learning process.

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a) Determining the Validity of the e-ReSP-AR Module

The calculation of the appropriate level average according to expert assessment is based on the Content Validation Index (CVI). The CVI value in a study can be evaluated using two methods, namely the Item Content Validation Index (I-CVI) and the Sum of Content Validation Index (S-CVI). For this study, the I-CVI method is used because the CVI value is calculated according to each item on the scale. Each expert involved is given a questionnaire and a validity assessment form. Next, the experts are asked to evaluate the items using a four-point (4) scale, namely 1 (Not Relevant) to 4 (Highly Relevant). Finally, the total evaluation score for each item is divided by the number of appointed experts.

$$\textit{Item Content Validation Index}\ (\text{I-CVI}) = \frac{\text{Total score of each expert}}{\text{Actual score total}}$$

$$\text{Content Validity Index (CVI)} = \frac{\text{Total I-CVI}}{\text{Number of experts}}$$

To ensure the high-quality development of this module and its suitability as an intervention tool for this study, its validity was evaluated. A total of nine experts from local universities were selected to assess the module's validity. Seven of these experts were appointed from among lecturers from the local university, with two experts from Teacher Training Institutes. The selected experts have extensive experience in the fields of Biology, Creativity, and Inquiry. Three experts with extensive experience in Augmented Reality were also selected to evaluate the heuristic instrument in terms of the usability of the developed app. The questionnaire used for module evaluation was adapted from Murugan Mini Ratamun (2018). The heuristic evaluation was based on Syamsul Bahrin Zaibon (2011). The details of the module reviewers and assessors are shown in the Table 4

Jadual 4. Details of the e-ReSP-AR Module Reviewer and Evaluator Panel

Number	Name	Position	Department / Institution	Expertise	Experience
1.	Expert 1 (Biology)	Lecturer (Dr.)	SEAMEO RECSAM	Biology	30 Years
2.	Expert 2 (Biology)	Senior Lecturer (Dr.)	Department of Biology FSM (UPSI)	Biology	21 Years
3.	Expert 3 (Biology)	Lecturer (Dr.)	Faculty of Science and Mathematics (UPSI)	Biology & Science Education	13 Years
4.	Expert 4 (Creativity)	Lecturer (Associate Professor)	Faculty of Psychology and Education (UMS)	Instructional Design & Development, Scientific/Mathematical Thinking, Scientific Mathematicaal, Creativity, Future Thinking Scientific Imagination, STEM Education	33 Years
5.	Expert 5 (Inquiry)	Lecturer (Dr.)	IPG Tuanku Bainun	Biology and Inquiry (IBSE)	22 Years
6.	Expert 6 (AR)	Senior Lecturer (Dr.)	Multimedia Department, Faculty of Computer Science and Information Technology (UTHM)	Augmented Reality, Human-Computer Interaction	12 Years

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7.	Expert 7 (AR)	Senior Lecturer/ Program Coordinator (Dr.)	Interactive Media (UTEM)	Multimedia Technology (AR)	15 Years
8.	Expert 8 (AR)	Senior Lecturer (Dr.)	School of Education, Faculty of Social Sciences and Humanities (UTM)	Educational Technology (AR)	1 Year (UTM) 10 Years (KPM
9.	Expert 9 (Language)	Academic Lecturer (Dr.)	Department of Malay Studies IPG Tuanku Bainun	Moral Ethics and Malay Language	14 Years

Overall, the evaluation panel provided positive feedback and expressed a high level of satisfaction with the assessed module in terms of content, structure, suitability of activities, and its usability in teaching and learning. In addition, the evaluation panel also submitted several comments and constructive improvement suggestions, specifically related to content delivery, clarity of instructions, and enrichment of activities. All comments and suggestions were carefully discussed and used as a guide to improve the module to make it more robust and effective.

b) Heuristic assessment instrument

According to David Benyon (2014), there are 12 important things to assess in heuristic evaluation, including: (1) Appearance, (2) Consistency, (3) Mobility, (4) Capability, (5) Navigation, (6) Control, (7) Feedback, (8) Recovery, (9) Constraints, (10) Flexibility, (11) Style, and (12) Compatibility. A 10-point semantic scale is used in the heuristic form for each item, with a score of 1 meaning strongly disagree to 10 meaning strongly agree. In this e-ReSP-AR app, the dimensions measured are app usability, mobility, ability to use the mobile application, and learning content.

i) **App Usability**
There were 15 dimensions assessed under app usability, focusing on the application interface in terms of layout and navigation design. Each dimension was labelled as UA (UA1- UA15).

ii) **Mobility**
Six dimensions were used to test app mobility, focusing on the speed of accessing and finding information within the app. The dimensions were labelled as MO (MO1-MO6).

iii) **Ability to use mobile applications**
Six dimensions were used to assess app usability, focusing on users' progress in using the application, such as whether the score display appears immediately after the respondent answers a question. The dimensions of the ability to use mobile applications were labelled as PL (PL1-PL6).

iv) **Learning content**
Under the learning content dimension, the content and objectives were assessed, with six dimensions labelled as KP (KP1-KP6).

Table 5. *Results of the Heuristic Evaluation Validity Index*

Dimension	Expert 1	Expert 2	Expert 3	CVI
Total score of each expert	.78	.83	1.00	.87

Based on the obtained CVI value of .87, it exceeded the accepted CVI value of 0.80 (Polite & Beck, 2006). Among the comments given by Expert 2 was that the arrangement of the layout structure and menu was appropriate, and the interaction of input icons and links worked well. Another comment from Expert 2 concerned the use of colour and button shapes that can be improved and needs to refer to Android UI/UX design.

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c) Validity of the Language Content used in the e-ReSP- AR module

The e-ReSP-AR module was developed in Malay according to the contents of the textbook. The language validity in terms of language and grammar usage was conducted by an experienced expert. Table 6 presents the calculation of the percentage from the scores given by the Malay language expert.

Table 6. Content validity for the language used

	Item	Language Expert 1
1	The content of this e-ReSP-AR module uses an appropriate language register.	9
2	The content of this e-ReSP-AR module uses correct language structure.	10
3	The content of this e-ReSP-AR module does not contain sensitive language that offends any party.	9
4	The content of this e-ReSP-AR module uses precise vocabulary in explaining the processes involved.	9
5	The content of this e-ReSP-AR module uses language appropriate to show the continuity of processes.	9
6	The content of this e-ReSP-AR module uses understandable language to explain the processes involved.	10
7	The content of this e-ReSP-AR module shows consistent and non-confusing terminology.	9
8	The content of this e-ReSP-AR module shows correct terms and spelling.	10
	Total	75
	Content Validity of The Achievement Test (100%)	94%
	Content Validity Coefficient	.94

The total CVI score for language validity was .94, which exceeded the acceptable CVI value of 0.80. According to the expert comments, this module uses appropriate language and is in line with the study.

d) Validity of Module Content

Five experts were given a questionnaire regarding the validity of the module in terms of curriculum aspects, pedagogy, and activity suitability. There were 14 items on the curriculum aspect assessment, 19 items on the pedagogy aspect assessment, and 8 items on activity suitability in the e-ReSP-AR module. Table 7 shows the evaluation of the five experts on this validity.

Table 7. Content validity of the module

Statement	Expert 1 - A (Biology Expert)	Expert 2 – Z (Biology Expert)	Expert 3 - S (Biology Expert)	Expert 4 (Creativity Expert)	Expert 5 (Inquiry Expert)	Total
Curriculum Aspect						
1	10	8	10	10	10	48
2	10	8	10	10	10	48
3	10	8	10	9	10	47
4	8	5	10	9	8	40
5	8	9	10	9	9	45
6	9	5	10	9	9	42
7	9	9	10	7	9	44
8	8	9	10	7	8	42
9	9	8	9	9	8	43

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10	9	7	9	9	9	43
11	9	8	9	8	10	44
12	9	8	10	9	10	46
13	9	8	8	9	10	44
14	9	8	9	9	10	45
Pedagogy Aspect						
1	9	10	10	8	10	47
2	8	6	9	9	7	39
3	8	8	8	9	7	40
4	9	10	10	8	8	45
5	9	10	9	8	7	43
6	9	10	9	9	9	46
7	9	10	9	9	9	46
8	9	9	10	9	9	46
9	8	10	9	8	8	43
10	9	10	10	9	10	48
11	9	9	9	8	10	45
12	10	9	10	9	10	48
13	9	9	9	8	8	43
14	9	9	10	8	8	44
15	9	9	10	9	9	46
16	9	9	10	9	10	47
17	9	8	10	8	10	45
18	9	9	10	7	9	44
19	9	6	10	7	8	40
Suitability of e-ReSP-AR module activities						
Activity 1	10	8	8	10	8	44
Activity 2	10	9	9	9	10	47
Activity 3	9	9	9	9	9	45
Activity 4	9	9	7	9	9	43
Activity 5	10	9	8	10	8	45
Activity 6	9	9	9	9	10	46
Activity 7	9	9	9	9	9	45
Activity 8	9	9	9	10	9	46
Total	370	349	383	357	368	1827
Validity of Achievement Content (100%)	90%	85%	93%	87%	90%	89%
Content Validity Coefficient (1.0)	0.9	0.85	0.93	0.87	0.9	0.89

The validity value obtained was .89, indicating that the content validity index exceeded the accepted CVI value, which is at least .80 (Davis et al., 1992). Based on expert comments, several aspects required revision, including a recommendation from the creativity expert to increase open inquiry activities, enabling students to create and thereby fostering creativity and innovation through these activities.

e) Face Validity of the e-ReSP-AR Module

Reliability and validity are important aspects that require more in-depth attention to assess the accuracy and appropriateness of each item in a research instrument (Creswell, 2014). Face validity refers to how a measurement tool clearly and accurately demonstrates validity to study respondents and other

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individuals. Six experts were given a questionnaire regarding the face validity of the module. The table below shows the evaluation of the six experts on validity.

Table 8. Face Validity of e-ReSP-AR Module

	Statement	Expert 1 - A (Biology Expert)	Expert 2 – Z (Biology Expert)	Expert 3 - S (Biology Expert)	Expert 4 (Creativity Expert)	Expert 5 (Inquiry Expert)	Expert 5 (Language Expert)	Total
1	The text used is clear and easy to read.	9	7	8	9	8	9	50
2	The font size in the e-ReSP-AR Module is appropriate.	9	7	8	9	7	10	50
3	The features of the text used are attractive.	9	7	9	9	8	9	51
4	The graphics used in the e-ReSP-AR Module are appropriate for the content.	8	8	8	9	8	9	50
5	The diagrams in the e-ReSP-AR Module help show the relationships.	9	8	9	8	8	10	52
6	The images used are systematic.	8	8	9	8	7	10	50
	Total	52	45	51	52	46	57	303
Content Validity of Achievement (100%)		86.67	75.00	85.00	86.67	76.67	95.00	50.5
Content Validity Coefficient (1.0)		.86	.75	.85.	.86.	.76	.95	.84

The total CVI for face validity was .84. According to Polit and Beck (2006), as well as Polit et al. (2007), if a minimum of six experts assesses the CVI, the acceptable value would be at least .83. Therefore, the validity value obtained can be accepted. According to Expert 1, the module design was satisfactory. Expert 4 commented that overall, the text and graphics were interesting and clear; however, some aspects require improvement, such as the background colour on Page 28, which should be brighter to enhance text readability. Expert 5 commented that the text could be standardised in terms of uniformity; however, the variation in text was intentionally maintained to prevent user boredom.

Table 9. Summary of Panel Review and Recommendations as well as Improvements

Aspects	Comments and Expert Suggestions	Improvements
The learning content is good and covers the existing sub-topics	The learning content is good and covers the existing sub-topics	Has made corrections for spelling mistakes
RPH 7 and 8 Learning Standards are listing but the level of thinking measured is creating	It is suggested to increase open inquiry activities to allow students to create so that creativity and innovation can be fostered through these activities	Has added open inquiry activities
Module design	Overall, the module design is good. Needs to be looked at from the language processing aspect. Improve i) please fix unclear images	Has repaired unclear images with clearer images

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	The background color on page 28 is better in a light type so that the text can be read easily. The diagram on page 105 is blurry and the text cannot be read	Has made background improvements. Added new images for the blurred page and text.
Font Consistency	The font size on page 17 is not uniform The font size on pages 25 and 33 is too small	Standardize the size and type of font to improve readability Enlarge the font size of questions for student comfort

MODULE RELIABILITY

The reliability of the module was assessed based on the students' ability to consistently and effectively follow the procedures and steps of the planned activities, in accordance with the approach proposed by Noah & Ahmad (2005), using Russell's Formula (1974). This assessment aims to ensure that the module functions optimally in supporting the achievement of the established learning objectives.

The reliability item was developed based on the teaching and learning constructs in the e-ReSP-AR Module, comprising five main phases, namely engagement, exploration, explanation, elaboration, and evaluation. This approach aligns with the inquiry-based learning framework that emphasises active student involvement in knowledge construction. A pilot study was conducted in 2022 involving 47 students from a secondary school in Penang, Malaysia. The study sample followed a teaching and learning intervention using the e-ReSP-AR Module for six weeks. The implementation of this study received official approval from the Penang State Education Department.

Before the intervention was carried out, the teachers involved were given briefings and training to ensure uniformity in the implementation of the module, particularly in terms of the integration of the science inquiry approach. Throughout the study period, the researcher acted as a non-participant observer to assess the suitability and feasibility of the module in the actual classroom context. The evaluation of the pilot study encompassed several critical dimensions, including the appropriateness of time allocation, relevance of content, clarity of instructions, level of acceptance by students and the school, availability of learning support facilities, and potential implementation constraints. The findings of this pilot study were used as an empirical basis for module improvements, thereby enhancing the validity, reliability, and effectiveness of the module in supporting inquiry-based teaching and learning practices. The reliability table can be used as a guide to assess the admissibility of the research instrument in terms of reliability based on the reliability coefficient (Cohen et al., 2007) as in Table 10.

Table 10. Cronbach's Alpha Reliability Coefficient

Coefficient	Description
0.90 or more	Very highly reliable
0.80 - 0.89	Highly reliable
0.60 - 0.79	Reliable
0.40 - 0.59	Marginally/minimally reliable
0.00 - 0.39	Unacceptably low reliability

Table 10 shows the value of Alpha Cronbach for the e-ReSP-AR Module, which was 0.91. This reliability coefficient indicates an excellent level of reliability for a research tool (Cohen et al., 2007).

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Table 11. Summary of Reliability Analysis of Assessment Instruments for the Pilot Study

Construct	Title in Module	Alpha value	Interpretation
Activity 1	Energy	0.91	Very highly reliable
Activity 2	Aerobic Respiration	0.90	Very Highly reliable
Activity 3	Let's do an Experiment	0.96	Very Highly reliable
Activity 4	Fermentation	0.90	Very highly reliable
Activity 5	What is the same	0.95	Very highly reliable
Activity 6	Yeast	0.88	Highly reliable
Activity 7	What is the difference	0.93	Very highly reliable
Activity 8	What is the difference	0.81	Highly reliable
The overall value of the Cronbach Alpha Instrument Assessment		0.91	Very highly reliable

The Cronbach's Alpha value obtained for the e-ReSP-AR Module was 0.91, suggesting a very high level of internal consistency among the items in the module. According to Cohen et al. (2007), a reliability coefficient of 0.90 and above is categorised as excellent, demonstrating that the instrument is highly stable and consistent in measuring the intended constructs. Modules that have a high reliability coefficient value are quality modules and can increase effectiveness when used (Harun & Yaacob, 2021).

This high reliability value highlights that the items within the module are well-aligned and function cohesively in assessing the targeted learning outcomes. It also indicates that the variability in the scores is primarily due to true differences among respondents rather than measurement error. Consequently, the module can be considered dependable for repeated use in similar educational contexts. Furthermore, the strong internal consistency implies that the constructs embedded in the e-ReSP-AR Module are clearly defined and systematically developed. This enhances the credibility of the module as an effective teaching and learning resource, particularly in supporting structured instructional delivery.

In addition, the high Cronbach's Alpha value reflects that the module has undergone careful design and validation processes, ensuring that each component contributes meaningfully to the overall framework. This strengthens its suitability for implementation in classroom settings as well as for research purposes. These findings are consistent with previous studies which emphasized that content validity is important to ensure the suitability and effectiveness of a module or instructional material (Polit & Beck, 2006; Noah & Ahmad, 2005). Therefore, the e-ReSP-AR Module can be confidently described as having excellent reliability, making it a robust and trustworthy instrument.

CONCLUSION

Referring to the results of the product development and testing, it can be concluded that the e-ReSP-AR Module, which is based on Inquiry-Based Learning and Augmented Reality for the topic of Cellular Respiration, is feasible for use as a learning resource for students. Overall, the e-ReSP-AR Module demonstrates a high level of reliability and validity. Findings from expert evaluations and pilot testing indicate that the module has been systematically developed and effectively implemented using appropriate pedagogical approaches. It is envisaged that this module can serve as a supplementary learning resource alongside existing materials and act as a useful reference for both teachers and students in implementing inquiry-based learning.

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Furthermore, future studies are recommended to evaluate the effectiveness of the e-ReSP-AR Module on students' achievement in the topic of Cellular Respiration, as well as their creativity and innovation among Form 4 students. This can be conducted through an experimental research design involving treatment and control groups, using pre-test and post-test instruments to measure the impact of the module.

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AUTHOR CONTRIBUTIONS

Nor Asniza Ishak acted as the main supervisor for this research, providing continuous guidance, critical feedback, and detailed content review throughout the dissertation process. Rozniza Zaharudin played a role as co-supervisor, primarily in reviewing the formatting and ensuring the document complies with academic standards and submission requirements.

CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest regarding the publication of this study.

AVAILABILITY OF DATA AND MATERIALS

Data available on request from the authors

DECLARATION OF GENERATIVE AI

During the preparation of this work, the author(s) used ChatGPT to enhance the clarity of the writing. After using the ChatGPT, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

REFERENCES

Adeosun, G., Oladejo, A. I., & Okebukola, P. A. (2022, March). Exploring the role of culture on students' learning of difficult concepts in biology: CTCA in action. In *Proceedings of the 95th Annual Conference of NARST, Vancouver, BC, Canada* (pp. 27-30).

Ahmad, J. (2002). *Kesahan, kebolehpercayaan dan keberkesanan modul program maju diri ke atas motivasi pencapaian di kalangan pelajar sekolah menengah negeri Selangor* (Doctoral dissertation, Universiti Putra Malaysia).

Benyon, D. (2014). *Designing interactive systems: A comprehensive guide to HCI, UX and interaction design* (3rd ed.). Pearson.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). Routledge.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1992). Extrinsic and intrinsic motivation to use computers in the workplace. *Journal of Applied Social Psychology, 22*(14), 1111–1132. https://doi.org/10.1111/j.1559-1816.1992.tb00945.x

Fajarniangtyas, D.A., & Jefri, N.H. (2020). Pengembangan petunjuk praktikum berorientasi pemecahan masalah sebagai sarana berlatih keterampilan proses dan hasil belajar mahasiswa IPA Universitas Wiraraja. *Jurnal pendidikan sains Indonesia, 8*(2): 2338-4379.

https://doi.org/10.37134/jpsmm.vol16.1.6.2026

Harun, M. T., & Yaacob, M. I. H. (2021). Penilaian kualiti Modul FZ-STEM: Aspek kesahan dan kebolehpercayaan. *Jurnal Pendidikan Sains dan Matematik Malaysia, 11*(Special Issue), 107–117. https://doi.org/10.37134/jpsmm.vol11.sp.10.2021

Hasnawati, H. (2023). Pelaksanaan Projek Stem Dalam Proses Pengajaran Dan Pembelajaran Sains Dan Matematik Kanak-Kanak Prasekolah Di Aceh Tengah. *Jurnal Pendidikan Dan Keguruan*, *1*(10), 2979-2989.

Jamaluddin, F., Abdul Razak, A. Z., & Abdul Rahim, S. S. (2025). Navigating the challenges and future pathways of STEM education in Asia-Pacific region: A comprehensive scoping review. *STEM Education, 5*(1), 53–88. https://doi.org/10.3934/steme.2025004

Ministry of Education Malaysia. (2018). *Biology form 4 and form 5 curriculum and assessment standard document (DSKP).* Curriculum Development Division, Ministry of Education Malaysia.

Muhammad, S., & Ibrahim, N. N. (2021). Kesediaan guru STEM melaksanakan pendidikan STEM di sekolah pesisir pantai. *International Journal of Education, Islamic Studies and Social Sciences Research*, *6*(1), 1-15.

Noah, S. M., & Ahmad, J. (2005). *Pembinaan dan pengesahan instrumen bagi penyelidikan pendidikan.* Universiti Putra Malaysia Press.

Obikezie, M. C., Okpala, C. C., & Amobi, U. V. (2022). Biology Teachers Level of Utilization and Awareness of Innovative Teaching Strategies in The teaching and learning of Biology in Secondary Schools. *Journal Plus Education/Educaţia Plus*, *30*(1).

Patro, T. (2008). Teaching aerobic cell respiration using the 5Es. *The American Biology Teacher, 70*(2), 85–87. https://doi.org/10.1662/0002-7685(2008)70[85:TACRUT]2.0.CO;2

Pérgola, M., & Pérez, G. (2025). Epistemological obstacles in teaching and learning cellular respiration. *Foundations of Chemistry, 27*, 319–338. https://doi.org/10.1007/s10698-025-09538-0

Purwaningsih, W. I., & Supriyono, S. (2020). Analisis kemampuan berpikir kreatif siswa dalam menyelesaikan masalah matematika. *Jurnal Pendidikan Surya Edukasi, 6*(2), 157-167.

Putri, S., & Tambunan, E. P. (2023). The effect of self-efficacy and self-regulated learning on students' creativity in biology practicum. *Jurnal Pembelajaran dan Biologi Nukleus, 9*(3), 707-716.

Polit, D. F., & Beck, C. T. (2006). The content validity index: Are you sure you know what's being reported? Critique and recommendations. *Research in Nursing & Health, 29*(5), 489–497. https://doi.org/10.1002/nur.20147

Polit, D. F., Beck, C. T., & Owen, S. V. (2007). Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. *Research in Nursing & Health, 30*(4), 459–467. https://doi.org/10.1002/nur.20199

Ratamun, M., & Osman, K. (2018). The effectiveness comparison of virtual laboratory and physical laboratory in nurturing students' attitude towards chemistry. *Creative Education, 9*, 1411–1425. https://doi.org/10.4236/ce.2018.99105

Rice, S. C. (2013). Tips and tools: Using interactive animations to enhance teaching, learning and retention of respiration pathway concepts in face-to-face instruction. *Journal of Microbiology & Biology Education, 14*(1), 113–115. https://doi.org/10.1128/jmbe.v14i1.450

Rosa, J. P. O. D., & Vital, R. A. D. (2016). The use of Facebook in argumentative writing: towards an instructional design model. *AsTEN Journal of Teacher Education*, *1*(2).

Rosli, R., & Ishak, N. A. (2024). Integration of virtual labs in science education: A systematic literature review. *Jurnal Pendidikan Sains dan Matematik Malaysia, 14*(1), 81–103. https://doi.org/10.37134/jpsmm.vol14.1.8.2024

Russell, C. H. (1974). *The measurement of content validity* (Unpublished doctoral dissertation). University of Northern Colorado.

Schmidthaler E., Anđic B., Schmollmüller M., Sabitzer B., & Lavicza, Z. (2023) Mobile augmented reality in biological education: Perceptions of Austrian secondary school teachers. *Journal on Efficiency and Responsibility in Education and Science*, 16(2), 113-127

Shuai Y (2024) Unraveling the Mysteries of Cellular Respiration: A Comprehensive Overview. Cell Mol Biol, 70: 328.

Smaldino, S. E., Lowther, D. L., & Russell, J. D. (2015). *Instructional technology and media for learning* (11th ed.). Pearson.

Stanič, K., & Špernjak, A. (2025). Augmented Reality in Biology Education: A Literature Review. *Multimodal Technologies and Interaction*, *9*(12), 117. https://doi.org/10.3390/mti9120117

Zaibon, S. B. (2011). *Mobile game-based learning (mGBL) engineering model* (Unpublished doctoral dissertation). Universiti Utara Malaysia.

https://doi.org/10.37134/jpsmm.vol16.1.6.2026