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An Agile Deployment of a Virtual Learning Environment: Insights from a Cybersecurity Interactive Course for Spanish-Speaking Children

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Abstract

Implementing a cybersecurity course for children is challenging due to the sensitive nature of learning topics such as sexting, cyberbullying, and grooming. In addition, forced lockdowns during the Covid-19 pandemic increased children's exposure to threats on the Internet due to the lack of effective parental/teacher supervision while teleworking. Although existing online initiatives have been implemented to teach cybersecurity to minors, they lack structure and engagement; particularly, for non-English-speaking children. In this article, we explore the experiences of deploying a virtual learning environment (VLE) to teach cybersecurity to Spanish-speaking children using an agile approach. The design, development, deployment and publication of the VLE is carried out using a 5-phase Scrum-based methodology by combining UDL, ADDIE, and DPIPE. These learning models serve as strategies to create interactive learning content, using 3D anthropomorphic characters and storyboards to enhance the learning experience. Also, in our proposal, during the evaluation phase, we assess the VLE's performance, the course design usability, and the course content. Regarding the VLE performance, functional and non-functional tests are conducted. For usability, both SUS and Nielsen models are applied in order to assess the users' engagement with the course design. Finally, to evaluate the course content, both the learning experience and the learning outcomes were assessed through navigation tests, sentiment analysis and learning tests. The results demonstrate that our proposed agile approach delivers an acceptable performance and a pleasant learning experience for children, parents, and teachers despite the complexity of learning cybersecurity-related topics.

Keywords: moodle, scrum, vle, virtual learning, cybersecurity, 3D, character design, storyboard, addie, dpipe, udl, Nielsen, Sus, usability.

1 Introduction

The widespread adoption of home Internet connections has exposed families to a range of emerging online threats, such as child pornography, sexting, and cyberbullying [2]. These risks have become increasingly perilous as the unintentional leakage of personal information on social networks has become more prevalent [3]. Moreover, the COVID-19 pandemic and subsequent lockdowns have exacerbated the vulnerability

*Corresponding author. This paper is an extended version of the work published in [1]. We extend our previous work by analyzing the course design using usability metrics (Section 5.3.2) as well as the course content using sentiment analysis (Section 5.3.3). Both additions are explained in Section 4.5 as extensions of our methodology, the results are later discussed in Section 6, and included in the final remarks in Section 7.

of children to these dangers, particularly because they relied on the Internet to attend school through virtual learning environments (VLEs) [2]. The pandemic significantly affected education systems around the world, forcing authorities to adopt alternative measures to ensure learning continuity while schools remained closed [4]. In Ecuador, the situation was no different as children had to use VLEs as emergent tools to learn at home. However, this transition to online learning posed various difficulties, including the lack of training for parents in using these tools and the limited expertise that the majority of Ecuadorian schools had in effectively deploying these learning platforms [2]. Amidst the resurgence of VLEs and the increasing need to protect children online, the design of virtual courses has become even more critical, aiming to enhance user experience (UX) and facilitate effective learning for a safer digital environment [5].

This paper focuses on two aspects: (i) VLE construction and (ii) cybersecurity teaching. Regarding (i), a novel 5-phase Scrum-based methodology is proposed for learning content production and deployment. This methodology is a hybrid application of three VLE design paradigms: the Universal Design for Learning (UDL), the ADDIE model (Analysis, Design, Development, Implementation, Evaluation), and DPIPE (Design, Production, Implementation, Evaluation). Our methodology leverages Scrum's iterative approach for refining the VLE learning content based on regular feedback while UDL ensures that diverse learning needs are met. ADDIE and DPIPE provide a structured design process for iterative development and assessment of learning content [6]. About (ii), we showcase the application of our proposed methodology in the development, deployment and assessment of an interactive VLE specifically designed to teach cybersecurity to children, as a case study. The VLE content is deployed on a Learning Management System (LMS) powered by Moodle, and is focused on promoting awareness of online threats while providing effective responses to common cyberattacks. A key aspect in our interactive content is the design of 3D anthropomorphic characters to enrich the learning experience through interactive stories, videos, and games [7], and to foster active communication between schools and homes through fun activities and games. Building on our previous work [1], we also assess the effectiveness of the VLE using the System Usability Scale (SUS) and Nielsen usability heuristics, in line with approaches similar to those in [8]. Furthermore, as suggested in [9], we introduce sentiment analysis to better understand student engagement and reactions to the course content, using the Analytic Hierarchy Process (AHP) alongside the WEBLEI framework [10, 11, 12].

Hence, related work on VLE construction methodologies, and teaching strategies is explored in Section 2. Essential concepts to ease the understanding of our proposal are discussed in Section 3. Section 4 introduces our novel 5-phase methodology, providing a detailed overview of its structure and application. A comprehensive understanding of the application of the methodology for the implementation and evaluation of a VLE for teaching cybersecurity are presented in Section 5, as a case study. Particularly, during the evaluation phase, performance, usability, and course content assessments were carried out, the results of which are discussed in Section 6. Finally, this work concludes with remarks about our current research results in Section 7, highlighting the ongoing commitment to advancing cybersecurity education for children, parents, and teachers in the digital age.

2 Related Work and Contribution

In this research, we have analyzed aspects related to the construction of VLEs, and trends in cybersecurity teaching.

2.1 About VLE Construction

Recent work has been developed in the field of virtual learning environments (VLEs) to support learning objectives. In [13], a framework for the construction of VLE was proposed, focusing on the integration of SOA-based modules to ease the scalability and interoperatibility of virtual learning content. Likewise, in addition to technical aspects, researchers have proposed best practices for designing VLEs, considering usability, accessibility, and instructional design paradigms [14]. Also, gamification techniques, such as achievement points, badges and rankings have been analyzed [15] to enhance student engagement. On the other hand, in [16], the application of artificial intelligence has been explored, leveraging students' preferences and their learning pace for adaptive learning.

2.2 About Teaching Cybersecurity

There are several courses incorporating 3D animation, such as *Interland*[17], which primarily addresses cybersecurity ethics for fostering peaceful digital interactions. Additionally, paid cybersecurity courses targeting adults have been introduced [18], which have more technical complexity than those delivered for minors. For instance, the cybersecurity content on Cerebriti [19] is designed for knowledge evaluation rather than instructional purposes. A noteworthy Spanish-language open resource is *Kit Digital* [20], offering text content, tips, and videos on information security, focusing on creating awareness rather than interactive learning. Formal sponsored initiatives in Latin America include a Mexican website [21] providing general advice against bullying, Internet threats, and potential abductions. Ecuador has been a pioneer in implementing children's cybersecurity policies [22, 23], promoted through in-person training sessions [24]. Meanwhile, in developed countries, proactive measures have been taken to protect citizens from Internet threats, with initiatives such as the FBI's [5, 25, 26] and the British Think You Know program [27].

Regarding the construction of VLEs, our aim is to fill the gap between VLE usability and the production of effective learning content. Thus, we provide educators and content creators with a comprehensive 5-phase Scrum-based approach for the development of VLEs and the agile deployment of learning content. In terms of cybersecurity teaching, despite current efforts, the availability of information and courses dedicated to children remains scarce and unstructured. Most of the existing resources are in English, limiting their reach to Spanish-speaking audiences. Furthermore, many available tools and courses do not offer interactive learning experiences tailored to younger learners. Our proposed VLE aims to address this problem by creating content specifically designed for Spanish-speaking children. We incorporate 3D characters, and apply the proposed methodology for the efficient design, production, and publication of interactive learning material to engage learners through enjoyable experiences.

3 Background

VLEs are not just basic educational websites but rather intricate information systems designed for distance learning [28]. These systems enable the delivery of virtual courses to a larger and more diverse group of learners. To gain a better understanding of the technical aspects covered in our proposed methodology (Section 4) and in the developed cybersecurity course for children (Section 5), the next subsections provide an overview of the agile implementation approach, the importance of using a Learning Management System (LMS), design principles for creating virtual learning content, methods for conducting usability testing, and basics of sentiment analysis.

3.1 The Paradigm of Agile Development

This approach to product development is centered on collaboration among teams, flexibility in planning, and quick development. An example of this is Scrum [29], an agile framework that emphasizes iterative and incremental prototyping, along with continuous integration and testing. We chose Scrum for this project because, even though we are not specifically creating software, this framework has been useful for project managers in various industries (not just software) [30] in ensuring customer satisfaction and sustainable product maintainability. By implementing Scrum, we have not only been able to meet the performance expectations of the VLE, but also guarantee a suitable learning experience for children, parents and teachers, despite the lack of structured information (as mentioned in Section 2) and unclear learning needs.

3.2 Learning Management Systems (LMSs)

VLEs and LMSs are similar but distinct concepts. VLEs refer to learning environments that utilize technology to facilitate and manage the distribution and presentation of learning content. On the other hand, LMSs are information systems that serve as interfaces between the VLE and students throughout the learning process [31]. For example, Moodle is an LMS that enables the management of multiple VLEs (or virtual courses) within a unified platform. For example, to deploy our VLE for cybersecurity teaching, we used Moodle as LMS (Section 5.3.1).

3.3 VLE Design Paradigms

Our research emphasizes the importance of interactivity in order to make the content more appealing [32] and reduce the learning workload [33]. To achieve this goal, various methodologies have been considered, including Universal Design for Learning (UDL), the ADDIE model, and the DPIPE method. UDL is a neuroscience-based framework for instructional design that focuses on engagement, representation, and action and expression [34, 35]. The ADDIE model is a 5-phase process for implementing virtual learning environments, involving analysis, design, development, implementation, and evaluation [36, 37]. Similarly, the DPIPE method is a Venezuelan strategy that follows phases such as design, production, implementation, publication, and evaluation [38]. In our proposal, we combine these methodologies with Scrum, as explained later in this paper in Section 4.

3.4 Usability Testing and Heuristics Evaluation

Assessing usability is a straightforward method to determine the extent to which a VLE is user-friendly for prospective learners. In this study (Section 5.3.2), we utilize both the System Usability Scale (SUS) [39] and the Nielsen Usability Heuristics [40] to assess the course design, aiming to identify the overall usability level and address any minor usability issues. *The System Usability Scale (SUS)* provides a high-level score for measuring the usability of a system. In this research, applying SUS allowed us to design learning content understanding the required usability level based on the resulting scores to gauge users' agreement or disagreement with statements ranging from the "perceived ease of use" to the "intuitiveness of the interface". *The Nielsen Usability Heuristics* helped us to determine the perception of usability in each course module by identifying any design issues. To achieve this, the Nielsen analysis delves into usability heuristics to assess the effectiveness of the learning content design and the interactivity of the VLE's interface. In Section 5.3.2, we specifically employ SUS to evaluate the overall usability of the LMS platform (Moodle), and the users' interaction with learning materials. Meanwhile the Nielsen heuristics help identifying usability issues in the design of the VLE.

3.5 Sentiment Analysis

Sentiment analysis is important to understand users' opinions, thoughts, and impressions when interacting with products or services [10]. As such, it becomes a crucial component in identifying nuances when creating learning content, which may be related to language and culture. Our approach leverages the fuzzy evaluation of the Analytic Hierarchy Process (AHP) [11] and the Web-based Learning Environment Instrument framework (WEBLEI) [12]. The use of AHP provides a structured method to prioritize and assess the emotional aspects expressed by young learners when studying complex topics in a cybersecurity course. Additionally, the WEBLEI framework allows for the inclusion of factors like usability, engagement, and effectiveness, enabling a comprehensive evaluation of the emotional impact of the cybersecurity-related topics. As a result, sentiment analysis, when applied to our proposed cybersecurity course (Section 5.3.3), enables a better understanding of the emotional responses expressed by students while interacting with the learning content. For instance, analyzing actions on both H5P content and learning games can reveal prevalent sentiments among learners such as surprise or happiness.

4 Methodology: Introducing a 5-phased approach for VLE Construction

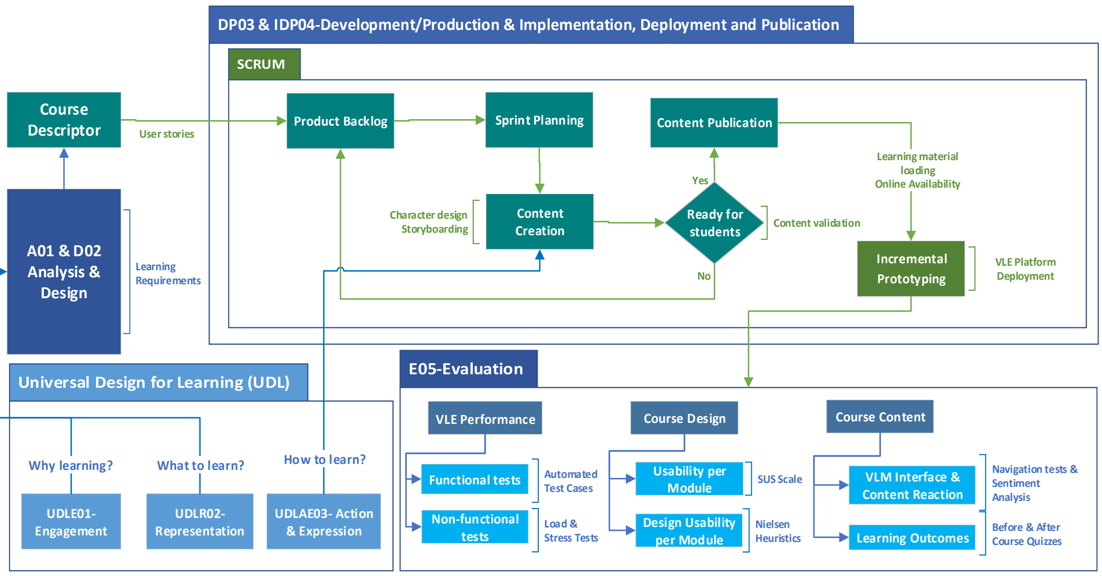


Figure 1: A Scrum-based Approach for Developing, Producing, Deploying, Publishing and Evaluating Interactive Virtual Content

Our proposed 5-phase methodology is illustrated in Figure 1. We propose a combination of ADDIE and DPIPE as a baseline for the rapid design, production, and publication of learning content along with UDL as a model focused on the learners' needs. The main objective was to address three key questions: *why, what and how to learn* [35]. Notice that in our proposed approach, Scrum is used as an agile project management framework, exclusively during the *Development, Implementation, Deployment, and Publication* phase. This allowed us to take advantage of its agile features not only for content creation and publication, but also for fast incremental prototyping. This was particularly useful while improving the learning material before its evaluation. The phases of our approach are further explained below:

4.1 Analysis Phase (A01)

During this phase, the primary tasks aim to define the objectives and extent of the course [37] by addressing the "why learning" question in the UDL paradigm (UDLE01). In this stage, the problem, the *learning requirements*, and the target audience of the course are established to involve learners with intention and motivation, ultimately achieving the following objectives [35].:

1. Provide choice and autonomy.
2. Reduce distractions through challenging yet interesting activities.
3. Manage expectations, self-assessment, and reflection.

4.2 Design Phase (D02)

The design phase integrates ADDIE [37] and DPIPE [38] to create the instructional design or *course descriptor*, which is based on the identified learning requirements. The instructional design should provide clear learning objectives and specify the content (activities and assessment resources) to address the question of "what needs to be learned" in the UDL paradigm (UDLR02). The goal of this phase is to actively involve capable and knowledgeable learners in this way [35]:

1. Enable a correct perception of displayed information.
2. Identify audiovisual communication requirements.
3. Define a clear communication protocol (language).
4. Identify requirements for the correct visualization, structure, transfer, and generalization of knowledge.

4.3 Development & Production Phase (DP03)

During this phase, we merge the ADDIE development stage [37] with the DPIPE production stage [38]. Our objective is to address the UDL question of "how to learn" (UDLAE03) [35]. The focal point of this phase is to create designs for *3D anthropomorphic animals* and *sketch storyboards* (situational scenarios) to enhance the comprehension of the learning components outlined in the course descriptor.

4.3.1 Designing 3D Characters

Covering topics about grooming, sexting, and bullying is not easy because bluntly talking about them may expose the audience to reminisce about relatable yet potentially traumatic and frightening abuse experiences. Instead, we propose a fun way to do it to reduce the tension when explaining them to a non-adult audience by introducing friendly 3D characters so that children can feel safer when learning these complex topics.

4.3.2 Sketching Storyboards

Storyboarding, also known as storytelling, utilizes a series of images and pictures to illustrate narratives [41]. While it has traditionally been employed in the realms of comics and animation, basic storyboarding techniques have recently been used in user-centered computer design to depict intricate scenarios [42]. By employing storyboards, content designers are able to represent delightful memories that often align with children's cartoons and humorous situations. The use of storyboards has proven to be advantageous in enhancing children's learning experiences [43], as characters can employ body language and facial expressions to depict various difficult situations in an enjoyable manner.

In summary, using characters in relaxed scenarios to convey complex learning topics to children and their families improves the creation of content because of three primary benefits: (i) the prevention of instilling stereotypes (related to race, religion, and gender) in individuals' thoughts, (ii) the clear, distinctive, and identifiable portrayal of characters (both the heroes and the villains), and (iii) the moderation of harsh realities in contentious subjects which may induce involuntary revictimization.

4.4 Implementation, Deployment, and Publication Phase (IDP04)

Figure 1 provides an overview of the Scrum phases aligned with ADDIE and DPIPE for the development, production, implementation, validation, deployment, and publication of learning content in the proposed VLE. During this phase, learning material was created in an agile and systematic manner, allowing us to focus on ADDIE activities such as developing, producing, and testing the dynamics of the scene (characters in different situations). Similarly, with regards to DPIPE, the incremental prototyping features of Scrum made it possible to quickly implement, deploy, and publish interactive elements like videos and games as learning resources for the VLE (the prototype). However, before making these resources available to students, they underwent *content validation* to refine them. Ultimately, following the Scrum approach, each validated content became *pieces of learning material* that were *deployed on the VLE platform*.

4.5 Evaluation Phase (E05)

The ADDIE model suggests identifying areas for future improvement during the evaluation phase [37]. As per the methodology we have proposed (Figure 1-E05), the evaluation stage is focused on the VLE performance along with the course's design usability and its content. To *evaluate performance*, a Moodle-based test environment was utilized to conduct functional and non-functional tests on the initial version (release) of our proposed VLE. Regarding the *course design's usability*, the assessment involves conducting specific evaluation tasks [38] and ensuring alignment with the learning objectives [37]. Through a detailed evaluation of the course design, areas for potential improvement are identified to define whether the learning objectives were successfully achieved. Finally, about *assessing the course content*, navigation tests, sentiment analysis, and learning tests are used. The aim is to identify the user's impression with the learning content through interface interaction, sentiment reaction, and knowledge attainment, respectively. In Section 5, we present a comprehensive explanation of the analysis, design, implementation, deployment, publication, and evaluation process of the proposed VLE to teach cybersecurity, as a case study.

5 Case Study: An Agile Implementation and Evaluarion of an Interactive Cybersecurity VLE

The following section provides a brief explanation of the main results obtained from the implementation and evaluation of our interactive VLE for teaching cybersecurity, using the proposed 5-phase methodology:

5.1 Analysis and Design (A01 & A02)

The identification of the audience, learning requirements, and course content is essential in addressing the UDL questions related to *why and what to learn.* The course was specifically created for parents, children, and teachers interested in cybersecurity. The result of phases A01 & D02 is in Table 1 which briefly outlines the course descriptor with audience, objectives, and detailed course topics.

Table 1: Course Descriptor: Audience, Learning Outcomes, Objectives and Topics

<table>
<tr><td>Course title:</td><td colspan="3">Cybersecurity for Students, Parents and Teachers</td></tr>
<tr><td>Audience:</td><td colspan="3">This course is for parents, students and teachers who are interested in learning about effective ways for identifying, responding and defending against Internet threats.</td></tr>
<tr><td>Learning outcome:</td><td colspan="3">Upon course completion, participants will be able to identify, respond to, and defend against online threats; whether these come via web-hosted content, or through consensual communication with a stranger.</td></tr>
<tr><td>Aim:</td><td colspan="3">To empower parents, students and teachers, as regular Internet users so that they can take preventive and corrective actions, in case of being threatened, either by an unknown person or by any content accessed on the Internet.</td></tr>
<tr><td>Learning Objectives (Lo):</td><td colspan="3">- (Lo_1) To identify the most common online threats, and the role of social engineering in facilitating them.
- (Lo_2) To learn about monitoring child online activities and safe Internet navigation.
- (Lo_3) To identify manipulation strategies used by attackers for harassment and extortion in order to force people to engage in illegal actions.
- (Lo_4) To respond to Internet threats through effective family communication and timely action in conjunction with the authorities.</td></tr>
<tr><td colspan="4">Course Topics</td></tr>
<tr><td>Module 1
Understanding
Internet Threats</td><td>Module 2:
Social Engineering used
by Paedophiles</td><td>Module 3:
Responding to Unwanted
Online Threats</td><td>Module 4:
Safe Internet
Surfing</td></tr>
<tr><td>- Bullying
- Grooming
- Sexting
- Pornography
- Identity Theft</td><td>- What is Social Engineering?
- Social Engineering Attacks
- The Social Engineering Process</td><td>- Getting to know the local laws
- Fostering effective intra-family communication
- Improving parent-children relationships
- Parenthood and the Internet
- Toxic Online Communities and Online Relationships</td><td>- Social Networks and Blogs
- Virtual Communities
- Online Video Games
- Mobile Communications</td></tr>
</table>

In order to define the course topics, a survey was administered to a total of 745 individuals from three schools in Ecuador, mainly children and teenagers due to their vulnerability to online threats:

- Between 4 to 6 y/o: 55 participants.
- Between 9 to 13 y/o: 123 participants.
- Between 14 to 17 y/o: 256 participants.

Based on the expressed learning needs of the participants, these course topics were determined:

1. *Internet Threats:* Approximately 56 percent of the participants possess a personal electronic device equipped with basic monitoring and parental control features.
2. *Social Engineering used by Paedophiles:* In various age groups, numerous participants reported engaging in online sexual conversations or being solicited by individuals seeking explicit images.
3. *Responding to Unwanted Threats:* Minors aged 9 to 17 have a certain level of fear regarding the possibility of being scammed or encountering more serious dangers while online. Although some parents monitor their children's online activities, minors often feel disconnected from their parents and are reluctant to discuss potential dangers with them.
4. *Safe Internet Browsing:* A total of 639 individuals from various age groups engage in unsupervised video game play and possess at least one social media account such as Facebook, Instagram, and TikTok.

5.2 Development, Production, Implementation, Deployment & Publication (DP03 & IDP04)

Throughout these phases, course material was created and organized based on the identified course topics in Table 1. To accomplish this, as discussed in Section 4.4, we applied Scrum as a means of managing this process. Such an approach facilitated both the *agile development and production of the learning content*, as well as the *gradual implementation and deployment of an evolving prototype*, i.e., the final VLE.

5.2.1 Product Backlog and Sprint Planning

In the context of this study, the identified four course topics (and subtopics), which were identified as the *learning requirements* in the previous phases, are referred to as *sprint epics*. In Scrum [30], an epic is a requirement that is comprised of an unspecified number of user stories. While a user story should represent the smallest unit of work in a Scrum project, for clarity, the user stories presented in Table 2 represent recurring goal activities that were further broken down into smaller tasks in this project.

Table 2: User Stories Distributed in Sprints of the Current Product Backlog

User Story		**Sprint Planning**									**Teams**		
Id.	Description	1	2	3	4	5	6	7	8	9	Storytelling	Production	Ludic
Us_1	Training	$M_{1,4}$	$M_{1,4}$	$M_{1,4}$	$M_{1,4}$	$M_{1,4}$	$M_{1,4}$	$M_{1,4}$	$M_{1,4}$	$M_{1,4}$	x	x	x
Us_2	Voice casting	$M_{1,4}$										x	
Us_3	Content structure & documentation	$M_{1,2}$	$M_{1,2}$	$M_{1,3}$	$M_{3,4}$	$M_{3,4}$	$M_{3,4}$				x	x	x
Us_4	Dialogue & Storyboards	$M_{1,2}$	$M_{1,2}$	$M_{1,3}$	$M_{3,4}$	$M_{3,4}$	$M_{3,4}$				x		x
Us_5	Storyboard Amendment	$M_{1,2}$	$M_{1,2}$	$M_{1,3}$	$M_{3,4}$	$M_{3,4}$	$M_{3,4}$				x		x
Us_6	Audiovisual Production		$M_{1,2}$	$M_{1,2}$	$M_{1,3}$	$M_{3,4}$	$M_{3,4}$	$M_{3,4}$					x
Us_7	Voice-overs		$M_{1,2}$	$M_{1,2}$	$M_{1,3}$	$M_{3,4}$	$M_{3,4}$	$M_{3,4}$				x	
Us_8	Game Production		$M_{1,2}$	$M_{1,2}$	$M_{1,3}$	$M_{3,4}$	$M_{3,4}$	$M_{3,4}$			x	x	x
Us_9	Quality Assurance				$M_{1,2}$		$M_{2,3}$		$M_{3,4}$	$M_{1,4}$		x	x

Our objective is to demonstrate how the recurring goal activities (recurring user stories) were allocated across 9 sprints, which represent the project's work breakdown (product backlog) in a time-boxed continuous development cycle. Then, let a *product backlog* be loosely defined as the projection of $Us \times M \times Sp$, where Us is a set of user stories, M a set of epics (modules), and Sp a set of sprints. A tuple $\langle Us_i, M_{m,n}, Sp_j \rangle$ is a mapping between goal activities (user stories) which have been recurrently performed from modules m *to* n across Sp_j sprints for implementing, deploying, and publishing learning content.

5.2.2 Creation of Learning Content

The development of the learning content was guided by the activities outlined in Table 1 and involved the following steps:

1. *Defining Creative Teams:* As detailed in Table 2, three teams were established. The *Storytelling Team* was responsible for creating storyboards, dialogues, scenarios, and infographics. The *Production Team* handled the creation of audiovisual content based on the materials provided by the Storytelling Team. The *Ludic Team* developed educational games and activities, ensuring they aligned with the course descriptor and maintained high quality.

(a) Scene 1: Charly using his mobile phone alone (b) Scene 2: Family discussing with the police

(c) Scene 3: Reporting cyberbullying to a teacher (d) Scene 4: Rick planning a cyberattack

Figure 2: Scenes depicting real-world situations and character interactions

2. *Creating 3D Anthropomorphic Characters:* To enhance engagement, visually appealing 3D characters were created. Using animals to address complex topics like grooming or sexting helps avoid uncomfortable situations for children, preventing potential traumatic responses [44]. These characters help make the learning experience enjoyable and relatable.

3. *Establishing Scene Dynamics:* Scenarios are crucial for shaping character interactions. Figures 2a through 2d illustrate various scenes in which some of the created characters interact. For instance, Charly using his phone alone, a family discussion with the police, a teacher addressing cyberbullying, and Rick planning a cyberattack. These scenarios help familiarize children with different environments and reinforce important lessons about online safety [45].

4. *Producing Learning Games:* Educational games were developed using Genially and Scratch, with enhanced formative evaluations carried out using H5P-enabled videos. Examples of these videos are available in the project's YouTube playlist [46].

5.2.3 Content Publication

As illustrated in Figure 1, the Scrum framework emphasizes *prototyping and continuous evaluation*. Therefore, *systematic quality checks were performed by educational experts* before publication to ensure that the content was suitable for students, compatible with existing VLE content, and aligned with the course descriptor. Content passing these checks was released in the final VLE prototype. This approach, as shown in Table 2, facilitates planning changes within sprints, easing content management during VLE updates and maintenance. Additionally, both the VLE and LMS platforms were assessed for performance, usability, and content quality to prevent technical issues and enhance user experience. These evaluations will be discussed in the following section.

5.3 Evaluation (E05)

The primary research question addressed in this paper is "How feasible is deploying an interactive VLE for teaching cybersecurity concepts to children?" A straightforward answer cannot be given, so the methodology depicted in Figure 1 explains the evaluation phase (E05) of the produced learning content. This phase focuses on assessing such content at a *high level of abstraction*, using both quantitative and qualitative tests to support our hypothesis **(Ho)**: *Delivering a virtual course is feasible with **a)** acceptable performance (Section 5.3.1), **b)** minor usability issues per module (Section 5.3.2), and **c)** a rewarding learning experience (Section 5.3.3).*

5.3.1 Performance Assessment

In order to evaluate the performance of the Virtual Learning Environment (VLE), as detailed in **Ho.a)**, both functional and non-functional tests were conducted. These tests enabled us to assess the front-end functionality and performance of the VLE learning content as well as the configuration features of the Learning Management System (LMS). The measurements were performed automatically using *Cypress*, *Testim.io*, and *JMeter*.

Table 3: Test Scenarios

Id.	**Scenario**	**Test Type**		
		Funct.	*Non-Funct.*	*Navigat.*
Sc_1	Send enrollment email	x	x	x
Sc_2	Profile customization			x
Sc_3	Forget password feature	x	x	
Sc_4	Hide/Show modules	x	x	
Sc_5	Download student grades	x	x	
Sc_6	Block/Unblock tests	x	x	
Sc_7	Navigate with left menu pane	x	x	x
Sc_8	Progress on Mods. 1-4	x	x	x
Sc_9	Ludic activities on Mods. 1-4			x
Sc_{10}	Get badge of Module 1			x
Sc_{11}	Get badge of Module 2			x
Sc_{12}	Get badge of Module 3			x
Sc_{13}	Get badge of Module 4			x
Sc_{14}	Course overall achievement	x	x	x
Sc_{15}	End-to-end flow in Module 1	x	x	x
Sc_{16}	End-to-end flow in Module 2	x	x	x
Sc_{17}	End-to-end flow in Module 3	x	x	x
Sc_{18}	End-to-end flow in Module 4	x	x	x
Sc_{19}	End-to-end flow in the course	x	x	x
Sc_{20}	Online activities in Mods. 1-4	x	x	x

In Table 3, *black-box test scenarios* [29] were outlined to evaluate the functional, non-functional, and navigational features of the VLE. The first two types of evaluations are discussed in this section, while navigational tests are covered in Section 5.3.3 as part of the learning content evaluations.

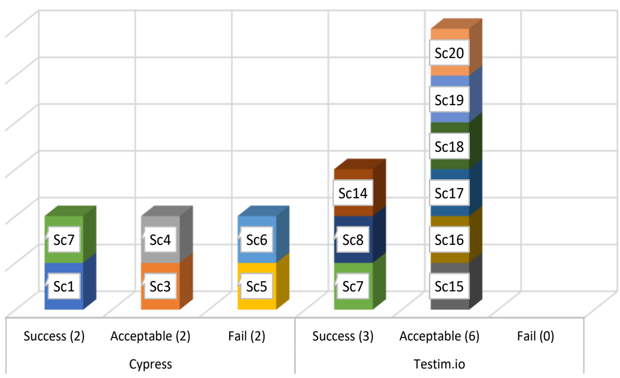


Figure 3: Functional Test: *Cypress* vs. *Testim.io*

Functional Tests: Figure 3 presents the results of using *Cypress* and *Testim.io* for executing automated functional tests. This method provides precise automated observations of test scenarios through regression tests [47]. Such an approach is especially advantageous in a Scrum project, where continuous integration and prototyping are required.

Non-Functional Tests: The non-functional assessments focused on quantifying the performance of the VLE. The LMS, powered by Moodle, was implemented on the following platform:

- CPU: Intel Xeon E-2176G Hexa-Core Coffee Lake
- RAM: 64 GB DDR4 ECC RAM
- HDD: 2 x 512 GB NVMe SSD (Gen 4, Software RAID 1)
- OS: Linux CentOS 7

JMeter was used for performance measurement, and *BlazeMeter*, a Chrome extension, facilitated continuous performance testing. These tools were employed to create synthetic workloads under controlled conditions, allowing us to perform *load and stress tests* and analyze the error/success ratios in the test scenarios.

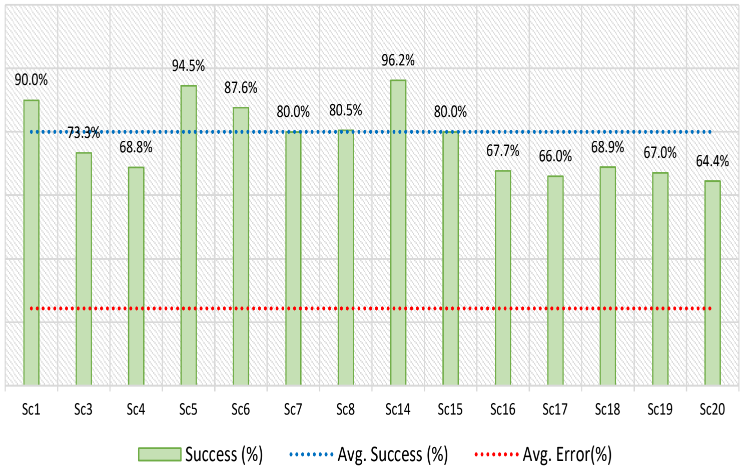


Figure 4: Load Test in *JMeter* - Avg. success: 79.98% & Avg. error: 24.35%

For *load tests* (Figure 4), assuming a 4-week course with a total of 20 notional hours, students were advised to spend at least 40 minutes per hour of learning within an 8-hour working day. Consequently, to simulate a scenario where 30 students connect simultaneously every 5 minutes over the course of an hour, the following settings were used in *JMeter*:

1. 30 threads (each simulating one student)
2. Each thread was launched twice (2 loop counts) every 5 minutes (300 seconds)

Table 4: Stress Test in *JMeter* with Low, Medium & High Workload

	No. Threads/min.	**Avg. Success (%)**	**Avg. Error (%)**
Low	1-100	43.14%	59.60%
Medium	100-300	24.06%	79.94%
High	301-3000	6.15%	97.70%

In stress tests, a high workload scenario was randomly selected, deploying a large number of threads to determine the maximum threshold at which the LMS platform would fail. It was found that a workload of 3000 threads per minute (equivalent to 50 users per second) was the maximum stress level before disruption. The results of the stress tests are presented in Table 4.

5.3.2 Usability Assessment of the Course Design

In the realm of usability evaluation, a multidimensional approach is imperative to comprehend the intricate facets of user experience. As mentioned in **Ho.b)**, our aim is to assess whether our proposed VLE has minor usability issues per module. Consequently, we employ the *Nielsen Heuristics* and the *System Usability Scale* to scrutinize the *learning content design* based on well-established guidelines. As a result, both techniques complement each other when it comes to understanding the intricacies of user behavior as well as identifying specific interaction challenges. While the Nielsen heuristics provide a set of principles to determine design issues per module, SUS presents a standardized scale to evaluate the overall VLE usability. Our study involved 42 participants between the ages of 19 and 22, all university students of usability and user experience (UX), with no previous exposure to the learning content, and selected to participate in a four-hour long VLE usability evaluation per module (4 modules in total). This resulted in 1*68 SUS (10 questions)* and *168 Nielsen (10 heuristics)* evaluations per module, which is equivalent to 3,360 observations, the results of which are explained as follows:

The SUS Usability Analysis is an objective and widely-accepted method for unraveling nuanced aspects of user behavior, preferences, and challenges that might go unnoticed. SUS employs 10 questions:

(Q.1) I think that I would like to use this system frequently.
(Q.2) I found the system unnecessarily complex.
(Q.3) I thought the system was easy to use.
(Q.4) I think that I would need the support of a technical person to be able to use this system.
(Q.5) I found the various functions in this system were well integrated.
(Q.6) I thought there was too much inconsistency in this system.
(Q.7) I would imagine that most people would learn to use this system very quickly.
(Q.8) I found the system very cumbersome to use.
(Q.9) I felt very confident using the system.
(Q.10) I needed to learn a lot of things before I could get going with this system.

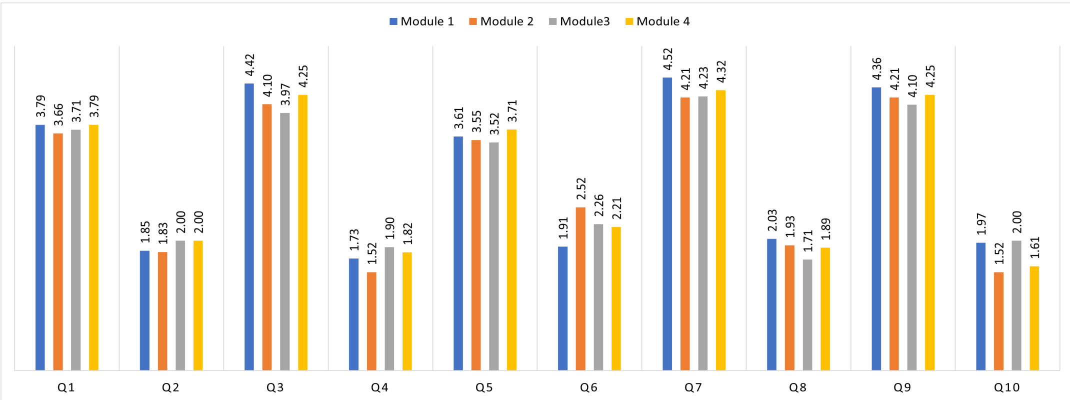


Figure 5: SUS Average Scores per Question Q_i on each Module

In Figure 5, SUS average scores per question on each module are shown to provide valuable insights about user satisfaction and potential areas for improvement. Each question was evaluated with a consistent likert scale (from 0 to 5) so that users give a score which can be later used to identify acceptable, marginal, and not acceptable results:

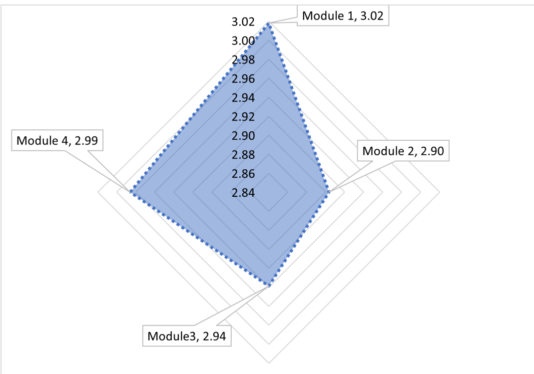


Figure 6: SUS Average Scores per Module

(1) Ease of Use: The average responses suggest variability in the perception of the product's ease of use. Some users find it relatively easy to use (average around 4), while others face significant difficulties (average around 1.9). This indicates specific areas that may need improvements in terms of usability.
(2) Usability Issues: Low average scores in certain questions (around 1.7 and 2) suggest that there are significant usability problems with certain aspects of the VLE. Addressing these issues is crucial as they may pose significant obstacles for users.
(3) User Satisfaction: Response values also indicate varying user satisfaction. Some users seem relatively satisfied (average around 4.4), while others are less satisfied (average around 1.9). Addressing the concerns of unsatisfied users is important to improve the overall perception of the course.
(4) Areas for Improvement: Average values around 3.6 and 3.8 indicate aspects that are at an intermediate level in terms of usability and satisfaction. While these areas may not be as problematic as others, they could still benefit from incremental improvements.
(5) Individual Differences: The variation in responses suggests that users have different perspectives and experiences with the VLE. It is essential to consider these individual differences when addressing usability issues and designing improvements. Despite the variation in users' usability perception on each question, the average scores per module shown in Figure 6 are around 3.00. This reports an acceptable (medium) level of usability for the VLE, considering that the participants had no previous contact with the course and/or prior experience with the learning content. Continuous improvement strategies can further elevate the VLE's usability, ensuring an optimal and user-centric educational experience.

The Nielsen Heuristic Analysis encompass general aspects to identify usability issues, also using in 10 questions:

(H.1) Visibility of system status: Are users provided with clear and consistent feedback about the system's state?
(H.2) Match between system and real world: Does the system speak the users' language, using terminology familiar to them?
(H.3) User control and freedom: Can users easily navigate the VLE and recover from errors?
(H.4) Consistency and standards: Is the design consistent, adhering to established conventions and standards?
(H.5) Error prevention: Does the system anticipate user errors and provide mechanisms for prevention?
(H.6) Recognition rather than recall: Are system functions, instructions, and options visible and easily retrievable?
(H.7) Flexibility and efficiency of use: Can experienced users navigate through the VLE efficiently, and can novices easily learn to use it?
(H.8) Aesthetic and minimalist design: Is the interface visually appealing and free from unnecessary elements?
(H.9) Help users recognize, diagnose, and recover from errors: Are error messages clear, and does the system assist users in error recovery?
(H.10) Help and documentation: Is user assistance readily available, and is it easily accessible when needed?

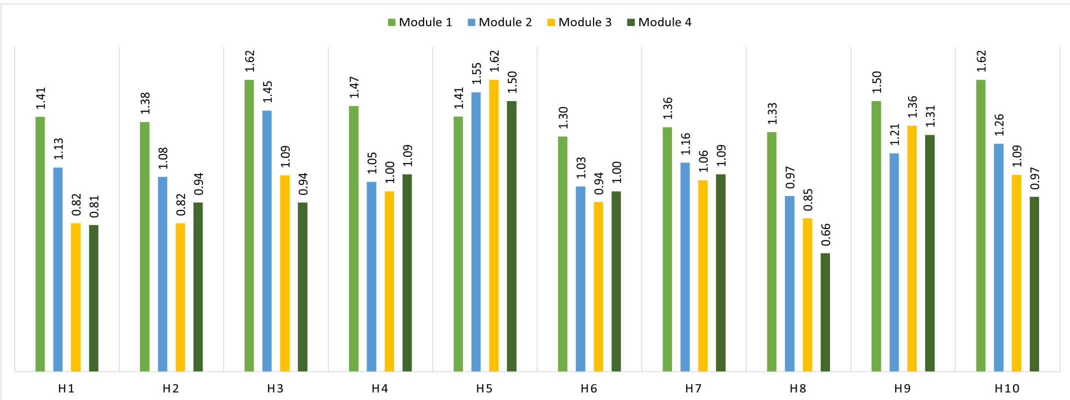


Figure 7: Nielsen Average Scores per Heuristic H_j on each Module

According to Nielsen, the usability perception is measured on a scale of 0 to 4, with lower ratings indicating that there is no usability problem. Ratings of 1 or 2 indicate either a cosmetic issue or a minor problem. However, scores of 3 and 4 indicate major usability problems that are of high or severe priority. The participants were mainly asked to provide feedback based on their experiences using the interface of the VLE; i.e. Moodle, showing specific areas for improvement and optimization while interacting with the learning content. Despite having participants showing a variation in their responses and agreement with the VLE usability, the Nielsen average scores per heuristic in Figure 7 are between 0.66 and 1.62. Meanwhile, as shown in Figure 8, neither module exceeds the average value of 1.5 per module. These results suggest that the general perception of participants ranges from minor to low usability issues in the VLE. Summing up, by combining both the SUS and Nielsen frameworks, we obtained a dual perspective regarding the usability of the VLE. On the one hand, SUS captured subjective perceptions about the general usability of the learning content. On the other hand, Nielsen provided a nuanced examination of specific usability issues in the VLE interface while interacting with the course content. These approaches allowed us to identify and analyze granular design elements that may contribute to future improvements of the

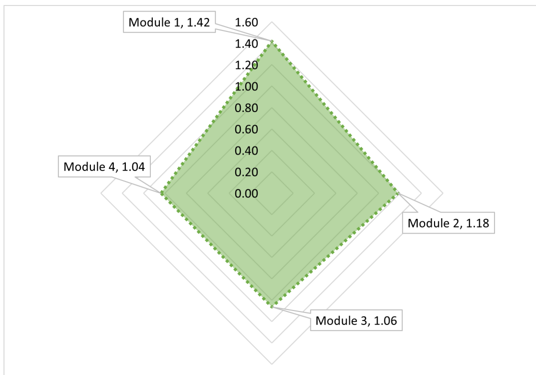


Figure 8: Nielsen Average Scores per Module

proposed VLE, and to the overall success of the students' learning journey, considering not only the holistic user experience but also the detailed design aspects of the learning content.

5.3.3 Course Content Assessment

Following our hypothesis for **Ho.c)**, we want to determine whether students are definitely immersed in a rewarding learning experience. For achieving this, at this stage, we performed navigation tests, sentiment analysis, and learning tests in order to observe the user response when interacting with the learning content and the VLE interface during the learning experience. For the navigation and sentiment evaluations, the same sample of 42 participants (as in Section 5.3.2) were employed. For the learning tests, a smaller sample of users was used, as the evaluations had to be more controlled and focused on learning outcomes.

Navigation Tests: During the evaluation, the participants were assigned a set of intuitive navigation tasks for each navigation test scenario (Table 3). They were required to complete these tasks within a specified time frame. The objective of these navigation tasks was to assess the users' perception of the interface's intuitiveness and visual appeal, as well as the time taken to complete each task.

Table 5: Navigation Test Scenarios

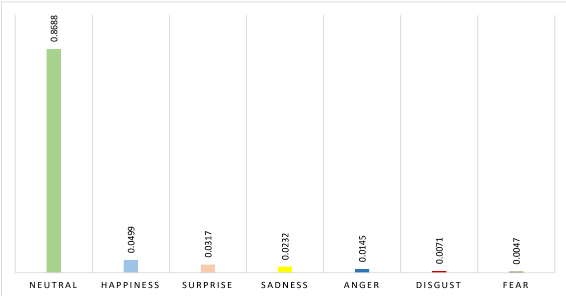
Id.	**Navigation Test**	**Given** t	**Actual** t
Sc_1	Click email link → enter credentials→Access course Req. change psswd.→click email link→change psswd. Enter new credentials→Access course	15 mins.	20 mins.
Sc_2	Access course→Settings→Update info→ Save	4 mins.	7 mins.
Sc_7	Start section→Module 1→ Next module	14*20 mins.	14*25 - 30 mins.
Sc_8	Start section → Find student guides → Read		
Sc_9	Start section → Find Modules Course home → Find Module icon → Access Module		
Sc_{10}	Click on video → Watch in fullscreen		
Sc_{11}	Find material → Download → Open in computer		
Sc_{12}	Find genially game → have fun → submit progress		
Sc_{13}	Find quiz → Answer questions → submit progress		
Sc_{14}	Find Module → Progress → Check achievement		
Sc_{15}	5*Find Module → Complete activities → Go to next module		
Sc_{16}			
Sc_{17}			
Sc_{18}			
Sc_{19}			
Sc_{20}	Find Module → Find Zoom link → Access conference Return to Module → Do activities → Submit progress		

In Table 5, the navigation test results reveal that while the *actual completion time* slightly exceeded the originally allocated time, users were still able to complete the scenarios within a reasonable timeframe. These deviations may be attributed to the fact that all 42 participants had no prior exposure to the VLE and its content. Nonetheless, the navigation results demonstrate that the VLE is intuitive and engaging enough to support a timely learning experience.

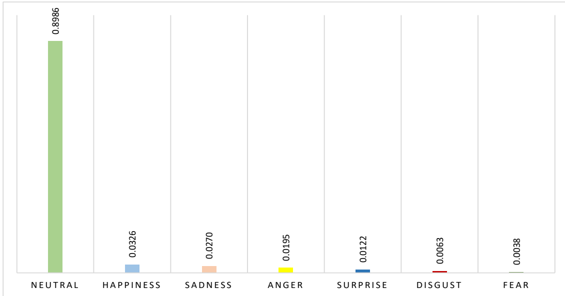
Sentiment Analysis: In this section, we present the results of sentiment analysis performed in the 4 modules proposed in Table 1 after applying the Analytic Hierarchy Process (AHP) along with the WEBLEI framework. We observe a prevalent trend of neutral sentiments among participants. This neutrality in sentiment responses is indicative of the inherent complexity and potentially shocking nature of the topics explored in the various modules. We explain these findings as follows:

- The topics "Understanding Internet Threats" and "Social engineering used by Paedophiles" covered in Modules 1 and 2; respectively, discuss intricate methods employed by individuals with harmful intentions. Potential reactions to these topics are shown in Figures 9a and 9b that depict various emotions ranging from concern to discomfort. Neutral sentiments in these modules could be the result of a deep reflection of the participants in response to the topics covered in the learning material.
- Similarly, Module 3, titled "Responding to Unwanted Internet Threats" may expose learners to scenarios involving online threats and harassment. Figure 9c shows that the nature of this content, which involves responding to potentially distressing situations, could elicit a neutral emotional response as participants navigate the educational content of the module without expressing strong positive or negative sentiments.
- In the case of Module 4, which focuses on "Safe Internet Browsing", Figure 9d shows that neutral sentiments could be attributed to the more informative and instructional nature of the content. In

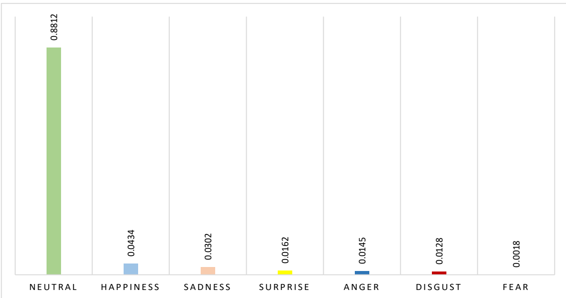
fact, participants may perceive the information as valuable and practical without necessarily being emotionally overwhelmed.



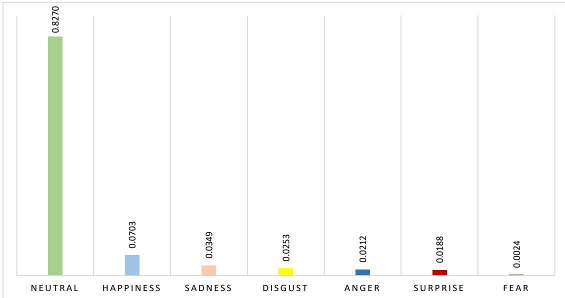
(a) Average Sentiment Scores in Module 1



(b) Average Sentiment Scores in Module 2



(c) Average Sentiment Scores in Module 3



(d) Average Sentiment Scores in Module 4

Figure 9: Sentiment Analysis per Module: Participants' reactions to the Course Content in terms of neutral, happiness, surprise, sadness, anger, disgust, and fear

The predominance of neutral sentiments suggests that learners approached the sensitive topics with a measured and analytical mindset. This balanced perspective may enhance the learning experience. Detailed *correlation analysis* of sentiment responses provides further insight into the interplay of emotions:

	neutral	*happiness*	*sadness*	*anger*	*fear*	*disgust*	*surprise*
neutral	1.0000	-0.6343	-0.4345	-0.3313	-0.2553	-0.2640	-0.4985
happiness	-0.6343	1.0000	0.0019	-0.0040	-0.0084	0.0097	-0.0394
sadness	-0.4345	0.0019	1.0000	0.0367	0.0614	0.0583	0.0061
anger	-0.3313	-0.0040	0.0367	1.0000	0.0275	0.1087	0.0658
fear	-0.2553	-0.0084	0.0614	0.0275	1.0000	0.0391	0.1454
disgust	-0.2640	0.0097	0.0583	0.1087	0.0391	1.0000	0.0347
surprise	-0.4985	-0.0394	0.0061	0.0658	0.1454	0.0347	1.0000

Figure 10: Sentiment Correlation in Participants' Emotions while Interacting with Module 1

Figure 10 reveals patterns in Module 1, where higher happiness levels may be associated with lower surprise levels. This weaker negative correlation indicates that enjoyable interactions may evoke surprise, especially when dealing with complex topics like Internet threats.

	neutral	*happiness*	*sadness*	*anger*	*fear*	*disgust*	*surprise*
neutral	1.0000	-0.6127	-0.5523	-0.3999	-0.2383	-0.3074	-0.2916
happiness	-0.6127	1.0000	-0.0033	-0.0022	-0.0057	0.0124	-0.0264
sadness	-0.5523	-0.0033	1.0000	0.0139	0.0680	0.0526	0.0203
anger	-0.3999	-0.0022	0.0139	1.0000	-0.0052	0.1373	0.0049
fear	-0.2383	-0.0057	0.0680	-0.0052	1.0000	0.0423	0.0859
disgust	-0.3074	0.0124	0.0526	0.1373	0.0423	1.0000	0.0261
surprise	-0.2916	-0.0264	0.0203	0.0049	0.0859	0.0261	1.0000

Figure 11: Sentiment Correlation in Participants' Emotions while Interacting with Module 2

Figure 11 shows that in Module 2, there is a weaker correlation between happiness and surprise, and a negative relationship between neutrality and surprise. Participants expressing more disgust also showed more surprise, reflecting the shocking nature of social engineering techniques.

	neutral	happiness	sadness	anger	fear	disgust	surprise
neutral	1.0000	-0.6599	-0.5169	-0.3006	-0.1418	-0.3864	-0.2834
happiness	-0.6599	1.0000	-0.0252	-0.0278	-0.0042	-0.0136	-0.0363
sadness	-0.5169	-0.0252	1.0000	0.0693	0.0619	0.1342	-0.0083
anger	-0.3006	-0.0278	0.0693	1.0000	0.0394	0.0449	0.0265
fear	-0.1418	-0.0042	0.0619	0.0394	1.0000	0.0157	0.0470
disgust	-0.3864	-0.0136	0.1342	0.0449	0.0157	1.0000	0.0076
surprise	-0.2834	-0.0363	-0.0083	0.0265	0.0470	0.0076	1.0000

Figure 12: Sentiment Correlation in Participants' Emotions while Interacting with Module 3

Figure 12 indicates that Module 3 participants maintain a neutral stance with less expression of strong emotions. A positive correlation between sadness and disgust suggests that these emotions are expressed together, while increased neutrality correlates with decreased surprise, reflecting a measured response to threat scenarios.

	neutral	happiness	sadness	anger	fear	disgust	surprise
neutral	1.0000	-0.6558	-0.4254	-0.3376	-0.1246	-0.4292	-0.2315
happiness	-0.6558	1.0000	-0.0489	-0.0331	-0.0174	-0.0368	-0.0565
sadness	-0.4254	-0.0489	1.0000	0.0088	0.0363	0.0727	-0.0145
anger	-0.3376	-0.0331	0.0088	1.0000	0.0163	0.1255	0.0064
fear	-0.1246	-0.0174	0.0363	0.0163	1.0000	0.0182	0.0464
disgust	-0.4292	-0.0368	0.0727	0.1255	0.0182	1.0000	-0.0128
surprise	-0.2315	-0.0565	-0.0145	0.0064	0.0464	-0.0128	1.0000

Figure 13: Sentiment Correlation in Participants' Emotions while Interacting with Module 4

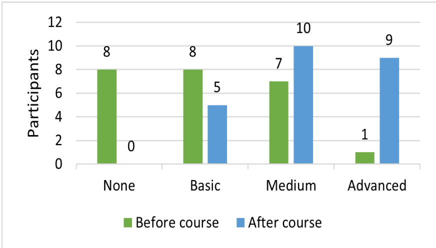
Figure 13 shows similar findings for Module 4, where a neutral emotional stance is predominant. The negative correlation between happiness and surprise, along with a positive correlation between sadness and disgust, demonstrates a consistent pattern across modules with more interactive content.

Learning Tests: The virtual cybersecurity course was conducted over four weeks at a primary school in Quito, Ecuador, requiring participants to dedicate 5 hours per week, totaling 20 hours. Twenty-four participants, including 10 males and 14 females, completed the *before-the-course quiz*, engaged with the course activities, and then completed the *after-the-course quiz*:

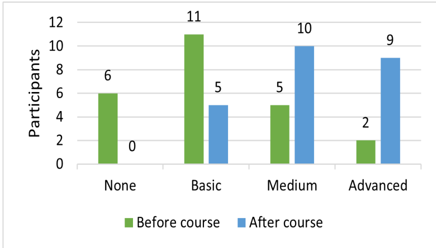
- 11 children aged 8-12
- 5 young adults aged 18-25
- 3 adults aged 25-35
- 2 adults aged 35-40
- 2 adults aged 40-65

The quizzes were designed according to guidelines outlined in [5, 7, 48, 22, 2, 25, 26, 27] and aligned with the *learning objectives* (*Lo*) detailed in Table 1. The results per learning objective are summarized as follows:

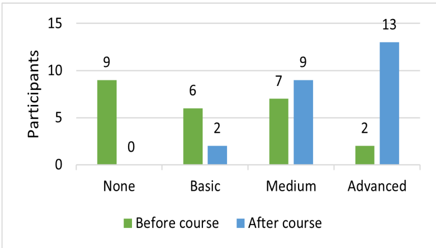
- (Lo_1) *Families' ability to recognize social engineering methods exploiting personal information shared on social networks.* Figure 14a illustrates participants' understanding of social engineering attacks like spamming, phishing, and vishing.
- (Lo_2) *Parents and educators' ability to supervise children's online actions.* Figure 14b shows participants' progress in knowledge and use of cybersecurity tools such as parental controls, antivirus software, and password managers.
- (Lo_3) *Families' ability to counter online manipulation techniques.* Figure 14c demonstrates participants' proficiency in strategies to prevent grooming by sexual predators.
- (Lo_4) *The impact of course modules on effective communication within families and schools.* Figure 14d highlights participants' advancements in understanding active communication, recognizing behavioral changes in children, and seeking legal assistance when needed.



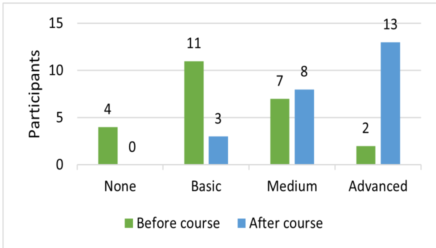
(a) (Lo_1): Preventing Social Engineering



(b) (Lo_2): Installing Cybersecurity Tools



(c) (Lo_3): Responding to Internet Threats



(d) (Lo_4): Using Effective Communication

Figure 14: Virtual Course Learning Evaluation Results

6 Discussion of Results

In this section, we discuss general remarks about the performance evaluation of the VLE, the course usability tests, the sentiment analysis of the VLE, and the learning tests.

6.1 About the VLE Performance

The *functional tests* shown in Figure 3 confirm the proper operation of both the VLE and the LMS. These tests, implemented using *Cypress* and *Testim.io*, mostly resulted in satisfactory outcomes. However, two scenarios in *Cypress* failed due to limited access to certain programmable features in Moodle. In contrast, automated tests performed on *Testim.io*, being AI-driven and not dependent on specific code, offered an advantage when conducting black-box testing of Moodle features. In relation to *non-functional tests*, the outcomes of load tests (Figure 4) indicate that most of the implemented scenarios in JMeter were executed with a success rate of approximately 79 percent, which is close to the average, despite having an error rate of 24.35 percent when executing these tests. On the other hand, the stress test results presented in Table 4 demonstrate that the current hardware configuration can handle a cohort of less than 100 students effectively. However, for having more students, the LMS platform will not perform well under high concurrency, as it will collapse when the user rate reaches approximately 3000 users per minute. Nevertheless, both performance tests delivered acceptable results, demonstrating that the current VLE configuration and associated components can operate in optimal conditions, validating the hypothesis (**Ho.a**) proposed in Section 5.3.

6.2 About the Course Usability

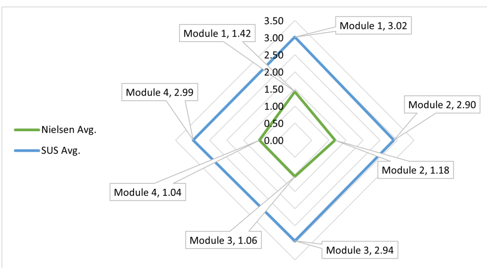
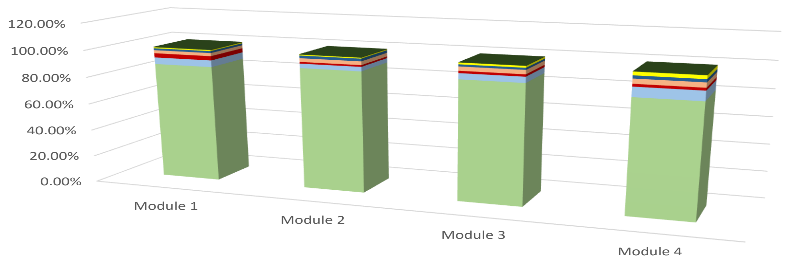


Figure 15: SUS Average Scores per Module

The SUS and Nielsen results per module are shown in Figure 15. Module 1 has the highest SUS score with 3.02/5.00, followed by Module 4 with 2.99/5.00. The lowest SUS scores are in Module 3 and Module 2, with 2.94/5.00 and 2.90/5.00, respectively. Regarding Nielsen, the highest issues are in Module 1 with a score of 1.42/4.00, followed by Module 2 with 1.18/4.00. Modules 3 and 4 have the lowest design issues with 1.06/4.00 and 1.04/4.00, respectively. Despite some minor usability problems and few design issues, the proposed VLE has an acceptable usability level (blue line) with an average SUS score of around 3.00/5.00, as well as low usability problems (green line) with an average Nielsen score of less than 1.45/4.00.

Based on these results, the hypothesis (**Ho.b**) is validated, having a final product with high usability and minor design issues per module.

6.3 About the Sentiment Analysis



	Module 1	Module 2	Module 3	Module 4
fear	0.47%	0.38%	0.18%	0.24%
disgust	0.71%	0.63%	1.28%	2.53%
anger	1.45%	1.95%	1.45%	2.12%
sadness	2.32%	2.70%	3.02%	3.49%
surprise	3.17%	1.22%	1.62%	1.88%
happiness	4.99%	3.26%	4.34%	7.03%
neutral	86.88%	89.86%	88.12%	82.70%

Figure 16: Sentiment Analysis: Avg. Percent of Emotions within Responses per Module

Regarding the overall results of the *sentiment analysis*, Figure 16 provides the following remarks:

- A predominant 86.88 percent of responses lean towards a neutral sentiment, forming the prevailing emotional tone. Following closely are instances of happiness and surprise, albeit in a smaller proportion. Negative emotions encompassing sadness, anger, disgust, and fear, exhibit lower percentages in user responses. This nuanced analysis unveils a landscape where neutrality prevails, punctuated by sporadic positive sentiments, and a minimal expression of negative emotions when learners are exposed to topics related to threats on the Internet. The exploration of these emotional nuances lays the foundation for a deeper understanding of user interactions within Module 1, guiding potential refinements for an enhanced learning experience in the proposed VLE.

- In Module 2, an overwhelming 89.86 percent of responses indicate a prevalence of neutral sentiments, with happiness and sadness following in smaller proportions. Negative emotions exhibit low percentages in user responses. This analysis underscores the predominant neutral tone within Module 2, with intermittent expressions of positive emotions and minimal indications of negativity despite the complexity of learning topics related to social engineering and paedophilia. The nuanced examination of sentiment distributions contributes to a comprehensive understanding of user experiences, guiding potential refinements for an enriched learning journey within the cybersecurity course.

- Neutral responses maintain predominance in Module 3, followed by instances of happiness and sadness. Negative emotions register relatively low percentages, with fear being the least expressed. This analysis highlights the prevalence of neutral sentiments within Module 3, complemented by intermittent positive and minimal negative emotional expressions. This was particularly noted in Section 5.3.3 when participants engaged in content to learn effective ways to respond efficiently to Internet threats. Understanding these sentiment distributions contributes to a nuanced interpretation of user experiences, offering insights for potential enhancements to the learning content.

- Likewise, neutral responses predominate at 82.70 percent in the final module, followed by expressions of happiness and sadness. Notably, negative emotions exhibit more significant percentages compared to the other modules when participants examined the content related to safe Internet browsing where tools for online activity monitoring were encouraged. This analysis sheds light on the prevalence of neutral sentiments in the concluding module, accompanied by varying degrees of positive and more pronounced negative emotional expressions. Examining these sentiment patterns contributes to a comprehensive understanding of user experiences, perhaps to reinforce the positive aspects of monitoring online activity despite an apparent privacy invasion when using tools for this purpose.

Additionally, Figure 17 provides a comprehensive view of the emotional responses of all participants. Neutral is the most prevailing sentiment, appearing in approximately 87 percent of the total responses. This indicates

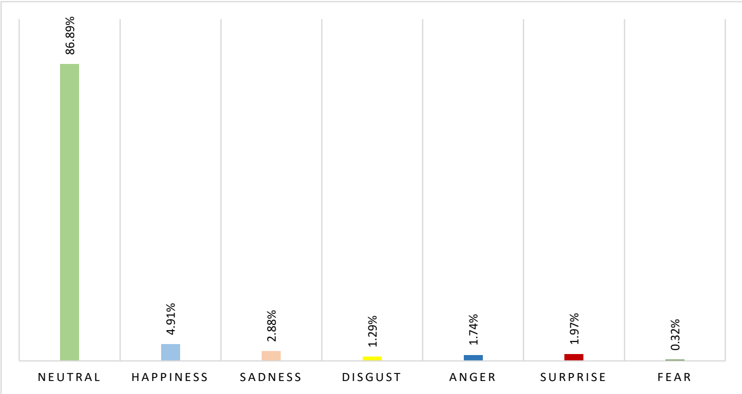


Figure 17: Sentiment Analysis: Overall Emotion Perception in the Proposed VLE

that most of the participants tend to express a neutral stance. Happiness follows at 4.91 percent, suggesting the presence of a positive mood in the participants. The remaining emotions like sadness, surprise, anger, disgust, and fear appear in the responses in smaller proportions. This makes sense as shocking topics such as grooming, bullying, sexting, among others, are designed to be introduced slowly to prevent traumatic or exaggerated responses in the audience.

	neutral	happiness	sadness	anger	fear	disgust	surprise
neutral	1.0000	-0.6407	-0.4823	-0.3424	-0.1900	-0.3468	-0.3262
happiness	-0.6407	1.0000	-0.0189	-0.0168	-0.0089	-0.0071	-0.0397
sadness	-0.4823	-0.0189	1.0000	0.0322	0.0569	0.0795	0.0009
anger	-0.3424	-0.0168	0.0322	1.0000	0.0195	0.1041	0.0259
fear	-0.1900	-0.0089	0.0569	0.0195	1.0000	0.0288	0.0811
disgust	-0.3468	-0.0071	0.0795	0.1041	0.0288	1.0000	0.0139
surprise	-0.3262	-0.0397	0.0009	0.0259	0.0811	0.0139	1.0000

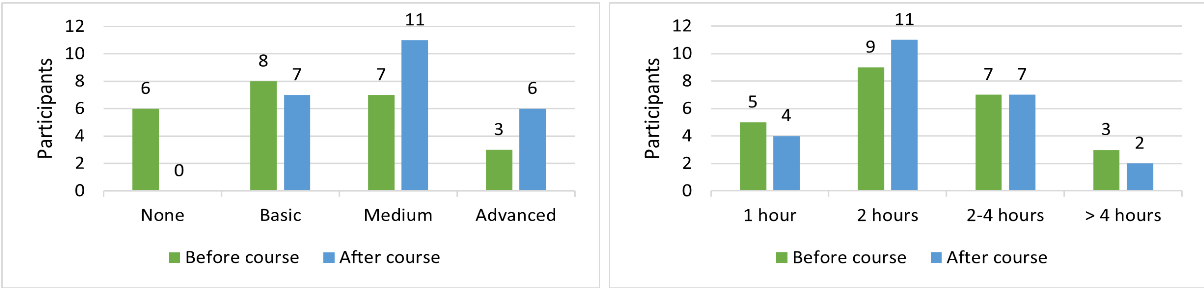
Figure 18: General Sentiment Correlation in Participants' Emotions

In general, the sentiment analysis performed on the VLE demonstrated a strong negative correlation between neutral responses and emotions expressed as happiness, sadness, anger, fear, disgust, and surprise. Figure 18 illustrates a significant negative correlation which means that as the level of neutrality in responses increases, the expression of these emotions tends to decrease, and vice versa. In every module of the VLE, students reacted more neutrally, meaning that in certain topics they were not able to express strong emotions. However, there is a nuanced relationship between happiness and surprise where emotional expressiveness tends to be inversely related to the degree of expression of such emotions in responses; i.e., surprise tends to decrease when happiness increases. Additionally, a positive correlation is evident between the emotions of sadness and disgust; i.e., either increases when the other does. Overall, these findings offer a better understanding of how different emotions manifest and interact within the proposed VLE. In fact, the emotional patterns observed provide valuable insights for educators and designers to tailor the learning content in a way that it resonates effectively with the emotional responses of students, thereby promoting a more engaging and meaningful learning experience.

6.4 About the Course Navigation and Learning Outcomes

The results of the *navigation test* presented in Table 5 indicate that certain tasks within each scenario were completed in timeframes that were relatively close to the estimated durations. Our virtual learning environment (VLE) was implemented as an interactive course, featuring visual icons for accessing learning modules and various interactive plugins. As a result, users may need additional training sessions to become acquainted with the unique design of this VLE, as it differs from other traditional course formats.

About *learning tests*, Figure 19a illustrates the remarkable progress made by parents, children, and teachers in understanding general concepts in cybersecurity. This progress was achieved using domestic broadband connections, with most participants having speeds between 50 and 100 Mbps. Only a small number of participants had speeds between 2 and 20 Mbps. The majority of participants completed the virtual course from their homes using various devices, with laptops and PCs being the most commonly used devices, followed by mobile phones and tablets. It is possible that PC and laptop users had a better learning experience due to faster data trade-off compared to mobile device users. However, the allocated hours per week to complete the course, as shown in Figure 19b, indicate that most participants spent between 2 and 4 notional hours on



(a) General cybersecurity knowledge achieved

(b) No. of hours/week allocated for virtual learning

Figure 19: Participants' General Virtual Course Attainment

the course. This suggests that the workload was appropriate for covering all the learning content in a course that was originally designed for 5 notional hours per week.

In summary, the experiences after evaluating the course content (Section 5.3.3) validated the hypothesis (**Ho.c**), ensuring that the proposed VLE provided the potential students with a rewarding learning experience. This was achieved through a comprehensive evaluation of the course navigation, sentiment analysis of the reactions when interacting with the learning content, and learning tests to measure the students' attainment at the end of the course.

7 Conclusion and Future Work

Implementing a Virtual Learning Environment (VLE) to teach cybersecurity to Spanish-speaking children, parents, and teachers presents significant challenges. Topics such as grooming, sexting, and cyberbullying are sensitive and complex, making it difficult to discuss them without potentially exposing the audience to traumatic situations or uncomfortable memories. This research builds upon our previous work [1, 8] by enhancing our cybersecurity course using a *5-phase Scrum-based methodology*. This approach enables rapid development, deployment, and publication of high-quality learning content. Our expanded work includes evaluating the VLE's performance, usability, and course content to demonstrate that our methodology effectively delivers a virtual course with acceptable performance, minor usability issues, and a rewarding learning experience.

In the proposed methodology detailed in Section 4, Scrum is integrated with ADDIE, DPIPE, and UDL to facilitate the agile development of learning content while aligning with the course structure and learning objectives. Our methodology successfully meets the technical and educational goals of the course, despite the complexity of teaching cybersecurity to diverse audiences. The use of Scrum allowed us to enhance existing materials, including 3D anthropomorphic characters in stories, games, and videos, which helps minimize the risk of triggering traumatic memories and ensures a positive learning experience. Although the team was relatively small (10-16 members), each member contributed at least 25 hours per week, allowing us to complete critical tasks such as content creation, audiovisual production, and publication efficiently by balancing the workload among storytelling, production, and interactive teams.

The *functional and non-functional tests* presented in Section 5.3.1 demonstrate that Moodle can be configured for an interactive learning experience without compromising performance or missing essential learning requirements. Functional test results, shown in Figure 3, confirm the proper functionality of both the VLE and the Learning Management System (LMS). Most scenarios tested with Cypress and Testim.io yielded successful outcomes, although two scenarios in Cypress failed due to access restrictions to certain Moodle features. In contrast, Testim.io's AI-driven automated tests offered an advantage by testing Moodle features in a black-box mode. Non-functional tests, including load tests depicted in Figure 4, showed that scenarios executed in JMeter achieved a success rate of approximately 79 percent, with an error rate of 24.35 percent. Stress test results in Table 4 indicated that the current hardware configuration supports optimal performance with fewer than 100 students but may struggle with high concurrency nearing 3000 users per minute.

For assessing usability (Section 5.3.2), we combined SUS and Nielsen methods to bridge expert evaluations with user-centric perspectives. This combination created a comprehensive framework for evaluating usability across different dimensions, providing insights into user experiences in digital environments. Our VLE achieved acceptable usability scores with minor design issues, as illustrated in Figure 15.

In terms of *sentiment analysis*, we employed AHP and the WEBLEI framework to understand users' emotional reactions to the learning content. We found strong negative correlations between neutral responses and various emotions, such as happiness, sadness, anger, fear, disgust, and surprise. This indicates that higher neutrality in responses is associated with a decrease in specific emotions and vice versa. The nuanced relationship between different emotions suggests potential areas for improving content to enhance emotional engagement and prevent negative experiences during learning. This is particularly relevant in cybersecurity education, where ensuring a positive emotional experience is crucial to avoid triggering traumatic memories.

Regarding the *learning experience*, navigation tests showed that the course interface is intuitive, with users completing tasks within reasonable timeframes. Some tasks were completed close to the estimated times, suggesting that users may need additional familiarization with the interface's iconographical features and interactive plugins. A sample of 24 participants from a primary school in Quito, Ecuador, used home broadband connections, predominantly between 50 and 100 Mbps, with a few participants on slower connections. Most participants used laptops and PCs, which likely provided a better learning experience compared to mobile devices. Despite this, the course demonstrated significant improvement in participants' understanding of cybersecurity concepts (Figure 19a). The allocation of 2 to 4 notional hours per week, as shown in Figure 19b, aligns well with the course's design for 5 notional hours per week, indicating that the workload was appropriate.

Wrapping up, this research highlights the benefits of deploying a VLE with an agile approach supported by thorough evaluation of technical and educational aspects. Our VLE, tailored for Spanish-speaking children, parents, and teachers, ensures effective knowledge transfer and an engaging educational experience. However, there are limitations in our current research such as the need of an approach for tackling ethical aspects and their implications for data protection, and including younger participants in usability testing. These are important aspects that will be considered in future work when redesigning the learning content based on the results presented in this article.

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