Geografia-Malaysian Journal of Society and Space 21 issue 3 (172-189)
 https://doi.org/10.17576/geo-2025-2103-11

Expert validation of e-module content on plant importance in mitigating climate change for primary school students

Nordiana Md Khamis, Kamisah Osman, Nurazidawati Mohamad Arsad

Centre for STEM Enculturation Studies Faculty of Education, Universiti Kebangsaan Malaysia

Correspondence: Kamisah Osman (email: kamisah@ukm.edu.my*)*

Received: 17 March 2025; Accepted: 21 June 2025; Published: 20 August 2025

Abstract

Digital learning tools, especially interactive e-modules are transforming climate change education by making complex concepts more accessible to young learners. However, many existing materials lack interactivity and structured validation, limiting their pedagogical impact. This study validates an interactive e-module designed to support primary students' understanding of plant-climate interactions. Six experts, selected based on their academic qualifications, professional experience (≥10 years), and expertise in science education, climate change, and plant science evaluated the module across seven dimensions: interface design, language use, climate literacy, plant awareness, science process skills, learning theories, and teaching activities. Using a Likert scale and the Content Validity Achievement (CVA) method by Sidek Mohd Noah and Jamaludin Ahmad, the module achieved a CVA score of 90.83%, surpassing the 70% validity benchmark. Expert ratings ranged from 4.17 (SD = 1.60) to 4.83 (SD = 0.41), with an overall mean of 4.54 (SD = 0.65), confirming the module's quality. Plant awareness (M = 4.70, SD = 0.48), interface design (M = 4.67, SD = 0.55), and science process skills (M = 4.67, SD = 0.71) received the highest ratings. Language use scored lowest (M = 4.17, SD = 1.60) with experts recommending clearer scaffolding of terms like "climate" and "greenhouse" through pre-teaching strategies. These findings confirm the module's validity and usability while highlighting areas for refinement. Future research should assess the module's effectiveness and accessibility for students with diverse learning needs, including those with special educational and cognitive differences.

Keywords: Climate literacy, e-module, expert validation, plant awareness, primary education, science climate education

Introduction

Malaysia is increasingly facing the adverse effects of climate change including erratic weather patterns, rising temperatures, biodiversity loss and habitat degradation. These environmental challenges threaten human livelihoods and ecosystems, highlighting the urgent need to integrate climate change education into school curricula (UNICEF, 2021). However, existing instructional resources often lack depth, interactivity and engagement, making it difficult for young learners to grasp complex climate concepts effectively. Addressing this gap, the present study underscores the importance of well-structured, inquiry-based e-modules in fostering climate resilience,

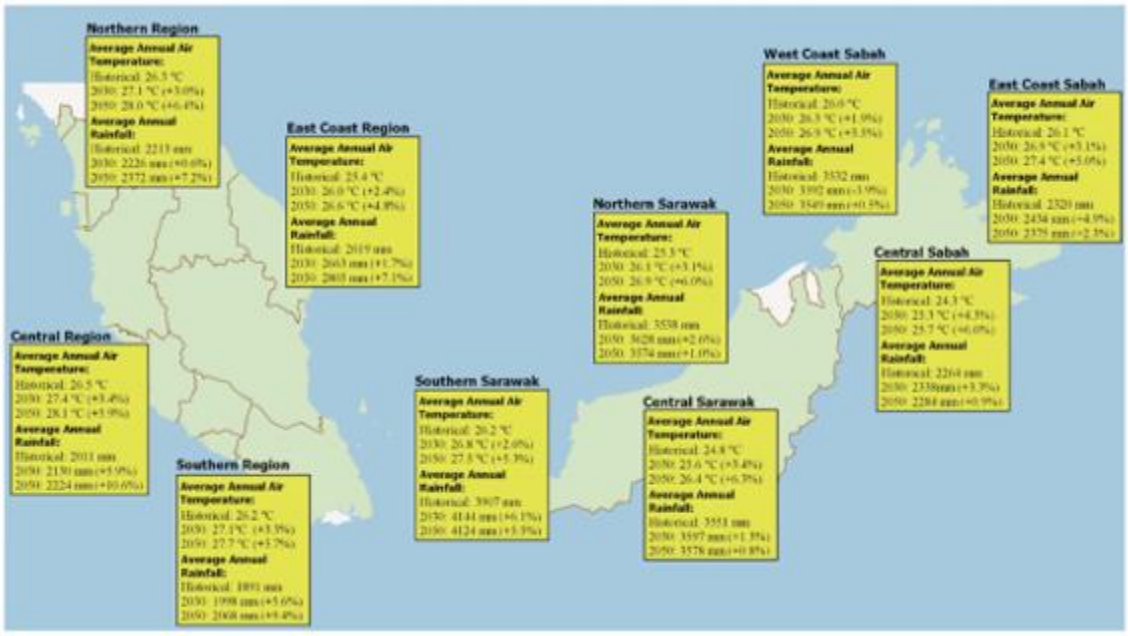
sustainability awareness and scientific literacy among students (UNICEF, 2021). Incorporating of e-modules within blended learning environments has transformed education by offering dynamic, interactive and student-centered learning experiences (Ormancı & Çepni, 2020). Such digital resources promote active engagement, critical thinking and scientific exploration, making them particularly valuable in addressing interdisciplinary topics such as climate change and environmental conservation.

In primary education, ensuring the scientific accuracy, pedagogical soundness and curriculum alignment of instructional materials is crucial to meeting established educational and cognitive learning standards (Dolan, 2022). Expert validation plays a key role in assessing these aspects to ensure that e-modules effectively enhance students' understanding. Furthermore, this study aligns with the United Nations Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) and SDG 13 (Climate Action). SDG 4 emphasizes the need for inclusive, equitable, and quality education supported by evidence-based and pedagogically sound practices, through innovative and ICT-enhanced learning approaches, while SDG 13 highlights the necessity of early climate literacy interventions to nurture environmentally responsible future generations (United Nations, 2023). The intersection of these SDGs reinforces the role of plant awareness in promoting ecosystem sustainability, carbon sequestration and biodiversity conservation. Therefore, this study aims to validate the interactive e-module through expert evaluation, focusing on the quality and clarity of content, instructional design and the learning approaches employed.

Literature review

Climate change issues in Malaysia

Climate change has increasingly impacted Malaysia's environment with significant changes observed over the past four decades. Average temperatures have risen by 0.6°C to 1.2°C and erratic rainfall patterns have led to shifting monsoon cycles. These changes have intensified natural disasters, such as floods and extreme droughts, posing significant threats to communities and ecosystems. Official reports submitted to the United Nations Framework Convention on Climate Change (UNFCCC) provide a comprehensive assessment of Malaysia's greenhouse gas emissions, climate impacts and strategies for mitigation and adaptation (MESTECC, 2018). Projections for the years 2030 and 2050 indicate further increases in average annual temperatures, ranging from 0.5°C to 1.0°C by 2030 and from 0.9°C to 1.6°C by 2050 as shown in Figure 1. These alarming trends underscore the urgency of addressing the climate crisis to safeguard Malaysia’s future.



Source: Malaysia Third National Communication and Second Biennial Update Report to the UNFCCC

Figure 1. Projections of average annual air temperature and rainfall for the periods 2030 (2020-2040) and 2050 (2040-2060)

The impacts of climate change are becoming increasingly apparent, posing significant threats to natural ecosystems. One critical concern is the rapid decline of natural habitats, such as mangrove forests, which have shrunk by approximately 5% to 30% (WWF, 2020). Similarly, coral reefs are experiencing severe bleaching, with reported cases increasing from 8% in 2014 to 30% in 2019 (Reef Check Malaysia, 2022). Figures 2 and 3 illustrate these alarming trends, emphasizing the urgency of conservation efforts.

Source: English News CN, Xinhua

Figure 2. The mangrove swamp is pictured in Pulau Merambong in the state of Johor, Malaysia, 2022

Source: Reef Check Malaysia, Julian's Blog

Figure 3. Our reefs faced the 4th mass coral bleaching phenomenon, 2025

In Addition, more alarming is the vulnerability of tropical forests which harbor immense biodiversity to threats such as wildfires and soil erosion. According to the International Union for Conservation of Nature (IUCN), at least 1,273 species in Malaysia are now at risk of extinction, with 8% of animal species and 9% of plant species classified as endangered (IUCN, 2021). In response to this escalating climate crisis, Malaysia must adopt more drastic and transformative measures. This includes mitigation strategies such as increasing the use of renewable energy and reducing carbon emissions. Furthermore, adaptation efforts such as water and disaster management, as well as biodiversity conservation must be strengthened to enhance resilience against the adverse effects of climate change.

Education is essential to combat climate

Education plays a pivotal role in shaping climate literacy among students from an early age, equipping them with the necessary knowledge and skills to understand, mitigate and adapt to climate change. At the primary school level, early exposure to environmental concepts is crucial in fostering long-term sustainable attitudes and behaviors. High-quality science education not only cultivates a foundational understanding of climate issues but also empowers students to make informed decisions and contribute to solutions that promote sustainable resource management, environmental conservation, and cleaner air quality. Scientific literacy at an early stage also plays a critical role in fostering critical thinking, curiosity and problem-solving skills, regardless of students' backgrounds or belief systems. Recognizing the significance of education in addressing climate challenges, the United Nations Framework Convention on Climate Change (UNFCCC) underscores its role as a key component of a global response strategy to climate change (MESTECC, 2018).

High-quality science education nurtures scientifically literate citizens capable of addressing global challenges effectively. The Organisation for Economic Co-operation and Development (OECD) highlights global competence as a vital skill in an interconnected world, requiring interdisciplinary understanding, motivation, real-world application and social engagement (OECD, 2020). In the context of climate education, e-modules have emerged as innovative tools that enhance student engagement by enabling interactive exploration of climate concepts. These digital resources foster interdisciplinary learning, problem-solving and collaboration as key elements in developing long-term environmental awareness (Cirkony et al., 2022; Mayr, 2023). The integration of e-modules in primary education further strengthens students' understanding of the role of plants in carbon sequestration, temperature regulation and biodiversity conservation. As a transformative force, science education supported by digital technology not only empowers future generations to tackle climate challenges effectively but also reinforces education as a catalyst for sustainable social change (Katauhi et al., 2022; Suwatra et al., 2018).

E-module development for teaching plant importance in mitigating climate change

The integration of plant science into climate education is essential for fostering climate literacy and awareness. Plants play a critical role in mitigating climate change through carbon sequestration, ecosystem stabilization, and biodiversity conservation (Espeland & Kettenring, 2018). E-modules serve as effective digital tools to enhance students' understanding of these processes by incorporating interactive and experiential learning strategies. Research highlights the significance of ecosystem-based adaptation and carbon sequestration mechanisms in climate

resilience, emphasizing the need for a multidisciplinary approach to climate education (Eckardt et al., 2023). Projects like TROP ICSU provide models for embedding climate literacy into curricula, while technological advancements, including ICT tools and virtual simulations, further enhance engagement and comprehension (Chopra et al., 2019; Elliott-Kingston et al., 2021).

To develop an effective e-module on plant-based climate mitigation, a structured framework should include fundamental climate change concepts, the role of ecosystem services, carbon sequestration mechanisms, practical applications and interactive learning assessments. Digital tools, such as online monitoring apps and virtual reality models, offer immersive educational experiences, reinforcing theoretical knowledge with hands-on learning (Andreopoulou et al., 2023). Assessments like quizzes, project-based evaluations and engagement metrics help measure the e-module's effectiveness (Cassagnes et al., 2022). By integrating scientific knowledge with interactive learning, e-modules can enhance climate literacy and encourage pro environmental behavior. Future research should investigate the long- term efficacy of these digital learning tools in shaping climate conscious individuals and fostering sustained engagement with environmental issues.

Web based educational content validity

The validity of the web based educational content is crucial in ensuring its quality, accuracy and pedagogical effectiveness. As online education continues to expand, the implementation of rigorous validation processes, including assessment systems, evaluation tools and quality metrics is imperative for enhancing both credibility and learning outcomes (Mahadzir et al., 2024). Notably, authentic assessment mechanisms, such as online forums, self-evaluations and peer reviews, have been shown to significantly improve content reliability (Nieminen et al., 2023). Furthermore, adaptive assessments that are tailored to learners' competencies and instructional objectives play a vital role in strengthening the validity of digital learning environments (Gutiérrez-Castillo et al., 2023). In addition, structured evaluation tools including rubric-based approaches and expert validation are essential in ensuring alignment with pedagogical principles and learner needs (Gregori-Giralt & Menéndez-Varela, 2021; Ragupathi & Lee, 2020). Moreover, in specialized fields such as healthcare education, expert and user feedback have proven instrumental in enhancing the credibility and usability of digital learning resources (Lioi et al., 2025; Nazeri et al., 2022). Collectively, these findings underscore the necessity of systematic validation processes in web based education, ensuring that digital learning materials remain reliable, effective and pedagogically sound.

User satisfaction is another critical determinant of content validity in web based education. Research suggests that factors such as instructional quality, multimedia integration and technological infrastructure significantly impact learners' perceptions of digital learning (Hidayah et al., 2023). The use of multimedia elements, such as YouTube videos, has been found to enhance engagement and comprehension though the reliability of user generated content necessitates careful instructor evaluation. Furthermore, institutional support and well structured e-learning service models contribute to sustained learner engagement and overall academic success (Gutiérrez-Castillo et al., 2023). Although emerging technologies offer promising solutions for automating content validation and enhancing adaptability, continuous refinement is necessary to address challenges related to content credibility, technological adaptation, and learner engagement. Integrating Artificial Intelligence and Machine Learning into educational settings can streamline processes and improve reliability, but empirical testing and structured verification approaches are

essential to ensure these technologies' effectiveness and trustworthiness (Gupta et al., 2025; Kharipova et al., 2024). Additionally, fostering collaboration among educators, instructional designers and subject matter experts is essential to maintaining high standards in digital learning environments. By integrating rigorous evaluation frameworks, expert validation and user centered design principles, web-based educational content can achieve higher reliability, ultimately improving learning outcomes and digital pedagogy.

Research methodology

This study evaluates the content validity of an e-module designed for Year 2 students in the science classroom, focusing on fostering climate literacy, awareness of plant-climate interactions, and science process skills. Using a quantitative research approach, data were collected through an expert assessment questionnaire to gain deeper insights into the module's strengths and areas for improvement. Questionnaires are widely recognized as an efficient and cost-effective method for evaluating user experiences with digital learning applications (Ghazali Darusalam & Sufean Husin, 2021). The expert review process followed a structured validation framework, ensuring a systematic evaluation of content accuracy, pedagogical alignment and accessibility. The workflow of this assessment as illustrated in Figure 4 guided the validation process to enhance the module's instructional quality for learners.

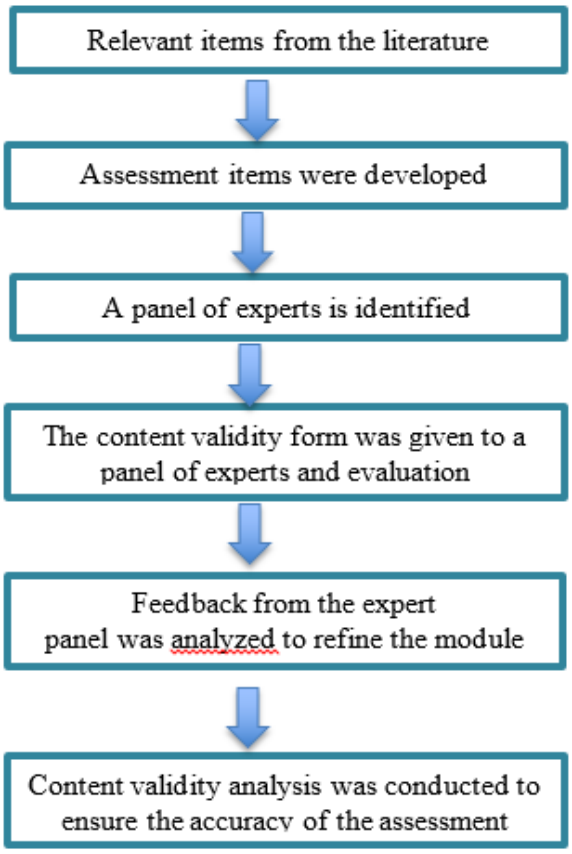


Figure 4. Research methodology

Expert involved

Six professional experts participated in the content validity assessment, comprising lecturers and professional staff from the Institute of Teacher Education, the Ministry of Education Malaysia, Universiti Sains Malaysia (USM), the University of Leeds and government primary school teachers. These experts possess more than ten years of experience in relevant fields and have been actively engaged in research related to science education, digital learning, climate change education, plant science and educational assessment. Their collective expertise spans various domains, including higher education, primary science education and postdoctoral research. Consequently, their involvement ensures a rigorous and comprehensive evaluation of the module's content validity, aligning with the perspectives of Ghazali Darusalam and Sufean Husin (2021). The details of the experts involved in this study are presented in Table 1.

Table 1. List of experts involved

Expert	Academic qualifications	Field / Position	Institute	Experience (Years)
E1 	PhD	• Lecturer • Science Education • M-learning • Digital Education	Institute of Teacher Education	22
E2 	PhD	• Lecturer • Science Education • Educational Assessment	Institute of Teacher Education	24
E3 	PhD	• Lecturer • Climate Change Education • Science Primary	University of Leeds	20
E4 	PhD	• Post doctoral • Plant Science	Universiti Sains Malaysia	13
E5 	Masters	• Excellent Teacher (Science)	Primary School	20
E6 	Degree	• Science Teacher	Primary School	17

Instrument

The content validity of the developed module was evaluated using a structured questionnaire specifically designed for expert validation purposes. This questionnaire was constructed based on the validation framework proposed by Russell (1974), which outlines five essential criteria for establishing module validity: target population, instructional situation, time required for module completion, anticipated student achievement, and expected changes in student attitudes. These criteria were systematically translated into 36 items, organized under seven thematic sections: (A) Interface Design, (B) Style and Use of Language, (C) Climate Literacy, (D) Plant Awareness, (E) Science Process Skills, (F) Application of Learning Theories and Models, and (G) Teaching and Learning Activities.

Prior to its administration to the expert panel, the questionnaire was reviewed by a module development expert from the Faculty of Education, Universiti Teknologi MARA (UiTM). This preliminary review focused on language clarity, grammatical accuracy, the precision of terminology for expert validation and the suitability of the Likert scale employed. The expert's feedback was incorporated to refine the questionnaire, ensuring it was pedagogically sound and accessible for use by expert evaluators. Sample items from the questionnaire include statements such as:

- *"The module enhances knowledge of the importance of plants for the Earth."*
- *"The module increases students' knowledge of the negative impacts of climate change."*

The questionnaire employed a 5-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), allowing experts to provide detailed evaluations regarding the clarity, relevance, and alignment of each module component with its intended educational objectives. Following this refinement process, the finalized questionnaire was then administered to a panel of experts who used it to systematically assess the content validity of the developed e-module. This instrument served as the primary tool for collecting expert feedback to validate the educational and instructional quality of the module. The collected data were analyzed using the Statistical Package for Social Sciences (SPSS) software. Descriptive analysis was performed by calculating mean scores and standard deviations to evaluate the content validity of the e-module based on expert assessments.

Results and discussion

This study presents a descriptive analysis of the findings, focusing on the assessment of content validity based on expert evaluations. Additionally, experts provided constructive feedback and recommendations to enhance the e-module application. In line with this, Elangovan & Sundaravel (2021) highlights that content validity is primarily determined through expert judgment rather than solely relying on numerical measurements. Furthermore, expert interviews were conducted, and all comments, opinions and suggestions were systematically documented for future revisions and improvements to the e-module.

Content validity analysis

The data from the content validity assessment performed with six experts (n=6) on the developed e-module are presented in Table 2. The selection of six experts was based on methodological guidance by Russell (1974), who emphasized that effective module development relies not on rigid axioms or formulas, but on the informed judgment and expertise of subject-matter specialists. In this context, conceptual adequacy was prioritized over statistical saturation. The six experts were purposefully selected to represent diverse disciplinary backgrounds, including science education, digital learning, plant science and instructional design. This ensured a comprehensive and balanced evaluation of the module content.

Table 2. Mean score of content validity survey items for e-module

Numbers	Item	Mean	Standard deviation
(A) Interface design			
1	The font type used is appropriate	4.67	.82
2	The font size used is suitable	4.50	.55
3	The graphic colours used are appropriate	4.83	.41
4	The icons used are easily understandable	4.83	.41
5	The user guide provided is easy to follow	4.50	.55
(B) Style and use of language			
6	The language used is appropriate	4.17	.75
7	The scientific terminology used is suitable	4.17	1.60
8	The sentence structure in the module is well organized	4.33	.82
(C) Climate literacy			
9	Facilitating students' understanding of the differences between weather and climate	4.33	1.21
10	Enhancing students' knowledge of the greenhouse effect	4.00	1.55
11	Expanding students' understanding of the causes of climate change	4.33	1.21
12	Increasing students' knowledge of the negative impacts of climate change	4.67	.82
13	Deepening students' knowledge of the importance of plants in mitigating the effects of climate change	4.67	.82
14	Boosting students' interest in climate change issues	4.33	.82
15	Strengthening students' confidence in the importance of environmental conservation	4.33	.82
16	Raising awareness about climate change among students	4.33	.82
17	Encouraging student behavior aimed at reducing the impacts of climate change	4.50	.84
(D) Plant awareness			
18	Increasing students' awareness of plants	4.67	.52

© 2025, e-ISSN 2682-7727 https://doi.org/10.17576/geo-2025-2103-11

19	Enhancing students' awareness of the existence of plants in their surroundings	4.83	.41
20	Improving students' knowledge of seed germination techniques	4.83	.41
21	Improving students' knowledge about how to care for plants	4.50	.55
22	Enhancing knowledge of the importance of plants for the Earth	4.67	.52
(E) Science process skills			
23	Observing	4.83	.41
24	Classifying	4.17	1.60
25	Measuring and using numbers	4.83	.41
26	Communicating	4.83	.41
(F) The application of learning theories and models			
27	This module are grounded in Vygotsky's Learning Theory (Social Constructivism), which emphasizes active learning and social interaction	4.50	.84
28	This module applies Mayer's Cognitive Theory of Multimedia Learning, which highlights the simultaneous processing of information through both visual and verbal channels to optimize comprehension and learning	4.50	.55
29	The teaching and learning strategies also integrate the Climate Change Bicycle Model, which encompasses elements of knowledge, critical thinking skills, environmental values, and actions to enhance students' climate literacy	4.50	.55
30	The ASSURE Model approach is employed in the teaching and learning strategies, focusing on the design of multimedia-based learning	4.67	.52
31	This module adopts the 5E Model which emphasizes guided inquiry based learning to stimulate in depth conceptual understanding	4.67	.52
(G) Teaching and learning activities			
32	Learning objectives within the module are aligned with student needs	4.50	.84
33	The module's instructional directions for student learning activities are appropriate	4.67	.52
34	Learning activities within the module are implementable	4.50	.55
35	Activities incorporated in this module enable student collaborative group engagement	4.67	.52
36	Module activities can be executed within the allocated timeframe	4.50	.55
	Overall mean score	4.54	.65

The evaluation encompassed seven key dimensions: interface design, style and use of language, climate literacy, plant awareness, science process skills, application of learning theories and models and teaching and learning activities. The analysis of dimension-specific performance provides detailed insights into the strengths and areas for improvement of the e-module. To begin with, the interface design dimension recorded a high mean score of 4.67 (SD = 0.55), indicating that the module's visual presentation covering aspects such as font selection, color usage, icon clarity and user guidance was considered clear, user-friendly and accessible by the panel of experts. In contrast, the style and use of language dimension received the lowest mean score of 4.22 (SD = 1.06). Expert feedback highlighted the need for better scaffolding of scientific terminology, particularly to match the cognitive development of Year Two pupils. Specific terms such as "climate" and "greenhouse" were identified as potentially challenging for young learners. As such, experts recommended that these terms be pre-taught or reworded using age-appropriate language to ensure comprehension without compromising scientific accuracy. Regarding climate literacy, the module achieved a mean score of 4.39 (SD = 0.99). Although this reflects generally positive expert evaluations, items related to the greenhouse effect received a relatively lower score (M = 4.00, SD = 1.55), suggesting the need for clearer explanations or the inclusion of additional visual supports to enhance understanding.

Notably, the plant awareness dimension achieved the highest mean score of 4.70 (SD = 0.48). This result underscores the module's effectiveness in raising students' awareness of the importance of plants in climate change mitigation. High ratings across all items within this dimension indicate that the module is strongly aligned with the intended learning outcomes. Similarly, the science process skills dimension also received strong ratings (M = 4.67, SD = 0.71). This suggests that the module effectively supports the development of inquiry-based learning skills, including observing, measuring, and communicating, which are critical for scientific literacy. The learning theories and models dimension was evaluated with a mean score of 4.50 (SD = 0.65). This affirms the module's solid theoretical foundation, particularly its alignment with Vygotsky's Social Constructivism and Mayer's Cognitive Theory of Multimedia Learning, both of which are recognized for promoting active learning and cognitive processing through multimodal content delivery. Finally, the teaching and learning activities dimension received a high mean score of 4.57 (SD = 0.60). This highlights the practicality and educational relevance of the module's activities, which are designed to meet students' learning needs and promote active, inquiry-based engagement. In summary, the overall findings affirm that the e-module is pedagogically sound, scientifically accurate and visually engaging. The plant awareness and science process skills dimensions emerged as the key strengths of the module. However, the use of scientific terminology remains an area for improvement. Specifically, scaffolding complex terms and providing contextual explanations are necessary to optimize the accessibility and usability of the module for younger learners, ensuring that learning remains both meaningful and developmentally appropriate.

The inclusion of standard deviation values, which ranged from 0.41 to 1.60, enhances the statistical rigor of the validation process by capturing the degree of variability in expert responses. Most items demonstrated low variability, which reflects strong consensus among the experts. Items that exhibited slightly higher dispersion were carefully examined and used to guide targeted refinements. These statistical indicators, when considered alongside expert comments, provide a strong foundation for continuous improvement of the e-module. The validation process in this study was grounded in two theoretical frameworks. First, Russell (1974) offers the foundational criteria for module validation by identifying five key domains, which include the target population,

the instructional situation, the time required to complete the module, student achievement, and changes in student attitudes as essential components for establishing content validity. Second, Sidek Mohd Noah and Jamaludin Ahmad (2005) introduced a quantitative framework for computing content validity achievement (CVA), which measures expert consensus through a standardised formula (Sidek Mohd Noah & Jamaludin Ahmad, 2005):

$$\text{Content Validity Achievement} = \left(\frac{\text{Total Expert Score (x)}}{\text{Maximum Score}}\right) \times 100\%$$

Based on this method, the estimated content validity achievement for the e-module is 90.83%, surpassing the 70% threshold established by Sidek and Jamaludin. This result confirms the strong content validity of the e-module. Furthermore, content validity achievement can be represented as a decimal coefficient analogous to reliability coefficients. The content validity coefficient for this module is 0.91, reflecting its high reliability as an instructional resource. These findings align with prior research advocating the use of plant-based education to foster environmental awareness (Espeland & Kettenring, 2018). Moreover, studies by Chopra et al. (2019) and Elliott-Kingston et al. (2021) demonstrate that embedding climate-related topics across disciplines enhances conceptual understanding. Unlike earlier approaches that relied heavily on textual materials or physical gardens, this study utilises interactive digital tools to provide a scalable and engaging learning experience. The developed e-module constitutes a significant advancement in climate change education by integrating scientific knowledge, digital interactivity, and pedagogical scaffolding. Its strengths over conventional approaches include adaptive content delivery, real-time engagement, cross-disciplinary coherence, and broad accessibility. Collectively, these findings support the adoption of digital learning innovations in climate literacy and underscore the module's potential as a transformative resource in primary environmental education.

Recommendation and content improvement based on expert review

In addition to assigning evaluation scores, experts provided detailed feedback and recommendations to enhance the web-based educational content of the e-module on the role of plants in mitigating climate change. Data, including comments, opinions and suggestions collected through the questionnaire were systematically analyzed and documented to inform iterative revisions and improvements. The following section presents the key themes derived from expert feedback as summarized in Table 3.

Table 3. The key themes derived from expert feedback

Theme	Comment and Suggestions	E1	E2	E3	E4	E5	E6
E-module appropriateness for target audience	• Very suitable and highly relevant for primary science student. • Appropriate with improvements needed. • High value educational resources.	✓	✓	✓	✓	✓	✓

Assessment of e-module design and content quality	• Colors, language, activities are engaging;					✓	✓
	• All content built from "scratch".			✓		✓	
	• Integration of topics with science literacy is good.	✓			✓		
	• Needs some improvements but generally appropriate.			✓		✓	
	• Comprehensive content on climate change impacts on plants.			✓			
	• Add more local plant examples, academic references						
	• Needs modification for e-book format.						
Feedback on visual elements	• Appropriate for target audience			✓		✓	
	• Too wordy, needs more visual elements				✓		
	• Visuals help explain complex concepts well						
Language and accessibility	• Suitable for primary school level			✓		✓	
	• Storytelling method suitable but needs simplification				✓		
	• Dense but valuable content	✓		✓			
	• Concerns about terms 'climate' and 'greenhouse' for Year 2			✓			

	• Simplify languange for Year 2 students				
Implementation potential	• Ready for implementation • Continue with improvements • Strong potential as learning tool • Good for classroom implementation	✓	✓	✓ ✓	✓

Experts acknowledged the e-module's well-structured and visually engaging design, particularly its originality in integrating environmental topics. However, to enhance content delivery, the module requires refinements in organization and presentation. Streamlining information by reducing redundancy and incorporating concise, structured explanations will improve readability and knowledge retention. Additionally, age-appropriate modifications are necessary, particularly for younger students such as Year 2 (8-year-olds), as emphasized by Expert E3. Simplifying complex terms like 'climate' and 'greenhouse' and employing engaging storytelling methods will better align the content with their cognitive abilities. Similarly, improvements in language accessibility and readability are essential. Experts suggested replacing complex scientific terminology with simplified explanations and real-world analogies to facilitate comprehension. Reducing wordiness and restructuring verbose sections into more digestible segments will further enhance student understanding. Moreover, incorporating local context, such as Malaysian plant examples like oil palm, rubber and rice was recommended by Expert E4 to increase relevance and cultural contextualization.

Beyond content and language accessibility, strengthening visual representation was identified as a key area for improvement. Experts recommended integrating more visual storytelling elements, such as diagrammatic representations and story-driven visuals, to facilitate engagement and concept comprehension. Optimizing graphic design for better clarity and alignment with learning objectives will further enhance the module's effectiveness. Additionally, increasing interactivity and engagement through embedded quizzes, drag and drop activities, real-world case studies, and gamification techniques will sustain student interest and motivation. While the module demonstrates strong scientific accuracy, experts advised incorporating recent scholarly references to strengthen academic integrity and support claims. Expanding empirical examples of plant-climate interactions will also ensure practical applications and foster higher-order thinking skills. The expert validity assessment confirms that the e-module is a robust educational tool for fostering climate literacy. However, targeted refinements in content structure, visual engagement, interactivity, and scientific rigor will further enhance its impact, ensuring greater accessibility, engagement, and alignment with best practices in climate education.

Conclusion and future work

The expert validation of the e-module on plant importance in mitigating climate change for primary school students confirms its pedagogical soundness and potential effectiveness in fostering climate literacy, enhancing awareness of plant-climate relationships and strengthening science process skills. The module was positively evaluated for its structured and coherent content, engaging interface design and alignment with key educational objectives. Nevertheless, several critical areas for improvement were identified, including the need to simplify language for younger learners, enhance visual representations, embed interactive elements and reinforce scientific depth through updated sources and real-world contexts. Addressing these recommendations will not only improve the module's educational accessibility and engagement but also ensure its alignment with best practices in climate change pedagogy.

The findings highlight the significance of developmentally appropriate instructional design and the contextualisation of environmental topics within students' lived realities. The integration of gamified elements and interactive activities emerged as essential in promoting sustained learner motivation and facilitating deeper conceptual understanding. Furthermore, the validation process underscores the crucial role of expert feedback in ensuring that digital learning materials meet both scientific and pedagogical standards. The validated e-module stands as a credible, evidence-informed educational resource with strong potential for broader adoption in climate change curricula at the primary education level. To extend the effectiveness and reach of the module, future research should pursue several strategic directions. First, empirical testing through quasi-experimental designs should be conducted to assess the module's impact on students' climate literacy, plant-related awareness, and science process skills. This should include a detailed analysis of learner engagement, knowledge acquisition and cognitive load, which can guide refinements in instructional pacing and scaffolding. The use of adaptive learning technologies, particularly those driven by AI should be explored to enable personalized learning pathways that adjust content complexity based on learners' progress and comprehension. Real-time feedback mechanisms and interactive assessments can further support differentiated instruction by addressing individual learner needs.

In addition, future iterations of the module must prioritise accessibility for students with diverse learning profiles, including those with special educational needs and varying cognitive abilities. Universal Design for Learning (UDL) principles should be incorporated to ensure that all students can engage with the content meaningfully, regardless of their learning differences. This may involve integrating multimodal content delivery (e.g., audio narration, simplified text, visual supports) and providing alternative response formats that accommodate diverse learners. Future research should also evaluate the module's accessibility through targeted user testing with learners from inclusive education settings. Expanding the module's real-world relevance remains another priority. Integrating local case studies, citizen science initiatives and virtual simulations of plant-based climate solutions such as carbon sequestration and ecosystem restoration can significantly enrich experiential learning. These additions will bridge theoretical understanding with practical engagement, encouraging students to connect climate knowledge with actionable outcomes in their communities.

To assess the module's sustained impact, longitudinal studies should be undertaken to evaluate the long-term retention of climate concepts and the persistence of pro-environmental behaviours among learners. Finally, the module's adaptation into multiple languages and cultural contexts should be pursued to enhance its global accessibility. This includes translating content,

modifying cultural references, and incorporating region-specific examples of climate issues and plant biodiversity, thus making the module relevant and usable across diverse educational systems. In conclusion, the development and expert validation of this e-module represent a significant step forward in advancing climate change education for young learners. By embedding inclusive design, adaptive technologies and contextually grounded pedagogy, the module holds strong potential as a scalable, high-impact educational tool. Continued research and iterative development will be essential to sustain its effectiveness, accessibility and applicability in an increasingly diverse and dynamic learning landscape.

Acknowledgements

The author gratefully acknowledges the financial support provided by Universiti Kebangsaan Malaysia through Grant GG-2023-007.

References

Andreopoulou, Z., Papagiannopoulou, D., & Tsitsoni, T. (2023). Online app for the evaluation of climate change impact in urban green areas. IADIS International Conference e-Society 2023.

Cassagnes, M. P., Lehérissey, S., & Freulon, H. (2022). CLIMATVEG: Transition and sustainability of crop production systems in the context of climate change. *Acta Horticulturae 1355*, 441-448.

Chopra, R., Joshi, A., Nagarajan, A., Fomproix, N., & Shashidhara, L. S. (2019). Climate change education across the curriculum. In *Climate Change and the Role of Education.* Springer.

Cirkony, C., Tytler, R., & Hubber, P. (2022). Designing and delivering representation-focused science lessons in a digital learning environment. *Educational Technology Research and Development*, *70*, 881–908.

Dolan, A. M. (2022). *Teaching Climate Change: Setting The Context*. Routledge.

Eckardt, N. A., Ainsworth, E. A., Bahuguna, R. N., Broadley, M. R., Busch, W., Carpita, N. C., Castrillo, G., Chory, J., Dehaan, L. R., Duarte, C. M., Wolfe, M., & Zhang, X. (2023). Climate change challenges, plant science solutions. *The Plant Cell*, *35*(1), 24–66.

Elangovan, N., & Sundaravel, E. (2021). Method of preparing a document for survey instrument validation by experts. *MethodsX*, *8*, 101326.

Elliott-Kingston, C., Haines, N., Stewart, G., & McCabe, P. (2021). Creating a university evolution garden: An integrated learning approach for teaching land plant evolution. *Plants People Planet*, *3*(1), 761–774

Espeland, E. K., & Kettenring, K. M. (2018). Strategic plant choices can alleviate climate change impacts: A review. *Journal of Environmental Management*, *222*, 316–324.

Ghazali Darusalam, & Sufean Husin. (2021). *Metodologi Penyelidikan salam Pendidikan: Amalan dan Analisis Kajian* (3rd ed). Penerbit Universiti Malaya.

Gregori-Giralt, E., & Menéndez-Varela, J.-L. (2021). The content aspect of validity in a rubric-based assessment system for course syllabuses. *Studies in Educational Evaluation, 68.* 100971.

Gupta, S., Shukla, B., Sharma, U., Hinneh, P. J., Eswaran, B., Sinha, B. C., Kumari, A., Sharma, N., & Laddhu, S. (2025). Impact of artificial intelligence and machine learning on recruitment

process in MNCs of India. In *Sustainable Management Practices for Employee Retention and Recruitment* (pp. 177–198). IGI Global..

Gutiérrez-Castillo, J. J., Palacios-Rodríguez, A., Martín-Párraga, L., & Serrano-Hidalgo, M. (2023). Development of digital teaching competence: Pilot experience and validation through expert judgment. *Education Sciences 13*(1), 52.

Hidayah, N. A., Gunawan, M. N., Kusumawati, D., Maswani, Handayani, R., & Suparto. (2023). Student Perceptions of User Satisfaction and User Loyalty of Website Based E-Learning. 2023 11th International Conference on Cyber and IT Service Management, CITSM 2023.

IUCN. (2021). Red_List_Quadrennial_Report_2017-2020.

Katauhi, R. C., Widodo, W., & Sari, D. A. P. (2022). Implementation of the science e-module based on guided inquiry with the flipped classroom strategy to improve students science process skills. *Jurnal Pijar Mipa, 17*(5), 657–665.

Kharipova, R., Khaydarov, I., Akramova, S., Lutfullaeva, D., Saidov, S., Erkinov, A., Azizkhonova, S., & Erkinova, N. (2024). The role of artificial intelligence technologies in evaluating the veracity of scientific research. *Journal of Internet Services and Information Security, 14*(4), 554–568.

Lioi, F. M., Antonini, M., Elias, H. C., de Macedo Rocha, D., Melo Montanari Fedocci, E., Gir, E., & Reis, R. K. (2025). Validation of a website on combined HIV prevention for the general population. *ACTA Paulista de Enfermagem*, *38*(1).

Mahadzir, S. Y., Muda, Z., Hanawi, S. A., & Ramli, Z. (2024). Content validation through expert judgement of web-based megalithic culture visualization. *Geografia-Malaysian Journal of Society and Space*, *20*(2), 128-144.

Mayr, H. (2023). Promoting education for sustainable development using blended learning and digital tools: Two university courses, one case study. In *Digitalization, New Media, and Education for Sustainable Development*.

MESTECC. (2018). Malaysia Third National Communication And Second Biennial Update Report To The UNFCCC.

Nazeri, N., Haghighat, S., Jourabian, S., & Dorri, S. (2022). Design and Evaluation of e-Learning Package for Breast Cancer Prevention for Iranian Women. *Iranian Journal of Breast Diseases, 15*(1), 33–45.

Nieminen, J. H., Bearman, M., & Ajjawi, R. (2023). Designing the digital in authentic assessment: is it fit for purpose? *Assessment and Evaluation in Higher Education*, 48(4), 529-543.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric Theory* (3rd ed). McGraw-Hill.

OECD. (2020). PISA 2024 Strategic Vision and Direction for Science.

Ormancı, Ü., & Çepni, S. (2020). Investigating the effects of web-based science material for guided inquiry approach on information and communication skills of students. *Participatory Educational Research, 7*(1), 201–219.

Ragupathi, K. & Lee, A. 2020. Beyond Fairness and Consistency in Grading: The Role of Rubrics inHigher Education. In C. Sanger & N. Gleason (eds.), *Diversity and Inclusion in Global Higher Education.* Palgrave Macmillan.

Reef Check Malaysia. (2022). Status of Coral Reefs in Malaysia Annual Report.

Sidek Mohd Noah, & Jamaludin Ahmad. (2005). *Pembinaan Modul: Bagaimana Membina Modul Latihan dan Modul Akademik.* Penerbit Universiti Putra Malaysia.

Suwatra, W., Suyatna, A., & Rosidin, U. (2018). Development of interactive e-module for global warming to grow of critical thinking skills. *International Journal of Advanced Engineering, Management and Science, 4*(7), 543–549.

UNICEF. (2021). Kesan Perubahan Iklim terhadap Kanak-kanak. www.unicef.org/malaysia

United Nations. (2023). Synergy Solutions for a World in Crisis: Tackling Climate and SDG Action Together.

WWF. (2020). Bending the Curve of Biodiversity Loss Living Planet Report 2020. https://wwfin.awsassets.panda.org/downloads/lpr_2020_full_report.pdf