

**DEVELOPMENT OF TEDDLASS COMPUTER SIMULATION FOR GENETICS AND
EVOLUTION INSTRUCTION**

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Abstract

This study developed and validated TEDDLASS Computer Simulation (TCS) for teaching genetics and evolution in Colleges of Education in Katsina State, Nigeria. Using Havelock's Research, Development, and Diffusion (RD&D) model, the study involved needs assessment, software design, Alpha (expert) validation, and Beta (field) validation. TEDDLASS covers abstract concepts such as heredity, sex determination, linkage, mutation, and evolutionary theories, aligned with the NCCE (2012) Biology Curriculum (BIO 323). Validation involved 27 experts and 34 field validators, and data were analyzed using mean ratings, frequency distribution, and thematic analysis of open-ended responses. Findings revealed that TEDDLASS was appropriate across all validation domains, including content accuracy, instructional design, usability, and technical functionality, with 70% of content fully aligned with the curriculum. Field validation confirmed high usability, engagement, and pedagogical relevance. The study concludes that TEDDLASS is a valid, curriculum-aligned, and technically sound instructional tool suitable for teaching genetics and evolution at the NCE level. It was therefore recommended that TEDDLASS computer simulation should be adopted for teaching genetics and evolution in Colleges of Education in Katsina State, Nigeria.

Keywords: Computer Simulation, TEDDLASS, Genetics and Evolution, RD&D model, Instructional technology, Curriculum Validation

Introduction

The term 'simulation' finds its origins in the Latin word 'similis,' meaning to imitate, resemble, or enact. In the literature, simulation has diverse definitions; encompassing the emulation of real-life situations to facilitate learning, and the act of mimicking original processes (Almasri, 2022). It also serves as an educational method that replicates real-world occurrences and processes within controlled conditions (Yin & McKay, 2018). Simulations enable students to apply theoretical knowledge and essential skills while engaging with them in a manner similar to how they would react in real situations. A program that seeks to mimic or simulate an abstract system model is known as a computer simulation.

Computer simulations represent the culmination of ongoing advancements in digital information technology, a logical consequence of adapting to the developments in information and communication technologies, which includes the use of various virtual laboratories (Saputri, 2021). It involves creating a model of a real-world scenario and using a computer to predict how that scenario will unfold (Kumar, 2018). According to Ibezim and Asogwa, (2020), it is a program designed to replicate or simulate a non-concrete model of a specific subject, aiding students in comprehending complex concepts and applying what they have learned. A simulated program generates animated, interactive, and game-like environments that connect real events with the underlying scientific principles that support them (Lasisi, Arowolo, Agbeyenku, & Ojoko, 2021). This makes it a valuable tool for both teaching and learning of abstract concepts (Akhigbe & Ogufere, 2019).

Simulations in science education take various forms, including standalone programs, web-based models, and multimedia-enhanced formats (Egara & Mosimege, 2023). When rooted in constructivist theory, simulations enable learners to interact with and explore dynamic models, thereby supporting deep understanding of abstract science concepts (Ouahi, Mohamed,

Abdsselam, Taofik & El-Mehdi, 2021). TEDDLASS (Theories of Evolution, Evidence of Evolution, Darwinism Theory, Darwin's Theory of Natural Selection, Linkages, Autosomes, Sex Chromosomes & Sex Determination) in this regard, serves as a purpose-built simulation package that supports biology learning by allowing students to manipulate genetic materials, observe mutation processes, and understand evolutionary changes through active engagement.

TEDDLASS is a computer simulation developed by the researchers to enhance the teaching and learning of genetics and evolution in the NCE biology curriculum. The acronym TEDDLASS stands for Theories of Evolution, Evidences of Evolution, Darwinism Theory, Darwin's Theory of Natural Selection, Linkage, Autosomes, Sex Chromosomes, and Sex Determination, covering essential concepts in these fields, inspired by acronym-based educational tool like EPODEWALAD (Obeka, 2009). TEDDLASS provides an interactive and student-centered learning experience, making complex biological principles more accessible through simulations.

Specifically, TEDDLASS addresses fundamental concepts in evolution and genetics such as Darwinian evolution, mutation theory, linkage, autosomes, and sex determination. These simulations enable students to grasp complex inheritance mechanisms through interactive models that illustrate biological theory in real-life scenarios. In addition to content, TEDDLASS was designed using a suite of modern programming and educational technologies to provide an interactive, intuitive, and pedagogically sound simulation environment for teaching genetics and evolution. The platform was developed with HTML5 as its structural foundation, while CSS3 ensured a visually engaging interface. JavaScript was employed to enhance interactivity, enabling dynamic user engagement throughout the simulation process. On the server side, Python Django served as the backend framework, handling database operations, user data, and session management. The Adobe Creative Suite was instrumental in generating high-quality animations, graphics, and multimedia content that not only enhanced visual appeal but also supported conceptual clarity for complex biological phenomena.

This paper focuses on the development and validation of the TEDDLASS Computer Simulation for teaching genetics and evolution in Colleges of Education in Katsina State, Nigeria. It is delimited to the design process, curriculum alignment, and Alpha and Beta validation of the simulation. The simulation content was limited to selected topics drawn from the NCCE (2012) Biology Curriculum (BIO 323).

Research Objectives

The research was set to;

1. Develop the content of the TEDDLASS computer simulation for teaching genetics and evolution in Colleges of Education in Katsina State, Nigeria.
2. Validate the content and design of the TEDDLASS computer simulation for teaching genetics and evolution in Colleges of Education in Katsina State, Nigeria.

Research Questions

1. What content and design features are required for the development of the TEDDLASS computer simulation for teaching genetics and evolution?
2. To what extent is the content and design of the TEDDLASS computer simulation appropriate for teaching genetics and evolution based on expert and field validation?

Methodology

1. Design

This study adopted a Research, Development, and Diffusion (RD&D) method as articulated by Havelock (1976). The RD&D method was utilized for the systematic design, development, and validation of the TEDDLASS Computer Simulation (TCS). The RD&D method is structured into three interconnected phases: Research, Development, and Diffusion, each of which plays a critical role in the systematic creation, validation, and dissemination of the TCS.



Figure 1: Research, Development and Diffusion Model (Havelock's 1976)

This model emphasizes a systematic and iterative approach to problem-solving, idea generation, innovation development, and dissemination, making it highly suitable for the creation and validation of instructional technologies in education. The TEDDLASS simulation aims to enhance pre-service teachers' understanding of genetics and evolution by providing an engaging, interactive, and pedagogically relevant digital environment tailored to the Nigerian context.

The process began with the **Research phase**, which involved an extensive inquiry the challenges associated with the lack of culturally relevant computer simulation packages for science education in Nigeria, particularly in the teaching of genetics and evolution. This phase entailed a detailed need assessment aimed at identifying the challenges experienced in teaching abstract genetics and evolutionary concepts in Colleges of Education within Katsina State. It also incorporated a comprehensive review of related literature and a situational analysis of curriculum requirements, instructional gaps, and technological limitations affecting effective teaching and learning within Nigerian Colleges of Education. During this phase, the **Software Requirement Specifications (SRS)** for the TEDDLASS Computer Simulation (TCS) were identified and developed. These specifications were derived from insights gathered through literature review,

consultation with subject-matter experts, and alignment with the NCCE (2012) Biology curriculum (BIO 323). The SRS articulated the essential features, functional requirements, learning content, interactivity design, and cultural contextualization elements necessary for the development of TEDDLASS. The content of TEDDLASS was systematically structured into five core instructional units aligned with the NCCE (2012) Biology curriculum, namely: 1. Heredity and Environment; 2. Sex Chromosomes, Autosomes, Sex Determination and Sex Linkage; 3. Evidence for Evolution; 4. Theories and Trends in Evolution; 5. Darwinism and Natural Selection.

Following this, the **Development Phase** commenced, focusing on the systematic design, prototyping, and iterative refinement of the TEDDLASS simulation based on the preliminary SRS. This stage involved collaborative reviews between curriculum specialists and software developers to ensure the accuracy and pedagogical soundness of the content. The instructional materials were organized into conceptual modules corresponding to the identified curriculum areas, while the interface design, interactivity features, and multimedia components were developed according to the defined specifications. The development process adhered to best practices in instructional software design. Accordingly, TEDDLASS was designed based on a **modular software architecture** comprising four interconnected components, namely: **Student Model**: The student model represents the learner's current knowledge, skills, and affective characteristics. It uses data from user inputs, scores, and behavioral patterns to adapt the learning experience.

This model helps TEDDLASS differentiate instruction and provide feedback based on individual learner needs. **Domain Model**: This model defines the subject content of genetics and evolution, including key concepts, problem-solving rules, examples, and misconceptions. It ensures accuracy, alignment with curriculum standards, and coherence of the knowledge structure presented in the simulation. **Tutoring Model**: The tutoring model composes the interaction

between the domain content and the learner, providing feedback, hints, prompts, and remediation. TEDDLASS employs this model to scaffold learning through guided discovery, reflective questioning, and feedback loops embedded within each simulation segment. **User Interface (UI) Model:** The UI model defines how the learner interacts with the system. TEDDLASS provides a user-friendly, intuitive interface with animated instructions, clickable icons, drop-down menus, and simulation controls designed to minimize cognitive load and maximize learner engagement.

The simulation then undergoes validation process which includes; Alpha and Beta validation. The feedback obtained from these validations guided further revisions and enhancements to the simulation, ensuring it is both effective and practical. Alpha testing (credibility checks) and Beta testing (pilot implementation) were carried out, and feedback from these evaluations informed further refinement of both the simulation and its accompanying instructional strategies.

The **Diffusion Phase** commenced with the initial implementation of the TEDDLASS Computer Simulation (TCS). The **final Diffusion phase** emphasized encouraging the adoption and long-term use of TEDDLASS within biology education.

2. Population

The target population for this study comprised 88 participants, which included 13 computer programming experts, 8 experts in educational technology, 17 ICT technical staff, 34 field validators, and 16 subject experts drawn from Umaru Musa Yar'adua University, Katsina (UMYUK), Federal College of Education, Katsina (FCE K), and the Kyemetra Software Solution (KSS). Table 1 presents detailed information on the distribution of the population of computer programming experts, educational technologists, ICT technical staffs, field validators and subject experts.

Table 1: Distribution of the population of Computer Programmers, Educational Technologists, ICT Technical Staffs, Field Validators and Subject Expert

S/N		No. of Computer Programmers	No. of Educational Technologists	No. of ICT Technical Staffs	No. of Field Validators	No. of Subject Expert	Total
1	UMYUK	3	5	9	-	9	26
2	FCE K	2	3	6	34	7	52
3	KSS	8	-	2	-	-	10
Total Population		13	8	17	34	16	88

Source: Head of Departments (UMYUK, FCE K & KSS, 2023)

3. Sample and Sampling Technique

This study employed purposive sampling method to select specific categories of participants who were directly relevant to the development and validation of the TEDDLASS Computer Simulation (TCS). Their selection was based on their expertise, experience, and direct relevance to the software design, validation, and instructional alignment processes. Six (6) technical staff members and six (6) subject experts participated in the validation of the TEDDLASS Computer Simulation (TCS) contents. Moreover, no sampling was conducted for certain categories of respondents; namely, the thirteen (13) computer programming experts, eight (8) educational technologists and thirty four (34) field validators because their population size was manageable.

4. Instrumentation

Two researcher-developed instruments were used for the validation of the TEDDLASS Computer Simulation (TCS): TEDDLASS Expert Validation Checklist (TEVC) **and** TEDDLASS Field Validation Questionnaire (TFVQ).

The **TEDDLASS Expert Validation Checklist (TEVC)** was used during the Alpha validation phase to obtain expert judgments on the quality and appropriateness of the simulation. The checklist consisted of structured items rated on a four-point Likert scale ranging from *Strongly*

Agree (4) to Strongly Disagree (1). The instrument evaluated five major domains: content accuracy and curriculum alignment, instructional design and pedagogical quality, user interface and navigation, technical quality and functionality, and overall assessment. The checklist also included open-ended sections to allow experts to provide qualitative feedback and suggestions for improvement.

The **TEDDLASS Field Validation Questionnaire (TFVQ)** was used during the Beta validation phase to collect data from pre-service teachers and technical staff on the usability, instructional clarity, engagement, and technical performance of the simulation in authentic learning settings. The questionnaire comprised close-ended items rated on a four-point scale and open-ended questions designed to capture users' experiences, challenges, and perceptions of the simulation.

Both instruments were subjected to expert review for face and content validity before administration and were refined based on feedback to ensure clarity, relevance, and alignment with the study objectives.

5. Validity of TEDDLASS Computer Simulation TCS

The validation of the TEDDLASS Computer Simulation (TCS) followed the framework of Havelock's Research, Development, and Diffusion (RD&D) Model (Havelock, 1976), which is particularly suited for educational innovation that involves instructional software design. The RD&D model supports structured development and systematic validation of educational tools, ensuring they meet both pedagogical goals and technological standards.

The validation process was divided into two main phases: Alpha (Expert) Validation during the Development Phase and Beta (Field) Validation during the Diffusion Phase. Both phases integrated the evaluation of TEDDLASS software architecture, which comprises the Domain Model, Student Model, Tutoring Model, and User Interface (UI) Model.

a. Development Phase (Alpha Validation)

Alpha validation focused on ensuring that the TEDDLASS simulation adhered to development specifications, curriculum alignment, and instructional quality. This involved individual and collaborative expert reviews to assess the following:

Composition of the Validation Panel: A multidisciplinary validation team was assembled, comprising: Professors and Senior Lecturers from science education and biology departments UMYUK, chief lecturers from school of sciences FCE Katsina, Educational technologist from department of foundations UMYUK and Computer science department FCE Katsina. In addition, computer software developers and instructional designers from Kymetra technology solution, ICT departments of UMYUK and FCE Katsina. Each expert was given an evaluation header to assess different aspects of the simulation based on relevance, usability, instructional design, interface design, and content accuracy.

Architecture-Based Evaluation: The TEDDLASS simulation was analyzed according to the four core software architecture models: **Domain Model:** This model ensured that the simulation content was scientifically accurate, conceptually complete, and aligned with the NCCE BIO 323 genetics and evolution syllabus. Each of the five sub-units; Heredity & Environment, Sex Determination & Linkage, Evidence of Evolution, Evolution Theories, and Natural Selection was evaluated for curriculum compliance and conceptual accuracy. **Student Model:** This model was evaluated for its ability to support learner diversity by embedding flexible pacing, modular progression, and visual signs. Experts assessed whether the simulation anticipated different levels of prior knowledge and allowed scaffolding during exploration of content. **Tutoring Model:** The simulation instructional flow was reviewed to determine its effectiveness on embedded prompts, automated feedback and corrective hints. This model reflects the guidance mechanisms built into TEDDLASS that support problem-solving, decision-making, and critical

thinking during user interaction. **User Interface Model:** This model was reviewed for aesthetic design, navigability, responsiveness, accessibility features (e.g., readability, icon clarity), and language appropriateness. The interface was built using HTML5, CSS3, JavaScript, and Bootstrap, while animations were incorporated using Adobe after Effects to enhance visual engagement.

Curriculum Alignment Checklist: A curriculum alignment checklist was used to determine the similarity between the TEDDLASS simulation content and the prescribed NCCE curriculum (BIO 323). The checklist captured topic-by-topic mapping and required validators to assess content alignment as Fully, Partially, or Not Aligned, accompanied by qualitative remarks for feedback-driven revision.

Alpha Feedback Integration: Feedback was analyzed thematically and improvements were made in the following areas: Interface adjustments to improve user navigation and reduce cognitive load; Correction of minor content-related inaccuracies in sub-units; Addition of interactivity (e.g., quizzes); Enhancement of feedback response during concept simulations; and Developers identified minor technical issues related to audio synchronization, which were corrected before deployment.

b. Diffusion Phase (Beta Validation)

The second phase involved Beta validation with the improved version of TEDDLASS, which was field-tested aiming to evaluate TEDDLASS under realistic classroom conditions. This phase emphasized usability, user satisfaction, engagement, and instructional impact as perceived by the target users. A purposive sample of 34 biology pre-service teachers and technical staffs (drawn from the main study population) were selected for Beta testing. These participants were introduced to TEDDLASS and interacted with it during actual genetics and evolution instruction.

The validation instrument included TFVQ assessing usability, clarity, and learner engagement and open-ended items allowing participants to describe challenges, satisfaction, and areas for improvement. Participants provided feedback on: i. Ease of Use: Was navigation intuitive? ii. Instructional Effectiveness: Did it enhance comprehension? iii. Visual Appeal: Were the graphics and animations helpful? iv. Learning Engagement: Did it encourage critical thinking and creativity? v. Responsiveness and Interactivity: Was the feedback appropriate and timely?

6. Procedure for Data Analysis

Experts rated each item on a 4-point [rating](#) scale, and their responses were analyzed using mean and standard deviation to determine the appropriateness of each domain. The Beta Validation responses were analyzed through frequency and percentage distribution, complemented by thematic analysis of open-ended responses to capture suggestions for improvement. [The decision rule for the instruments was](#) weighted as follows: 4 = Very Appropriate, 3 = Appropriate, 2 = Inappropriate, and 1 = Very Inappropriate. The benchmarks mean score of 3.00 was derived by computing the average of the scale values ($4 + 3 + 2 + 1 \div 4 = 2.50$). However, for the purpose of ensuring stricter acceptance criteria, only items with a mean score of 3.00 and above were regarded as appropriate, while items with mean scores below 3.00 were considered inappropriate and subject to revision.

Findings

RQ1: What content and design features are required for the development of the TEDDLASS computer simulation for teaching genetics and evolution?

The development of TEDDLASS followed Havelock's Research, Development, and Diffusion (RD&D) model. The process began with the Research phase, which focused on identifying documented challenges associated with the lack of culturally relevant computer simulation packages for science education in Nigeria, particularly in the teaching of genetics and evolution. This phase involved a systematic review of empirical studies, curriculum documents, and contextual reports addressing difficulties in teaching abstract genetics and evolutionary concepts in Colleges of Education.

In addition, a detailed situational analysis of the NCCE (2012) Biology curriculum (BIO 323) was conducted to identify instructional gaps, content complexity, and pedagogical limitations relevant to genetics and evolution. The identification of requirements at this stage was grounded in curriculum analysis, literature synthesis, and expert consultation, rather than a respondent-based needs assessment survey.

Based on these sources, the Software Requirement Specifications (SRS) for the TEDDLASS Computer Simulation (TCS) were developed. The SRS articulated the essential content scope, functional requirements, interactivity design, and contextual considerations necessary for the development of TEDDLASS (see Appendix N). Consequently, the instructional content of TEDDLASS was structured into five core units aligned with the NCCE (2012) Biology curriculum: Heredity and Environment; Sex Chromosomes, Autosomes, Sex Determination and Sex Linkage; Evidence for Evolution; Theories and Trends in Evolution; and Darwinism and Natural Selection.

RQ2: To what extent is the content and design of the TEDDLASS computer simulation appropriate for teaching genetics and evolution based on expert and field validation?

Data related to this question were analyzed using mean ratings, thematic and frequency **analysis** for expert and field validations to determine the extent to which the TEDDLASS

software contents align with the NCCE (2012) Biology Curriculum (BIO 323) on Genetics and Evolution. The results are presented in Tables 2 to 5.

Table 2: Mean Ratings of Experts on the Appropriateness of TEDDLASS Software Components

Validation Domain	Number of Items	Mean (\bar{X})	Decision
Content Accuracy and Curriculum Alignment	3	3.76	Appropriate
Instructional Design and Pedagogical Quality	3	3.69	Appropriate
User Interface and Navigation	3	3.73	Appropriate
Technical Quality and Functionality	3	3.61	Appropriate
Overall Assessment	2	3.78	Appropriate
Overall Mean	—	3.71	Appropriate

Data presented in Table 2 show the mean ratings of 27 expert validators on the quality of the TEDDLASS Computer Simulation. The findings reveal that all five validation domains were rated as appropriate, with mean values ranging from 3.61 to 3.78. The Overall Assessment domain obtained the highest mean rating ($M = 3.78$), followed closely by Content Accuracy and Curriculum Alignment ($M = 3.76$). The lowest mean was recorded in Technical Quality and Functionality ($M = 3.61$). These results collectively affirm that TEDDLASS demonstrates appropriate content accuracy, pedagogical soundness, technical stability, and user-interface quality suitable for use in teaching genetics and evolution at the NCE level.

Table 3: Expert Validation of TEDDLASS Simulation Content

S/N	NCCE Curriculum Areas (BIO 323: Genetics & Evolution)	TEDDLASS Content & Coverage	Fully Aligned f (%)	Partially Aligned f (%)	Not Aligned f (%)	Remarks
1	Heredity Environment	and Included simulation unit	6 (100)	0 (0)	0 (0)	Covers key hereditary mechanisms with visual aids
2	Sex Chromosomes and Autosomes	Simulated interactive diagrams	6 (100)	0 (0)	0 (0)	Illustrates chromosome types accurately

Table 3: Expert Validation of TEDDLASS Simulation Content

S/N	NCCE Curriculum Areas (BIO 323: Genetics & Evolution)	TEDDLASS Content & Coverage	Fully Aligned f (%)	Partially Aligned f (%)	Not Aligned f (%)	Remarks
3	Sex Determination and Sex Linkage	Included in subunit	6 (100)	0 (0)	0 (0)	Includes examples of human sex-linked traits
4	Theories of Evolution	Darwinism, Lamarckism explained	6 (100)	0 (0)	0 (0)	Supported by animations and timelines
5	Evidence Evolution	for Fossil records, comparative anatomy	6 (100)	0 (0)	0 (0)	Real-life examples included
6	Natural Selection	Darwin's theory simulated	6 (100)	0 (0)	0 (0)	Interactive simulation of selection pressures
7	Genetic Inheritance (Mendelian and Non-Mendelian)	Covered through Mendel's laws	6 (100)	0 (0)	0 (0)	Punnett squares and gamete formation included
8	Mutation and Consequences	its Simulated animations	0 (0)	6 (100)	0 (0)	Mutation types covered but real-life impact limited
9	Modern Theory	Synthetic Introduced "Trends" subunit	0 (0)	6 (100)	0 (0)	Lacks integration with molecular content
10	Population Genetics	Not included	0 (0)	0 (0)	6 (100)	Not covered within TEDDLASS scope
Total (n = 6 experts)			42 (70%)	12 (20%)	6 (10%)	

Data analysis in Table 3 shows the frequency and percentage distribution of Subject Matter Experts' (SMEs) evaluation of TEDDLASS content alignment with the NCCE (2012) Biology Curriculum. Results revealed that **70% of the contents were rated as fully aligned with six out of eight core curriculum areas**, including Heredity and Environment, Sex Chromosomes, Sex Linkage, and Natural Selection. Two content areas; Mutation and its Consequences, and Modern

Synthetic Theory were found to be **20% as partially aligned**, and Population Genetics was **10% as not aligned**. This shows that TEDDLASS achieved substantial alignment with the NCCE BIO 323 curriculum.

Table 4: Validation Ratings of TEDDLASS by Field Validators (Users Validation)

Validation Area	Key Items Evaluated	% Agree/Strongly Agree
Interface and Usability	Ease of navigation, design quality, instruction clarity	90%
Learning Experience	Concept understanding, relevance, critical thinking stimulation	85%
Attitude and Motivation	Interest in subject, motivation, recommendation willingness	88%
Technical Performance	Speed, responsiveness, and multimedia functionality	80%

Data presented in Table 4 show the results of the Beta validation of the TEDDLASS Computer Simulation by field validators. The findings indicate that *Interface and Usability* received the highest level of agreement (90%), suggesting that participants found the simulation easy to navigate, visually clear, and instructionally coherent. *Attitude and Motivation* followed closely with 88%, showing that TEDDLASS enhanced students' interest, engagement, and willingness to recommend its use for learning. The *Learning Experience* domain was positively rated by 85% of respondents, indicating that the simulation promoted understanding of key concepts and stimulated critical thinking. The lowest agreement level (80%) was recorded under *Technical Performance*, implying that while the simulation functioned well overall, a few users experienced minor issues with multimedia responsiveness and system speed. Overall, these results affirm that TEDDLASS was perceived as pedagogically effective, user-friendly, and technically reliable for teaching genetics and evolution.

Table 5: Thematic Coding of Open-Ended Comments from Beta Validation

Respondent	Thematic Category	Sample Comment
R05	Engagement	"The animations kept my attention and made learning fun."
R06	Critical Thinking	"The activities made me think and not just memorize."
R08	Concept Clarity	"I finally understood sex-linked traits after the simulation."

R11	Technical Improvement	"Sometimes it takes a while to load. A progress bar might help."
R16	Usability Challenge	"Some buttons were not easy to find on my phone screen."
R17	Learner Support	"The tips and hints were helpful when I got stuck."
R19	Connectivity Issue	"Internet was slow during loading."
R20	Concept Clarity	"I understood natural selection better through the animations."

Table 5 presents the thematic analysis of open-ended responses from field validators during the Beta validation of TEDDLASS. The responses revealed strong engagement and positive learning experiences. Many participants highlighted that the animations and simulations captured their attention and made learning more enjoyable (e.g., R05). Several respondents emphasized that TEDDLASS enhanced *conceptual clarity*, particularly on complex genetics and evolution topics such as sex-linked traits and natural selection (e.g., R08, R20). Others noted that the activities encouraged *critical thinking* and independent reflection rather than rote memorization (e.g., R06), while some appreciated the *learner support* features, such as built-in tips and hints that facilitated problem-solving during use (e.g., R17).

However, a few respondents, including technical staff, pointed out areas for improvement, particularly related to technical [performance and](#) usability. These included occasional slow loading times (R11), difficulties in accessing certain buttons on mobile screens (R16), and internet connectivity limitations (R19). Overall, the thematic responses demonstrated that TEDDLASS was well received for its educational value and interactivity, with only minor technical refinements suggested to enhance user experience.

Overall, the feedback confirms that TEDDLASS is an engaging educational tool, though further enhancements are needed to improve mobile usability and reduce dependency on internet connectivity. Developers responded to real-time user feedback, fixing technical bugs and optimizing performance. This aligns with the "Demonstrate" and "Train" stages of Havelock's diffusion phase, validating the practicality of TEDDLASS in authentic educational settings.

Discussion

The systematic development of the TEDDLASS computer simulation followed Havelock's RD&D model, which emphasizes needs assessment, iterative development, and validation of educational innovations. This approach ensured that the simulation content was curriculum-driven, culturally relevant, and responsive to identified instructional gaps in genetics and evolution at the NCE level. By grounding the development process in curriculum specifications and expert input, TEDDLASS aligns with best practices in instructional technology design and supports constructivist learning principles reported in earlier simulation-based studies.

Findings from the study also revealed that the TEDDLASS Computer Simulation was rated as appropriate across all five validation domains: content accuracy, curriculum alignment, technical functionality, instructional design, and overall assessment. Both expert validators and field users affirmed its pedagogical relevance, technical stability, and usability. The software achieved substantial alignment with the NCCE (2012) Biology Curriculum, particularly in core topics such as heredity, sex linkage, and natural selection, indicating that TEDDLASS adequately covered the required competencies in genetics and evolution for pre-service biology teachers. These results confirm that the developed simulation met the essential standards for instructional tools in terms of content validity, technical reliability, and user engagement.

The findings are consistent with those of Ashiwere et al. (2025), who developed and validated a computer-animated simulation package for biology and reported high expert ratings on content accuracy and user interactivity. Similarly, Azi et al. (2025), in developing a simulation strategy for teaching cell biology, found that validation by experts and teachers confirmed the tool's effectiveness, technical adequacy, and curriculum relevance. The high level of expert consensus in both studies and the present research suggests that well-designed simulations that undergo rigorous validation processes are more likely to be pedagogically effective and contextually

relevant. Likewise, Kuta et al. (2024) reported similar validation outcomes for a computer-assisted instructional package in biology, emphasizing that close alignment with the national curriculum enhances credibility and learning impact. In addition, Gambari et al. (2014) developed and validated a Computer-Assisted Instructional (CAI) package for teaching physics at the senior secondary school level in Nigeria. The Validation was conducted in four stages: content validation by subject teachers, expert validation by computer programmers and educational technologists, individualized validation with students, and cooperative validation by groups of learners. Their findings showed that a systematically designed and thoroughly validated instructional package improved students' learning outcomes in physics. These parallel findings reinforce the reliability of simulation-based instructional development when content, pedagogy, and technology are coherently integrated.

However, the present findings differ from those of Isyaku et al. (2025), who developed a simulation-based learning strategy for genetics among pre-service teachers but reported lower ratings for usability and content sequencing. The discrepancy could be attributed to differences in the software development model and validation approach. Unlike TEDDLASS, which followed Havelock's Research, Development, and Diffusion (RD&D) model and underwent both Alpha and Beta validations, their tool relied solely on pilot testing without structured expert input during the design phase. This may have limited opportunities for iterative refinement and alignment with curriculum standards. While their simulation emphasized observation and replication of experiments, TEDDLASS integrated interactive feedback, scaffolding, and inquiry-based learning sequences that support deeper engagement and knowledge construction.

Conclusion

The TEDDLASS computer simulation was appropriately designed and validated as an instructional tool that aligns substantially with the NCCE (2012) Biology Curriculum in Genetics and Evolution. The content validation by experts and field users affirmed its pedagogical relevance, technical quality, and curriculum adequacy, indicating that TEDDLASS is suitable for effective classroom integration.

Recommendations

Based on the findings of this study, the following recommendations were made;

1. Curriculum developers, educational technologists, and teacher educators should adopt systematic design and validation procedures, such as those used in the development of TEDDLASS, when creating digital instructional materials. Future simulation tools should undergo both Alpha and Beta validation processes to ensure content accuracy, curriculum alignment, and pedagogical relevance before classroom implementation.
2. To ensure effective utilization of the TEDDLASS simulation, the Ministry of Education, through the National Commission for Colleges of Education (NCCE) and other relevant educational bodies, should organize training workshops for biology lecturers and pre-service teachers. These workshops should focus on instructional strategies for integrating TEDDLASS into lessons, optimizing interactive features, and addressing potential technical challenges.
3. Educational institutions and software developers should establish mechanisms for collecting feedback from users during classroom implementation. Continuous feedback will support updates, refinements, and expansions of the TEDDLASS simulation, ensuring sustained effectiveness and alignment with curriculum changes.

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Conflict of Interest and Declaration

The authors declare no conflict of interest regarding the publication of this paper. The development and validation of the TEDDLASS Computer Simulation were conducted solely for academic and educational purposes. The manuscript has not been previously published and is not under consideration for publication elsewhere. All sources cited have been appropriately acknowledged, and ethical standards guiding academic research and reporting were strictly observed.

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