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Evaluation of an Open Access Virtual Escape Room for Genetics Education in Undergraduate Nursing

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ABSTRACT

Genetics content is increasingly essential to nursing practice, yet it is commonly taught through didactic lectures, which offer limited opportunities for active learning. The objective of this study is to evaluate the user experience of the Genetic Odyssey VER designed to support genetics education in undergraduate nursing. A mixed-method usability study was conducted with a purposive sample of eight participants: four fourth-year Bachelor of Science in Nursing students and four faculty members. Data were collected through think-aloud observation with structured checklists, the mini Player Experience Inventory (miniPXI) and semi-structured individual interviews. Descriptive statistics were calculated for survey data, and qualitative data were analyzed to identify and categorise issues. Participants completed the VER in an average of 38 min. Functional aspects, including clarity of goals and progress feedback, were rated positively. Psychosocial constructs such as immersion, autonomy, and meaning received strong endorsement. Enjoyment scores were consistently high. Eighteen issues were identified across technical, navigation, design, and content-related domains. Eleven refinements were implemented to enhance clarity, reduce unnecessary cognitive load, and improve the overall user experience. The VER demonstrated positive experience among nursing students and faculty. The study successfully identified and resolved issues prior to broader release. As an open-access tool aligned with emerging genetics competency frameworks, the VER provides a practical and engaging approach to integrating genetics content into nursing education. Future research should

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explore its impact on learning outcomes across varied educational settings.

Keywords: Virtual Escape Room; Digital Escape Room; Usability Evaluation; Genetics Education; Undergraduate Nursing Education

1. Introduction

Virtual Escape Rooms (VERs) have increasingly been integrated into nursing education as an innovative tool to enhance learning, critical thinking, and application of theoretical knowledge to clinical practice [1–5]. Literature reviews and interventional studies indicate that escape rooms, as an interactive educational approach, support deeper learning and promote higher levels of student engagement compared to traditional instructional methods. They reinforce theoretical concepts through experiential application and enhance engagement and motivation by requiring learners to actively solve problems, interpret information, and make decisions within time-constrained environments [6–10]. Within nursing curricula, VERs have been successfully applied across a wide range of content areas, including medication administration and dosage calculations, patient assessment and vital signs interpretation, infection control and patient safety, ethics and legal considerations, professional communication, and emergency and acute care scenarios [1–3]. In nursing education, foundational courses such as pathophysiology are frequently delivered through traditional didactic lectures. The extensive scope and conceptual complexity of pathophysiological content have historically positioned lecture-based instruction as a common pedagogical approach in undergraduate nursing curricula, enabling systematic presentation of disease mechanisms and theoretical principles. However, the literature consistently reports that although didactic teaching is effective for content delivery, it often offers limited opportunities for active engagement, clinical reasoning development, and knowledge application. As a result, nurse scholars have increasingly highlighted the need to supplement traditional lectures with active and student-centred learning strategies to enhance engagement, critical thinking, and deeper understanding of complex concepts [11–13]. The Genetic Odyssey VER was designed to support the learning of fourth-year nursing students enrolled in a pathophysiology course within the undergraduate nursing program at Thompson Rivers University. To provide an alternative to the didactic conventional format and to enhance student engagement, the VER was developed as an interactive learning activity focused on genetic content. This approach aimed to support student learning by offering a more engaging, immersive, and enjoyable method for reinforcing key genetic concepts.

Current evidence indicates that, despite the increasing use of VERs in nursing education, their application remains concentrated in clinical, procedural, and professional domains such as medical-surgical nursing, emergency care, cardiovascular health, gerontology, community health, anatomy, infection prevention, mental health, professional values, and interprofessional teamwork [14–16]. Although some studies in broader biology education have explored virtual reality escape rooms for topics such as cell biology and enzymatic processes, these applications are not aligned with nursing specific genetic or genomic competencies [17,18]. Notably, none of the nursing focused reviews identify genetics or genomics as a thematic area of application [5–9]. This gap highlights a critical opportunity for the development and evaluation of VERs that are specifically designed to support genetics and genomics competencies in nursing education.

The purpose of this study was to evaluate the usability of The Genetic Odyssey VER among undergraduate nursing students and nursing faculty. Specifically, the study examined: (1) participants' experience across functional and psychosocial dimensions; (2) task completion times and navigation challenges across rooms; and (3) usability issues identified through iterative testing to inform design improvements prior to public release.

2. Research Design and Methods

A mixed-method usability study was conducted to evaluate the VER with respect to ease of use, perceived usefulness, and overall user experience, as well as to inform improvements to the VER before its broader implementation with the undergraduate students [19].

2.1. Data Collection

All Thompson Rivers University fourth-year Bachelor of Science in Nursing students who completed the pathophysiology course in Fall (Sept–Dec) 2024, as well as faculty members with an interest in or experience teaching genetics content, were invited to participate. The study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Board of Thompson Rivers University (Approval number 104251 and date of approval Feb 2025). All participants provided informed consent, and eligibility was assessed prior to data collection and participation in the study. Recruitment continued until a purposive sample of eight participants was achieved, comprising four students and four faculty members. Usability studies frequently employ small participant groups, because the first five to seven users typically reveal the majority of usability issues [19,20]. In alignment with established usability research practices, this sample size was deemed adequate to identify the usability challenges associated with the VER.

2.2. VER Intervention

The Genetic Odyssey: Unlocking the Secrets of Life VER was designed as a virtual interactive learning activity and developed using the free version of an interactive digital environment, the Affinity Learning Platform. It consisted of 10 sequential rooms, including Rooms 1–9 and a final multi-part challenge comprising Rooms 10A, 10B, and 10C, all to be completed within a 60-min time limit. Each room presented a genetics-focused task that participants were required to solve to progress, with most rooms offering optional hints to support learning. The final room was intentionally structured differently to create a sense of closure, with no option to return to previous rooms or access hints. The activity incorporated a visible countdown timer to remind participants of elapsed time. If the VER was not completed within the allotted time, the VER automatically closed and students restarted the experience. Immediate formative feedback was provided after each response using visual indicators, such as happy or sad emojis, to signal correct or incorrect answers. Each room followed a consistent task flow in which learners identified interactive hotspots, completed the assigned task, accessed hints if needed, and either progressed to the next room upon successful completion or repeated the room until the correct response was achieved. Completion of the final room unlocked a certificate of completion, reinforcing achievement and sustained engagement throughout the learning experience. See **Figure 1** for screenshots of some rooms.

Figure 1. Screenshot of some rooms.

The VER contained a total of 16 questions across 10 rooms, with several rooms incorporating multiple questions or multi-step tasks. The question design intentionally varied to assess different aspects of genetics knowledge and applied reasoning. Multiple question types, such as multiple-choice questions, sequencing and ordering tasks, matching tasks, and select-all-that-apply questions, were deliberately included to support the NCLEX, nursing licensure exam style for students. Overall, the VER employed a diverse range of question types to balance factual recall, conceptual understanding, and applied clinical reasoning via case studies within an interactive learning environment.

The Genetic Odyssey VER is open access and freely available through CAN-Sim and the LINKAGE (Linking Nursing Knowledge And GEnomics) website, and it can also be accessed directly via the following link: https://can-sim.ca/the-genetic-odyssey/. The assessment content for the VER was derived from the LINKAGE website learning modules 1–3. Participants are strongly encouraged to review these modules before attempting the VER, as they provide the foundational knowledge required for successful completion. These modules are also open access and freely available at https://linkage.trubox.ca/learning-modules/.

2.3. Procedure

The study incorporated three data collection methods. First, the think-aloud technique was used, during which participants engaged with the VER while verbalizing their thoughts, decisions, and reactions; a structured checklist was concurrently employed to systematically document participants' progression through the different rooms. Second, participants completed a mini Player Experience Inventory (miniPXI) survey following VER completion. Third, a 30–45 min semi-structured interview was conducted to explore perceived strengths and areas for improvement in detail.

Faculty and students followed different procedures. Faculty were not required to complete the genetics modules and could request answers during testing when needed. They received no honorarium and during the interview, participated in a facilitated review of all questions and hints to evaluate clarity, accuracy, and educational relevance. These procedural distinctions should be considered when interpreting comparisons between faculty and student data.

2.4. Data Analysis

Data from three sources, including think aloud checklist notes, miniPXI survey responses, and semi-structured interview transcripts, were analyzed with a primary focus on improving the VER. Descriptive statistics for the checklist notes and miniPXI survey data were calculated using Microsoft Excel. Inferential statistical analyses were not performed due to the exploratory nature of the study. An agile methodology guided the usability evaluation and refinement process. Participant feedback and usability issues identified during testing were reviewed iteratively, and targeted modifications were implemented to improve the VER before further evaluation. This approach facilitated continuous refinement of the intervention in response to user feedback [21]. The interview transcripts were later analyzed to examine broader learning experiences and engagement, which will be reported separately.

3. Results

This study was conducted primarily to evaluate the usability of and inform refinements to the VER. The findings provide valuable insights into participants' experiences and identify opportunities to strengthen the educational intervention. Results should be interpreted within the context of iterative intervention development and optimization. Given the study's small sample size, single-institution setting, and all-female participant group, the findings offer context-specific insights that may inform the development of similar educational initiatives. In addition, differences in testing conditions between faculty and student participants, including optional versus mandatory module completion and the availability of assistance during testing, should be considered when interpreting the findings. Consequently, comparisons between faculty and student performance should be viewed as exploratory and intended to inform refinement of the VER rather than to support definitive conclusions about group differences.

3.1. Participants' Characteristics

All participants identified as female. All faculty participants were aged 40 years or older, whereas student participants ranged from 18 to 34 years of age. Most participants (75%, n = 6) reported that they never or only occasionally played video games, while the remaining participants (25%, n = 2) reported playing video games frequently. With respect to prior experience with VERs, 37.5% (n = 3) reported having completed none, 25% (n = 2) had completed one to two, and 37.5% (n = 3) had completed three to four. There were no missing data. All faculty participants were from the nursing discipline, with the exception of one participant from the biology department.

3.2. Quantitative Findings

Participant performance was documented using a structured checklist to identify challenges. Data collection included overall completion time, task completion time for each room, number of attempts per question, points of hesitation, misinterpretation of instructions, and qualitative observational notes. Task difficulty was assessed in terms of cognitive load, defined as the knowledge and skills required to answer genetics-related questions, and interactional load, defined as the effort needed to locate hotspots and access questions or hints. All data were organized into structured tables to support identification of patterns across users.

Most participants completed the VER in an average of 38 min, with completion times ranging from 28 to 58 min, indicating that the allotted total time of 60 min was appropriate. Across all rooms, the mean completion time per room was approximately 3 min, with durations ranging from a minimum of 2 min to a maximum of 8 min. This variability reflects differences in room design, including the number of questions and the style of assessment. Rooms incorporating case-based questions required longer completion times, as they involved reading, interpretation, and analytical reasoning.

The fastest completion times were observed in Rooms 1, 2, and 10C. Rooms 1 and 2 were intentionally designed to facilitate early success and orient participants to the activity, whereas Room 10C involved a recall-based item that was frequently resolved through trial-and-error strategies. In contrast, the longest completion times occurred in Rooms 4 and 9, at approximately 8 and 6 min, respectively. In Room 4, increased interactional load contributed to delays, as participants often misinterpreted the cell image, experienced difficulty locating the hotspot, and in some cases overlooked the use of hints for the diagram-based question. Similarly, Room 9 required additional time due to a hotspot embedded within a chart featuring a small clickable area, an intentional design choice to increase difficulty. Room 3 demonstrated the highest number of attempts, attributable to a technical issue that prevented progression after selection of the correct response, resulting in repeated submissions. In contrast, Room 10B required the fewest attempts, reflecting clear and unambiguous question design. Despite these variations, most rooms were completed efficiently, with a median of one attempt and a mean of 2.04 attempts.

Comparison of faculty and student performance showed minimal differences in overall completion time, with students averaging 41 min and faculty 37 min . Both groups required the longest time in Room 4, indicating the need for refinement of this room. Faculty required slightly more attempts than students overall, with a mean of 2.10 compared with 1.98 and a higher median (2.00 vs. 1.71), likely reflecting variation in preparatory requirements. The largest difference occurred in Room 10A, where faculty required a mean of 4.25 attempts compared with 1.50 for students, often due to selecting only one response when multiple answers were correct. Conversely, students required more attempts in Room 10C (3.50 vs. 1.25), likely due to reliance on trial and error for a recall-based item. **Table 1** presents the completion time and number of attempts for each room, stratified by student, faculty, and total sample groups.

Table 1. Completion time and number of attempts for each room.

Rooms	Time in Minutes and Seconds/Room						Number of Attempts/Room					
	Total		Students		Faculty		Total		Students		Faculty	
	M	Md	M	Md	M	Md	M	Md	M	Md	M	Md
R 1	1:41	1:09	1:35	1:08	1:47	1:18	1.13	1	1.25	1	1.00	1
R 2	1:37	0:56	1:14	0:48	2:00	1:37	2.13	1	2.00	1	2.29	2
R 3	3:37	3:11	4:05	3:39	3:09	3:11	3.25	3	3.00	3	3.50	3.5
R 4	7:57	6:09	10:13	8:09	5:40	5:17	1.71	2	1.75	1.5	1.67	2
R 5	2:07	1:45	1:49	1:45	2:25	2:11	1.50	1	1.00	1	2.00	2
R 6	2:01	1:38	2:20	2:02	1:43	1:12	1.13	1	1.25	1	1.00	1
R 7	3:48	2:51	3:50	2:51	3:45	2:46	2.38	2	2.75	2.5	2.00	1.5
R 8	3:44	3:21	3:50	3:38	3:44	3:13	2.13	2	1.75	2	2.50	2
R 9	5:27	5:22	5:51	5:36	5:03	5:12	2.88	3	3.00	3	2.75	3
R 10A	2:49	2:46	2:27	2:13	3:12	3:23	2.88	3	1.50	1	4.25	4

Table 1. *Cont.*

Rooms	Time in Minutes and Seconds/Room						Number of Attempts/Room					
	Total		Students		Faculty		Total		Students		Faculty	
	M	Md	M	Md	M	Md	M	Md	M	Md	M	Md
R 10B	2:32	2:39	1:58	1:21	3:06	3:10	1.00	1	1.00	1	1.00	1
R 10C	1:33	0:55	1:58	1:25	1:07	0:55	2.38	1	3.50	2.5	1.25	1

Note: M = Mean; Md = Median.

The miniPXI is an 11-item abbreviated version of the full 33-item PXI, in which each item assesses a single PXI construct, organized into two domains of player experience: functional (5 items) and psychosocial (5 items), with an additional optional construct assessing enjoyment [22]. Items are rated on a 7-point Likert scale ranging from Strongly Disagree (−3) to Strongly Agree (+3), with higher scores indicating stronger endorsement of each construct. Validation studies show that the miniPXI has acceptable construct validity, though lower reliability than the full PXI, making it more suitable for exploratory or formative research [22–24].

Functional aspects of the VER were rated positively overall, with mean scores ranging from 0.6 (Ease of Control) to 2.1 (Clarity of Goals). Clarity of Goals (M = 2.1) and Progress Feedback (M = 2.0) were rated highest, indicating participants found the objectives clear and feedback helpful. Ease of Control received the lowest mean score (M = 0.6), with a wider range (−2.0–2.0), suggesting some participants experienced challenges with navigation. Faculty consistently rated functional constructs higher than students, particularly Audiovisual Appeal (Faculty M = 2.5 vs. Students M = 0.8).

Overall, participants reported positive experiences in the psychosocial domain. Mean scores for constructs ranged from 1.4 (Mastery) to 2.4 (Immersion), indicating moderate to strong agreement with VER. Immersion had the highest mean (M = 2.4, Median = 2.5), suggesting participants were highly focused during the VER. Meaning and Autonomy also scored highly (M = 2.0 and M = 1.9, respectively). Faculty responses tended to be slightly higher than students for most constructs, particularly Immersion (Faculty M = 2.8 vs. Students M = 2.0). Mastery showed the greatest variability (range: −1.0–3.0), reflecting differences in perceived competence.

Enjoyment scores were strongly positive (M = 2.2, Median = 2.0), with most participants agreeing or strongly agreeing that they experienced a high level of enjoyment while engaging with the VER. Faculty responses were slightly higher (M = 2.5) compared to students (M = 2.0). **Table 2** presents descriptive statistics for the miniPXI survey.

The miniPXI Responses were also grouped into positive, negative and neutral categories; both domains showed predominantly positive valence. For the psychosocial domain, 90% of responses were positive for both students and faculty. In the Functional domain, positive responses accounted for 80% among students and 85% among faculty, with neutral and negative responses primarily related to Ease of Control and Audiovisual Appeal. **Figure 2** illustrates the response valence across PXI domains.

Table 2. Descriptive statistics for the miniPXI survey.

Constructs	Total				Students				Faculty			
	M	Md	Min	Max	M	Md	Min	Max	M	Md	Min	Max
Functional Domain												
Audiovisual Appeal	1.6	2.0	−2.0	3.0	0.8	1.0	−2.0	3.0	2.5	2.5	2.0	3.0
Challenge	1.8	2.0	0.0	3.0	1.5	2.0	0.0	2.0	2.0	2.5	0.0	3.0
Clarity of Goals	2.1	2.0	1.0	3.0	1.8	1.5	1.0	3.0	2.5	2.5	2.0	3.0
Ease of Control	0.6	1.5	−2.0	2.0	0.8	1.5	−2.0	2.0	0.5	0.5	−1.0	2.0
Progress Feedback	2.0	2.0	1.0	3.0	1.5	1.5	1.0	2.0	2.5	2.5	2.0	3.0
Psychosocial Domain												
Autonomy	1.9	2.0	0.0	3.0	1.5	1.5	0.0	3.0	2.2	2.0	2.0	3.0
Curiosity	1.8	2.0	0.0	3.0	2.0	2.0	1.0	3.0	1.5	1.5	0.0	3.0
Immersion	2.4	2.5	1.0	3.0	2.0	2.0	1.0	3.0	2.8	3.0	2.0	3.0
Mastery	1.4	2.0	−1.0	3.0	1.5	2.0	−1.0	3.0	1.2	1.5	0.0	2.0
Meaning	2.0	2.0	1.0	3.0	2.0	2.0	1.0	3.0	2.0	2.0	2.0	2.0
Optional Construct: Enjoyment												
Enjoyment	2.25	2.0	1.0	3.0	2.0	2.0	1.0	3.0	2.5	2.5	2.0	3.0

Note: M = Mean; Md = Median; Min = Minimum; Max = Maximum.

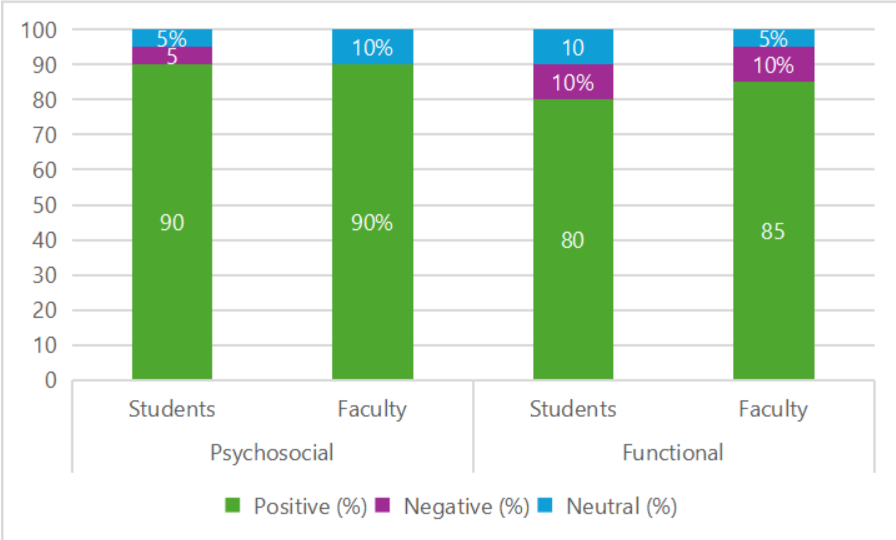

Figure 2. Response Valence across PXI Domains.

The VER scored well across the miniPXI functional and psychosocial categories. Functional aspects such as clarity of goals and feedback were well received, while psychosocial experience was uniformly positive, indicating players not only understood and interacted well with the game but also felt emotionally engaged and invested in the experience. Enjoyment was consistently high across both groups. The response valence distribution confirms overwhelmingly positive perceptions, with minimal neutral or negative feedback.

3.3. Qualitative Findings

Participant interview data from the usability testing complemented the checklist and PXI findings and provided deeper insight into issues identified through these methods. Participant suggestions for improvement were reviewed collaboratively by the research team, and feasible suggestions that enhanced clarity were incorporated. Aesthetic enhancements were not implemented in this iteration due to resource constraints and limitations associated with the free version of the platform. Overall, the interviews identified 18 technical, navigation, design, and content-related considerations, of which 11 informed iterative refinements to the VER, while 7 were intentionally retained by design or due to resource constraints.

Technical issues reported by participants included intermittent connectivity lag, device-related performance differences, with Android devices performing more consistently than Mac computers, and browser-specific challenges such as interference caused by Chrome extensions. A glitch in the matching question in Room 3 was identified and resolved by modifying the question type because the original format was not supported in the free version of the platform. In contrast, a minor issue affecting the ordering type question in Room 7, which required participants to rearrange responses prior to each submission, could not be resolved due to platform limitations. This issue did not appear to substantially affect usability during testing.

Navigation-related concerns included difficulty locating hotspots. Small or embedded hotspots contributed to navigational delays that were unrelated to task complexity. In response, hotspot sizing and placement were reviewed, and clickable areas were enlarged where appropriate. Participant suggestions for closed captioning, playback, and pause functions for the Artificial Intelligence (AI) generated audio were not implemented because the audio served an aesthetic rather than instructional purpose.

Visual design elements were generally well received and contributed to a coherent user experience. Participants responded positively to the room graphics, emoji-based feedback, progress indicators, and timers. The AI-generated voice was described as clear and appropriately paced, although several participants expressed a preference for a human-recorded voice. Minor design refinements were made to address usability concerns. For example, when visual representations did not align with participants' mental models and introduced unintended cognitive load, images were replaced or hotspot locations were adjusted.

Content-related feedback was largely positive. Participants indicated that the information provided was sufficient to support task completion. Questions were perceived as appropriately challenging, and hints were viewed as helpful without revealing answers. Revisions were made to improve clarity and consistency in language, including correcting grammatical issues and standardizing instructions for multi-response items. Certain elements, such as images and hints that participants perceived as distracting or not contributing to task completion, were modified or removed. Suggestions to include hints in the final rooms were not adopted because these features were intentionally excluded to preserve the immersive VER experience. Faculty expressed concerns regarding the use of the term "failure" in the introduction. However, it was retained to maintain alignment with the escape room narrative, with minimal anticipated negative impact. Students can make unlimited attempts to complete the VER to attain a certificate thus reducing the likelihood of potential adverse effects.

Table 3 outlines the refinements made to the VER based on findings from the usability evaluation to enhance functionality, navigation, visual design, and content clarity.

Table 3. Issues Identified During Usability Testing and Subsequent VER Refinements.

Issue/Location	Category	Resolution
Intermittent connectivity lag and device-related performance differences	Technical	Added a support notification at the beginning of the VER to direct users to technical assistance if needed.
Technical issue preventing progression (Room 3)	Technical	Converted the question format from drag-and-drop to multiple-choice.
Technical issue preventing progression (Room 4)	Technical	Converted the question format from drag-and-drop to multiple-choice.
Interactive hotspot difficult to locate (Room 4)	Navigation	Relocated the hotspot to improve visibility and accessibility.
Interactive hotspot difficult to locate (Room 5)	Navigation	Relocated the hotspot to improve visibility and accessibility.
Hotspot too small (Room 9)	Navigation	Increased the size of the interactive hotspot area.
Maze interaction resulted in random clicking (Room 10B)	Visual Design	Revised the maze image and associated instructions.
Confusing image (Room 9)	Content	Removed the image.
Multiple attempts required to move between the question and hint (Room 3)	Content	Moved the image from the hint section directly into the question.
Multiple-answer selection not clearly indicated (Room 10A)	Content	Added the instruction "Select All That Apply."
Confusing wording referencing "above" statements (Room 10B)	Content	Replaced "above" with "following" for greater clarity.

4. Discussion

The findings of this study support the growing shift in nursing education toward technology-enhanced, active learning strategies that align with the preferences and learning needs of contemporary students [25,26]. Generation Z students, often described as digital natives, demonstrate a strong preference for individualized and technology-mediated learning experiences. As the proportion of Generation Z learners increases in undergraduate nursing programs, there is a clear imperative to move beyond traditional lecture-based approaches and adopt more engaging, interactive, and immersive pedagogies. VERs offers a flexible learning environment that allows students to engage with content at their own pace and time, with opportunities for repeated attempts that support safe practice and mastery of learning materials [7,27,28].

Inclusion of genetics content within the VER is particularly noteworthy given the increasing importance of genomics in contemporary healthcare. As precision health continues to evolve, nurses are expected to develop competencies in genomics to support patient care and health promotion. National initiatives, such as those led by the Canadian Nursing and Genomics [29] steering group, emphasize the need to enhance genomic literacy among nurses and integrate genomics into practice. Embedding genetics education within an interactive and applied learning environment such as a VER offers a novel approach to addressing this need, enabling learners to engage with complex scientific concepts in a meaningful and contextually relevant manner.

The design of the VER in this study reflects established principles of game-based learning commonly reported in healthcare education. VER typically engages learners through cognitive puzzles, riddles, and coded tasks that are aligned with clinical objectives and structured around either narrative scenarios or patient case-based learning [8,30–33].

Consistent with the literature, most VERs adopt a sequential puzzle pathway, whereby completion of one task provides clues for subsequent challenges, supporting a logical progression of knowledge and sustained engagement. Time constraints are also a defining feature, with most studies reporting limits of approximately 60 min, introducing urgency and simulating time-sensitive clinical decision-making [34–36].

In contrast to the predominantly team-based approach reported in the literature, where participants typically work in groups of two to six or larger [14,37], the VER in this study was designed as an individual learning experience. While collaborative learning is widely recognized as a strength of VER pedagogy, emerging evidence suggests that Generation Z learners may also value flexibility, autonomy, and the ability to engage with content independently and at their own pace [25,26]. The individual format allowed learners to progress through the sequential puzzle structure with unlimited attempts, thereby reducing performance pressure and supporting mastery-based learning.

Despite the demonstrated benefits, the implementation of active learning strategies such as VERs is not without challenges. Consistent with the broader literature, barriers related to time, technological proficiency, and financial resources remain significant considerations [4,7,38]. Developing interactive, technology-based learning environments requires substantial upfront investment in design, testing, and refinement. Varying levels of digital literacy among educators may also limit adoption, particularly when platforms require advanced technical skills [5,38]. Financial constraints further complicate implementation, as many digital tools rely on subscription models or restrict functionality in their free versions [4,7]. Faculty workload and expertise present additional difficulties because effective development requires knowledge of game design, simulation, and educational technology, which adds complexity to existing instructional responsibilities [5,38]. Finally, the lack of clear guidance on optimal design, including puzzle structure and theoretical grounding, results in a trial-and-error approach that further increases workload [5,6].

Implications

From a pedagogical perspective, the findings suggest that VERs can serve as an effective supplement to traditional lecture-based approaches for teaching complex scientific content such as genetics and genomics. Participants reported high levels of immersion, enjoyment, autonomy, and meaning, indicating that the activity supported active engagement with the learning material rather than passive content consumption. The sequential puzzle structure, immediate feedback mechanisms, and opportunities for repeated attempts may promote self-directed learning, knowledge reinforcement, and mastery-oriented learning. These features are particularly relevant in nursing education, where students must apply theoretical knowledge to clinical decision-making contexts.

The findings also highlight the value of incorporating multiple assessment formats within a single learning activity. The inclusion of multiple-choice, matching, sequencing, and select-all-that-apply questions allowed learners to engage with genetics concepts through varied cognitive processes while simultaneously providing exposure to question formats commonly encountered in nursing licensure examinations. Nurse educators may therefore consider not only engagement tools but also opportunities to reinforce critical thinking, clinical reasoning, and examination preparedness within an authentic and interactive learning environment.

The findings also demonstrate the importance of designing educational technologies that minimize unnecessary cognitive load while maintaining an appropriate level of intellectual challenge. Participants consistently valued clear goals, timely feedback, and intuitive navigation, emphasizing that educational effectiveness depends not only on content quality but also on usability. Nurse educators developing digital learning resources should therefore incorporate iterative usability testing throughout the development process to ensure that interactional barriers do not interfere with learning. Including both faculty and student perspectives during development can further strengthen educational relevance and learner acceptance [39–42].

From a practical standpoint, the findings demonstrate that open-access VER represents a scalable and cost-conscious strategy for integrating genomics education into undergraduate nursing curricula. The average completion time of 38 min and successful completion within the designated 60-min period suggest that the learning activity can be readily incorporated into classroom, laboratory, online, or blended learning environments without substantial curricular disruption.

The study also demonstrates the importance of conducting usability testing prior to large-scale implementation. Several navigation, technical, and content-related issues were identified and resolved before broader deployment, improving the learning experience and reducing unnecessary cognitive burden on users. Educators developing technology-enhanced learning resources should allocate dedicated time for iterative testing with representative end users to ensure that learning challenges arise from the educational content rather than platform usability issues.

Furthermore, the open-access nature of The Genetic Odyssey increases its potential for adoption across nursing programs regardless of institutional resources. The use of freely available platforms and educational materials may help reduce financial barriers commonly associated with educational technology initiatives while supporting broader dissemination of genomics education. As nursing programs continue to address emerging genomics competency expectations, readily accessible digital resources such as VERs may offer a sustainable approach to curriculum enhancement that can be adapted for diverse educational contexts.

This study also provides a practical design framework for educators seeking to develop similar resources. Key design features associated with positive learner experiences included clear learning goals, immediate feedback, meaningful challenges, immersive environments, and opportunities for autonomous progression. Future educational technology initiatives may benefit from incorporating these elements to optimize learner engagement and usability.

5. Limitations

This study has several limitations that should be considered when interpreting the findings. All participants were recruited from a single institution using convenience sampling, which limits the transferability of findings to other nursing programs and student populations. The think-aloud technique may have introduced reactivity, whereby participants' verbalization of thoughts altered their natural interaction with the VER. Faculty and student data are not directly comparable, as faculty completed the preparatory genetics modules optionally and were permitted to request answers when stuck, whereas module completion was mandatory for students.

6. Conclusions

The Genetic Odyssey VER demonstrated strong usability among undergraduate nursing students and faculty. Participants completed the VER within the allotted time, reported high levels of immersion and enjoyment, and found the goals and feedback clear. Iterative usability testing was effective in identifying and resolving design barriers prior to public release, while intentionally preserving features that served the educational objectives. As an open-access resource aligned with emerging genomic competency frameworks for nursing, The Genetic Odyssey offers nurse educators a practical, evidence-informed tool for integrating genetics and genomics content into undergraduate curricula. Future researchers should examine the VER's impact on learning outcomes and explore its applicability across diverse nursing programs and student populations.

Author Contributions

Conceptualization, A.V. and S.K.; methodology, A.V. and L.A.K.; software, S.K. and F.P.; investigation, A.V. and F.P.; writing—original draft preparation, A.V.; writing—review and editing, A.V., L.A.K., F.P. and S.K.; project administration, A.V. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Board of Thompson Rivers University (Approval number 104251 and date of approval Feb 2025).

Informed Consent Statement

Informed consent was obtained from all participants involved in the study. Participation was voluntary, and participants were informed of the study purpose, procedures, potential risks and benefits, measures to protect confidentiality, and their right to withdraw at any time without penalty. All participants provided consent prior to participation.

Data Availability Statement

Not applicable. The simulation (VER) is freely available on the CAN-Sim website.

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Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

AI Use Statement

The authors declare that no artificial intelligence (AI) tools were used in the preparation of this manuscript.

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