Development and Validation of an Adaptive E-Learning Module Website for Teaching Genetics Vocabulary

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ABSTRACT

Genetics remains a challenging topic in Biology because it involves abstract concepts and technical vocabulary that learners often find difficult to understand. This study aimed to develop and validate an adaptive e-learning module website for teaching genetics vocabulary among secondary learners. Using a developmental research design with a quantitative evaluation approach, the study identified weak vocabulary under heredity and genetics and used these as the basis for developing three differentiated module versions: easy, average, and hard. The website was designed to direct learners to an appropriate module based on their pretest performance and guide them through vocabulary-focused activities. The developed website was evaluated using the SMOG Index for readability and expert validation for content quality and technical acceptability. Eight validators participated in the evaluation, composed of five content experts and three ICT experts. Results showed that the three modules were suitable for secondary learners, with SMOG scores of 8.46, 8.86, and 9.62. Content validation showed very high ratings in concept development and context, while ICT validation indicated highly acceptable functionality and accessibility, with excellent ratings in browser compatibility, mobile design-access, and privacy. Overall, the adaptive e-learning module website was found to be readable, content-valid, and technically acceptable for supporting genetics vocabulary instruction.

Keywords: adaptive learning, e-learning module website, genetics vocabulary, biology education, digital instructional material

INTRODUCTION

Biology learning becomes more challenging when students are expected to understand concepts that are both abstract and language-heavy. Among these topics, **genetics** is consistently identified as one of the most difficult areas in biology because learners often struggle with unfamiliar terms, invisible biological processes, and misconceptions involving inheritance, genes, chromosomes, and molecular mechanisms. International studies have shown that students frequently find it difficult to connect basic genetic terms with deeper biological functions, resulting in persistent misconceptions and weak conceptual understanding (Machová & Ehler, 2023; Ojo, 2024). At the same time, recent international literature emphasizes that adaptive and technology-supported learning environments can make instruction more responsive to learner differences by personalizing content, pacing, and support. In biology education, digital and mobile-based learning tools, including interactive and augmented reality-supported resources, have been shown to improve learner engagement with complex and abstract concepts (Gligorea et al., 2023; Nurdin et al., 2025; Sangur et al., 2025).

In the Philippine context, the use of digital tools in science education has expanded, but local studies show that implementation remains uneven and often depends on the availability of context-appropriate and validated instructional resources. A recent Philippine scoping review noted that digital innovations in K–12 science commonly include locally developed modules, simulations, gamified tools, and mobile-friendly resources, but

their use is still highly dependent on school conditions and access (Colegado, 2025). More specifically, local studies related to biology and genetics have shown encouraging results. Dolojan (2024) developed Android-based learning materials in genetics that were rated highly by both content and ICT evaluators, while Barrientos et al. (2024) developed digital interactive Mendelian genetics comic stories that also received excellent expert ratings. These findings support the need for additional validated and learner-responsive digital materials in biology, particularly those that address the vocabulary and conceptual demands of genetics. Further support comes from recent local development studies. Abulkhair et al. (2024) concluded that video lessons are useful supplementary materials in teaching heredity because they help teachers illustrate complex concepts, supplement traditional instruction, and improve students' conceptual understanding. Likewise, Laguindab et al. (2025) found that an interactive strategic intervention material in genetics was valid, usable, and effective, while also supporting independent and self-paced learning, particularly in resource-constrained educational settings. In this context, the present study developed and validated an adaptive e-learning module website for genetics vocabulary as a learner-responsive digital material for secondary biology instruction.

METHOD

This study followed a **developmental research design** with a quantitative evaluation approach. It focused on developing and validating an adaptive e-learning module website intended to support students in learning genetics vocabulary. The development process started with the identification of heredity and genetics as a difficult Biology topic, followed by the selection of vocabulary terms that learners commonly find challenging. From these results, three module versions were prepared: **easy, average, and hard**, each designed to match different levels of learner understanding.

The website was designed to guide learners to a suitable module based on their pretest performance. To support active learning, each module required students to interact with selected vocabulary words before moving to the next part of the lesson. The developed website was then evaluated through readability testing using the **SMOG Index** and expert validation. Five content experts reviewed the instructional quality of the material, while three ICT experts evaluated its technical features. The results were analyzed using mean scores and descriptive interpretations. Comments from the validators were also considered in revising the website, particularly in improving the lesson flow, navigation, accessibility, and mobile responsiveness. This approach is consistent with recent development-oriented studies that use readability measures, expert review, and usability criteria to establish the quality of digital instructional materials (Balo & Sanchez, 2025; Putri Azrai et al., 2025).

RESULTS AND DISCUSSION

This section presents the selection of genetics as the focus of the study, the identification of weak vocabulary, and the development, readability, validation, and revision of the adaptive e-learning module website.

Selection of Topic

The findings identified heredity and genetics as one of the least-mastered science topics among high school learners. This is consistent with recent literature showing that genetics remains a persistent area of difficulty because students often struggle to understand relationships among genes, traits, inheritance patterns, and molecular processes (Machová & Ehler, 2023; Ojo, 2024). The choice of this topic therefore reflects a real instructional need. Since genetics contains many unfamiliar and conceptually dense terms, selecting it as the focus of the module was appropriate for the development of a vocabulary-oriented intervention that could support both language comprehension and conceptual learning.

Identification of Weak Vocabulary Based on the Selected Learning Competency

After identifying heredity and genetics as a weak area, the study focused on vocabulary that learners commonly find difficult within the targeted competency. These included foundational and process-related terms in genetics that often function as barriers to understanding when students memorize definitions without fully grasping their meaning in context. Recent studies note that misconceptions in genetics are often linked

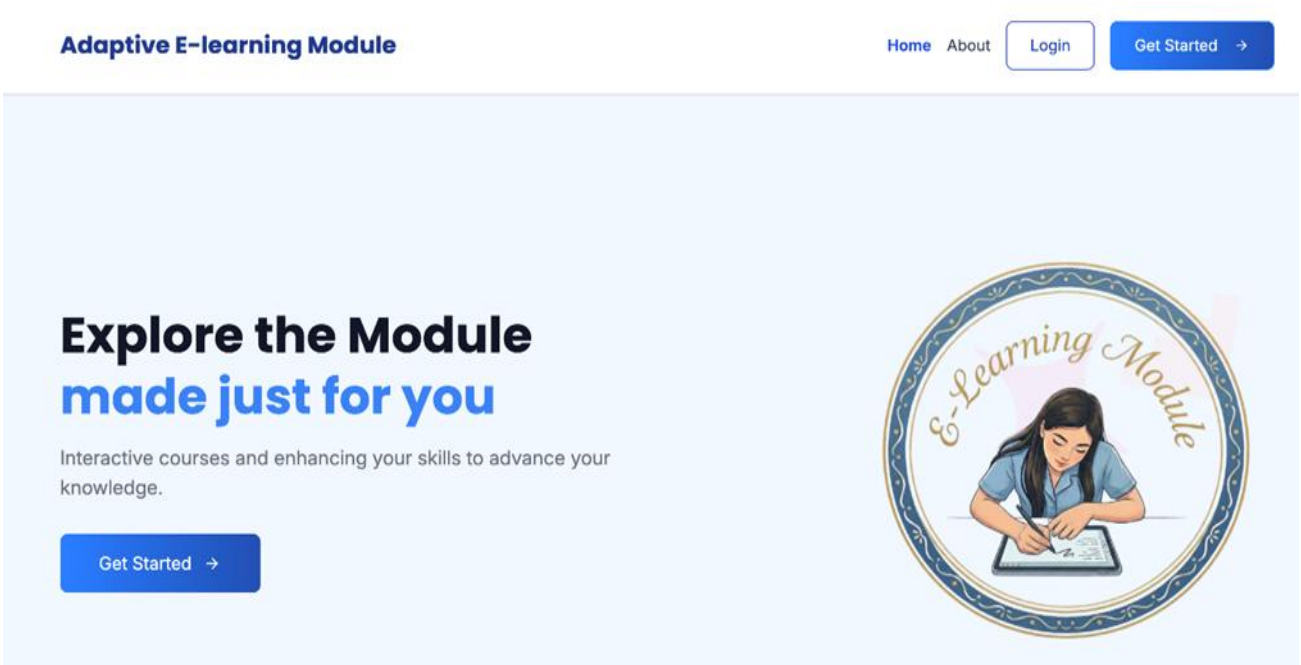
not only to abstract reasoning demands but also to students' weak understanding of the language used to describe inheritance, variation, and molecular processes (Machová & Ehler, 2023; Ojo, 2024). For this reason, identifying weak vocabulary served as an important step in ensuring that the website addressed actual learner difficulties rather than presenting content in a purely general form.

Development of the Adaptive E-Learning Module Website Suited for Learners' Conceptual Needs

The adaptive e-learning module website was developed to provide a more responsive and structured way of teaching genetics vocabulary. The website was designed to adapt to learners' conceptual understanding based on their pretest scores. Using an adaptive learning approach, the system assigned learners to one of three module levels—easy, average, or hard—depending on their initial performance. After the preface, progression through the module was controlled sequentially. In each succeeding page, learners needed to click a required word before the next page could be unlocked. This structure was intended to sustain attention, support guided learning, and ensure active engagement until learners reached the final post-test section.

This design is coherent with recent literature showing that adaptive and differentiated digital learning nvironments can better accommodate learner diversity and provide more personalized learning pathways in science education (Gligorea et al., 2023; Nurdin et al., 2025). In biology education, well-designed digital learning websites have also been found to support more interactive and meaningful engagement with complex concepts, especially when materials are structured around learner needs and curricular goals (Putri Azrai et al., 2025; Sangur et al., 2025). This is also consistent with recent local evidence showing that well-designed supplementary and intervention materials can improve the teaching of difficult genetics concepts. Abulkhair et al. (2024) found that video lessons help make heredity more understandable by allowing teachers to visualize concepts that are otherwise difficult to explain, while Laguindab et al. (2025) showed that interactive and visually enriched genetics materials can improve comprehension and support learners' independent pacing. Thus, the developed website was not merely a collection of genetics terms, but a guided and adaptive instructional material intended to make genetics vocabulary more accessible to learners.

Figure 1. Homepage of the Adaptive E-learning Website



Readability

The readability assessment using the SMOG Index showed a clear progression across the three module versions. The easy module obtained a SMOG score of 8.46, which corresponds to the 8th-grade level, with an estimated age range of 13–14. It was described by the calculator as average to slightly difficult and was based on 574 complex words across 275 sentences. The average module obtained a SMOG score of 8.86,

corresponding to the 9th-grade level, with an estimated age range of 14–15. It was classified as slightly difficult and contained 693 complex words across 301 sentences. Meanwhile, the hard module obtained a SMOG score of 9.62, corresponding to the 10th-grade level, with an estimated age range of 15–16. It was described as somewhat difficult and contained 805 complex words across 295 sentences. Taken together, these findings show a gradual increase in reading demand from the easy to the hard version, indicating that the modules were successfully differentiated according to readability level while remaining suitable for secondary learners.

The use of the SMOG Index in this study is supported by recent local research. In a Philippine study, Pitogo et al. (2026) used SMOG together with Flesch–Kincaid Grade Level to check the suitability of a Grade 10 chemistry diagnostic tool for its intended learners. Similarly, Mino et al. (2026) used the same readability measures to ensure that a General Chemistry assessment instrument was appropriate for Senior High School students. These studies support the use of SMOG as a practical tool for determining whether educational materials are aligned with the reading level of the target learners.

Validation of the Developed Adaptive E-Learning Module Website

The developed adaptive e-learning module website was subjected to expert validation to determine its quality in terms of content and technical acceptability. The validation involved eight experts, consisting of three ICT experts, one content expert with a doctoral degree, and four content experts with master's degrees. All content experts were in-service teachers. Using a rubric-based evaluation, the content experts assessed the website in terms of standards alignment, accuracy, concept development, sequencing, and context, while the ICT experts evaluated its functionality, accessibility, browser compatibility, mobile design-access, and privacy, data protection, and rights.

Table 1. Summary of Content Experts' Ratings of the Developed Adaptive E-Learning Module Website

CRITERIA	Mean	Description
1. Standards Alignment	**4.6**	**Very High**
2. Accuracy	**4.8**	**Very High**
3. Concept Development	**5.0**	**Very High**
4. Sequencing	**4.2**	**High**
5. Context	**5.0**	**Very High**

Table 1 presents the content validation results for the developed adaptive e-learning module website. The website obtained very high ratings in concept development (M = 5.0) and context (M = 5.0), followed by accuracy (M = 4.8) and standards alignment (M = 4.6). Sequencing obtained the lowest mean (M = 4.2), although it was still interpreted as high. These findings indicate that the website content was relevant, accurate, and aligned with the intended learning competency. The relatively lower rating in sequencing suggests the need for minor improvement in the flow and progression of lessons. Overall, the results support the validity and instructional suitability of the website as a teaching material for genetics vocabulary (Balo & Sanchez, 2025; Ula et al., 2025).

Table 2. Summary of ICT Experts' Ratings of the Developed Adaptive E-Learning Module Website

CRITERIA	Mean	Description
A. Functionality (15 pts.)	**12.7**	**Highly Acceptable**
B. Accessibility (10 pts.)	**8.7**	**Highly Acceptable**
C. Technical (Browser) (5 pts.)	**5**	**Excellent**
D. Mobile Design-Access (5 pts.)	**5**	**Excellent**
E. Privacy, Data Protection and Rights (5 pts.)	**5**	**Excellent**

Table 2 indicates that the ICT experts rated the adaptive e-learning module website positively in its technical aspects. For functionality, which included scale, ease of use, and hypermediality, the website obtained 12.7 out of 15, interpreted as highly acceptable. This suggests that the website was functional, easy to navigate, and

capable of presenting content through appropriate linked and multimedia features. For accessibility, which covered user-focused participation and required equipment, the website received 8.7 out of 10, also described as highly acceptable, indicating that it could support learner interaction while remaining practical for school-based use. Moreover, perfect scores in browser compatibility, mobile design-access, and privacy, data protection, and rights show that the website was technically stable, device-responsive, and aligned with essential digital safety standards (Aliyeva & Çakır, 2025; Putri Azrai et al., 2025).

Revision

After the readability assessment and expert validation, the adaptive e-learning module website was revised based on the comments and suggestions of the validators.

Table 3. Summary of Validators' Comments and Revisions Made on the Adaptive E-Learning Module Website

Validators' Concern	Revision Made	Purpose
Lesson sequencing needed improvement	Improved order of lessons and transitions	To make vocabulary learning more gradual
Navigation needed refinement	Improved buttons, labels, and links	To make the website easier to use
Accessibility needed improvement	Checked mobile responsiveness and page usability	To support learners using different devices

Based on the validators' feedback, the revisions focused on improving the sequencing, functionality, and accessibility of the adaptive e-learning module website. The lesson order and transitions were refined to present genetics vocabulary in a more gradual and coherent manner. Technical improvements were also made by enhancing the buttons, links, navigation, mobile responsiveness, and overall page usability. These revisions are important because digital instructional materials should not only provide accurate content but also ensure usability, accessibility, and learner support throughout the learning process (Nurdin et al., 2025; Aliyeva & Çakır, 2025; Putri Azrai et al., 2025).

CONCLUSION

This study developed an adaptive e-learning module website designed to support the teaching of genetics vocabulary among high school learners. The findings showed that the heredity and genetics topic was an appropriate focus because it remains a least-mastered and conceptually demanding area in biology. The website was developed with easy, average, and hard module versions assigned based on learners' pretest performance. Readability results showed that the modules were suitable for secondary learners, while expert validation confirmed strong content quality and technical acceptability. Overall, the developed website may serve as a valid, readable, and technically acceptable instructional material for supporting genetics vocabulary instruction. Its adaptive structure provides differentiated learning pathways, while its guided vocabulary-based design helps make abstract genetics concepts more accessible. Future implementation with learner-respondents is recommended to determine its effect on vocabulary acquisition, conceptual understanding, and engagement in genetics learning.

RECOMMENDATIONS

Based on the findings, the developed adaptive e-learning module website is recommended for use as a supplementary instructional material in teaching genetics vocabulary. The researchers' future direction for the study includes the following:

- Pilot testing the module with Grade 10 learners.
- Using experimental or quasi-experimental designs to measure learning gains and vocabulary retention.
- Conducting field testing with a larger and more diverse group of learners.
- Gathering learner feedback to improve engagement, usability, mobile access, and instructional design.
- Adding more genetics concepts, interactive activities, formative assessments, and progress-tracking features.

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APPENDIX

Appendix 1

Rubric for Content Experts
(Adapted and modified from: BSCS Center for Professional Development Colorado)

Validator: _____ Date Rated: _____

Direction: This scoring rubric was adapted and modified to rate the content of the Adaptive E-learning Module for Genetics Vocabularies. Examine the material carefully and for each evaluation criterion consider the extent (as described) to which the resource meets the criteria. Indicate the appropriate number of points in the last column.

Science Content Rubric	5 points	3 points	1 point	Score
1. Standards Alignment: Science content standards: -May originate at the national, state, district, or school level. -May include the subject matter disciplines in Genetics as well as science as inquiry, science and technology, science in personal and social perspectives, history and nature of science, and/or unifying concepts and processes.	All the science content standards designated for the specific course and/or grade level are addressed.	Some (at least five) of the science content standards designated for the Specific course and/or grade level are addressed.	No science content standards designated for the specific course and/or grade level are addressed and processes.	
2. ACCURACY Accurate science content: - Is grounded in current research on genetics education and conforms to factual accuracy (cited examples are relevant to the local or familiar context of learners). - Includes clear and developmentally appropriate explanations of genetics vocabulary (e.g., allele, genotype, phenotype, mutation) that promote conceptual understanding without distorting the original scientific meaning.	All the science content is accurate with few errors of fact or interpretation.	Some (at least five elements) of the science content is accurate with few errors of fact or interpretation	No science content is accurate.	
3. CONCEPT DEVELOPMENT Content developed for conceptual understanding: - Includes a focused set of key genetics vocabulary and concepts (e.g., allele, gene, genotype, phenotype, mutation) essential for understanding heredity and variation. - Develops these concepts in-depth & presents them at a developmentally appropriate level for learners. - Encourages students to apply and demonstrate their understanding of genetics vocabulary through varied activities, assessments, and contextual applications.	All key genetics concepts and definitions (e.g., allele, gene, genotype, phenotype, mutation, DNA, chromosome, trait, variation, heredity) are clearly developed for conceptual understanding.	Some (at least five) key genetics concepts and definitions are developed for conceptual understanding.	No key genetics concepts or definitions are adequately developed for conceptual understanding.	
4. SEQUENCING Content with coherent sequence a is organized in a deliberate fashion to promote student understanding. - Links facts and concepts in ways that facilitate retrieval and application. - Builds from and extends concepts previously developed. - Strongly connects concepts to an overarching conceptual framework.	All of the content has a coherent sequence.	Some (at least five elements) of the content has a coherent sequence.	The content has no coherent sequence	
5. CONTEXT Content that is context-rich: - Content is presented in meaningful and engaging contexts related to real-world genetics applications (e.g., inheritance of traits in families,	All key science concepts are addressed in a context-rich setting.	Some (at least five) key science concepts are addressed in a context-rich setting.	No key science concepts are addressed in a context-rich setting.	

genetic disorders, selective breeding, or local biodiversity examples). - Facilitates the assimilation or reorganization of knowledge by connecting new genetics vocabulary to learners' prior conceptions and everyday experiences. - Encourages learners to relate genetics terms and concepts to observable phenomena in their environment or community.				

Total Score:

Comments and Suggestions:

_____

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_____

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Validator: _____
Signature over printed Name

Appendix 2

Rubric for Multimedia Experts
(Adapted and modified from: Guba, S., 2022)

Direction: This scoring rubric was adapted and modified to rate the multimedia elements of the Adaptive E-Learning Module. Examine the material carefully and for each evaluation criterion consider the extent (as described) to which the resource meets the criteria Indicate the appropriate number of points in the last column.

Criteria	Very Satisfactory (5 pts)	Satisfactory (3 pts)	Not Satisfactory (1 point)	Points
A. Functionality				
A-1 Scale	The tool can be scaled to accommodate any size class with the flexibility to create smaller sub-groups or communities of practice.	The tool can scale to accommodate any size class but lacks flexibility to create smaller sub-groups or communities of practice.	The tool is restrictive to a limited number of users and cannot be scaled.	
A-2 Ease of Use	The tool is extremely user-friendly. Both instructors and students can easily navigate, access content, and perform tasks without guidance. Menus, buttons, and interactive features are intuitive, and users can personalize their experience smoothly.	The tool is moderately user-friendly. Users can navigate and access most content, though some features may require brief guidance. Minor usability issues may slow down interaction but do not prevent learning.	The tool is difficult to use. Navigation is confusing, menus and buttons $A = \pi r^2$ unclear, and users struggle to access or complete tasks. Usability issues significantly hinder learning and engagement.	
A-3 Hypermediality	The tool allows users to communicate through different channels (audio, visual, textual) and allows for non-sequential flexible/adaptive engagement with material.	The tool allows users to communicate through different channels (audio, visual, textual) but is limited in its ability to provide non- sequential, flexible/adaptive.	The tool is restrictive in terms of the communication channels employed (audio, visual, textual) and presents information sequentially in a rigid, inflexible format.	
B. Accessibility				
B-1 User-focused participation	The tool is designed to address the needs of diverse users, their various literacies, and capabilities, thereby widening opportunities for participation in learning	The tool has some limited capacity to address the needs of diverse users, their various literacies, and capabilities	The tool is restrictive in meeting the diversity of needs reflective in the student body. The tool likely restricts some students from fully participating.	
B-2 Required Equipment	Proper use of the tool does not require equipment beyond what is typically available to instructors and students (any smart device such as android phones/1phones, laptop or MacBook, tablets, internet connection with at least 5mbps, etc.)	Proper use of the tool requires specialized equipment (e.g. unique device) that likely requires purchase at a low cost.	Proper use of the tool requires specialized equipment requiring moderate to significant financial 1nvestment.	
C. Technical (Browser)	Users can effectively utilize the tool with any standard, up-to-date browser.	Users may encounter limited or altered functionality depending on the up-to-date browser being used.	Users are limited to using the tool through one specific browser.	

D. Mobile Design-Access	The tool can be accessed either through the download of an app or via a mobile browser, regardless of the mobile operating system and device. Design of the mobile tool fully takes into consideration the constraints of a smaller-sized screen.	The tool offers an app, but only for a limited set of mobile operating systems. Tool is not accessible through a mobile browser. Design of the mobile tool constrained by the limitations of the mobile device.	Access to the tool is limited or absent on a mobile device.	
E. Privacy, Data Protection and Rights	Use of the tool does not require the creation of an external account or additional login, such that no personal user information collected and shared.	Either instructors are the only users required to provide personal information to set up an account; or the tool has been vetted through appropriate channels to ensure strict adherence to local. institutional. or personal policies/standard ds for protecting the collection and use of student personal data by a third-party group.	All users (instructors and students) must provide personal information to a third party in creating an account and there is some question or concern of the adherence to local, institutional, or personal policies/standard ds for protecting the collection and use of such data by the third- party group	

Total Score:

Comments and Suggestions:

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_____

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Validator: _____
Signature over printed Name