Developing an Adaptive Virtual Learning Environment for Sustainable Learning in Individuals with Down Syndrome

Abstract

This study focuses on the design and technological development of a virtual learning environment tailored to instruct students with Down Syndrome in sustainability concepts. The system grants students access to free software designed for teaching fundamental principles related to environmental awareness, recycling, and sustainable construction. The platform's creation is underpinned by Fogg's Persuasive Technology methodology, emphasizing the acquisition of new competencies through technology to promote sustained engagement with novel technology habits, thereby facilitating a seamless integration into the learning process. The study utilized a phased approach: content adaptation, technological development, and usability evaluation. It emphasized collaboration with stakeholders, including Down Syndrome associations and academic institutions. Recommendations include adherence to universal design principles and further research on the platform's impact. The platform's usability was assessed in terms of simplicity, intuitiveness, performance, robustness, and accessibility. Observations revealed that an impressive 91.7% of students derived genuine enjoyment from the learning tool. Feedback from both tutors and professionals indicated that 91.4% found the virtual learning environment to be well-organized, 88.6% regarded the content as suitable and comprehensible, and nearly 80% affirmed its utility for their professional practice.

Keywords Virtual Learning Environment, Sustainability Learning programmes, Intellectual disabilities, Down Syndrome, Adaptive learning technologies, Inclusive education.

1 Introduction

The study addresses a crucial area of educational inclusivity and accessibility by focusing on the design and technological development of a virtual learning environment tailored specifically for students with Down Syndrome. Down Syndrome is a genetic condition associated with intellectual disabilities, and providing tailored educational resources is essential for their holistic development. The context of the problem lies in the need to effectively teach sustainability concepts to this demographic, a vital aspect of modern education given the increasing global focus on environmental awareness, recycling, and sustainable practices. Traditional teaching methods may not always cater to the unique learning styles and needs of students with Down Syndrome, necessitating innovative approaches like virtual learning environments. Thus, the study aims to bridge this gap by leveraging technology to create an engaging and accessible platform for teaching sustainability principles. By employing Fogg's Persuasive Technology methodology, the platform not only delivers educational content but also fosters sustained engagement and habit formation, enhancing the integration of technology into the learning process for these students. At the United Nations Sustainable Development Summit in New York (UNITED NATIONS, 2022) held in September 2015, Member States formally adopted the 2030 Agenda for Sustainable Development. The agenda contains 17 goals, including a new global education goal (SDG 4). SDG 4 seeks to ensure inclusive and equitable quality education and to promote lifelong learning opportunities for all and contains seven targets and three means of implementation (UNESCO, 2022). This SDG requires action addressing people's education, with the ultimate goal being to establish new educational references that contribute to people's inclusion in society. Economic growth, social welfare and environmental protection must be built and implemented from the structure and organisation of education systems (Dang et al., 2019). In this context, the pillar of an inclusive society is playing an increasingly important role, as it entails recognising the needs of all groups who may have some kind of difference –such as those with disabilities– and the deployment of the resources needed to respond to them (Hermann & Bossle, 2020).

Currently, there is a lack of coherent measures and curricula across the European Union for people with Down Syndrome (DS) and intellectual disabilities, and training programmes are often insufficient, as they are limited by the number of teachers available to cater for these students (Holmgren, 2022). As a result, students with Down Syndrome are often relegated to basic vocational training programmes for early inclusion in the labour market. There are two skills in which children with Down Syndrome excel: visuospatial memory and tactile or kinaesthetic learning. Yet their limited motor and visual skills, together with the cognitive and perceptual characteristics associated with this type of disability, pose a challenge in terms of developing specific technologies for this group

(Shahid et al., 2022). The literature review (LR) delves into existing research and initiatives concerning the development and implementation of virtual learning environments tailored specifically for individuals with Down Syndrome. This encompasses studies on technology use in education for people with disabilities, examples of VLEs designed for this demographic, and strategies for adapting content and interface design to meet their learning needs. Digital didactics –through the use of information and communication technologies (ICTs) in educational environments for people with disabilities– is a valuable resource (dos Santos Dourado et al., 2019). It facilitates perceptual aspects through multimedia resources and generates complementary links to traditional teaching spaces, thereby contributing to accessibility, learning, and social inclusion (de Menezes et al., 2020; Olakanmi et al., 2020). ICTs are tools for creative use that improve the development of the skills and abilities of people with intellectual disabilities. They can also offer a valuable pedagogical element to improve the learning process of students with intellectual disabilities (Sánchez Montoya, 2008; Ok & Rao, 2019).

Several researchers have put into practice the use of ICTs in learning environments for people with intellectual disabilities. Prominent among these learning environments are those focused on people with Down Syndrome, such as the research project "YO LO SÉ!", which has developed a web application with HTML5 technologies for young people with Down Syndrome to learn mathematics, language, social sciences, and natural sciences (Navarrete Mendieta et al., 2020). The project "Diversidade e Inclusão EDI TIC" has developed a game-based application geared towards the teaching and learning process of young and adult students with Down Syndrome (16-34 years old) and seeks to enhance their perceptual, behavioural and competence skills (Moreira et al., 2017). The application was designed and developed to facilitate the teaching of basic mathematical operations to people with Down Syndrome. The research is supported by a descriptive design and a quasi-experimental implementation aimed at testing how the application can impact the teaching of mathematics to people with support needs. In most studies, technology has been shown to be mainly geared towards "Ability support for DS". The support required for this group of people is subscribed to five different areas: social, physical, health, cognitive, and autonomy. In the social domain, skills in communicating emotions and socialising need to be improved. Students must exercise their fine motor skills, multi-touch gestures and coordination in general (physical support). Support in terms of a careful diet (health) is essential as is the search for independence in order to develop daily living skills (autonomy). Another key area involves strengthening visual and hearing skills, memory and literacy (cognitive area) (Banta Lavenex & Lavenex, 2021).

Some initiatives funded by the European Commission, such as the (POSEIDON) (Engler & Schulze, 2017), are designed to improve the capabilities of people with Down Syndrome in different areas –particularly, autonomy (money management and mobility) and time management. These new learning environments are personalised in order to allow educators to manage different types of learning at the same time, with all that this implies, with the same activity proving able to help learners improve an array of different skills (Augusto et al., 2013; Engler & Schulze, 2017;Kramer et al., 201; Rus & Braun, 2016).

Assistive Technology (AT) is the basis of a technology called Casa+, which is designed to support adults with Down Syndrome in their quest for daily autonomy (Alesii et al., 2013; Franchi et al., 2016). The authorities in the Italian region of Liguria have also funded an AT-based project –Smart Angel– aimed at subjects of all ages (adolescents, young people and adults). It enables urban mobility through learning based on simple games that improve orientation skills (Bottino et al., 2015; Costa et al., 2015; Freina et al., 2015).

The DS-AGEING project is committed to training people with Down Syndrome in the use of ICT tools that favour active ageing. Through an innovative training programme, this project aims to increase the competences (attitudes, skills, knowledge) of people with Down Syndrome who are over 30 years old, as well as professionals and families (Zăvăleanu et al., 2019).

Like the previous initiatives, the "SUSKIDS" Project "SUSKIDS" 2018-ES01-KA201-050639 (*SUSKIDS - Enabling Professionals and Families to Transfer SUstainable Knowledge and SKills to Down Syndrome Individuals*, n.d.), co-funded by the Erasmus+ Programme of the European Union, seeks to promote the development of knowledge and skills in students with Down's Syndrome, in this case in environmental sustainability. Its main objective is to transfer knowledge and skills related to the environment, sustainability, and recycling in the field of construction, in order to broaden the curriculum and competencies of these individuals, favoring their future integration into the job market and their even more active participation in society. Thus, through a digital environment adapted to the characteristics of the target students, it aims to provide them with

training on specific subjects related to sustainability, while also educating them on the use of ICT as a source of knowledge and personal enrichment.

Subsequently, the LR examines research on usability evaluation methods and frameworks, especially within the realm of educational technology for individuals with special needs. It also encompasses studies exploring the perspectives and feedback of experts, practitioners, and educators on the usability and effectiveness of virtual learning environments for students with Down Syndrome or other disabilities.

As for research on user satisfaction assessment in educational technology, with a particular focus on methodologies for gathering and analyzing feedback from students with disabilities, some references have been found on investigating the impact of thematic content and user experience on the overall satisfaction and engagement of students with other disabilities. A study examined the use of virtual reality (VR) technology for assessment and treatment of autism spectrum disorder (ASD), particularly focusing on its applications in educational and interventional contexts (Zhang et al., 2022). Other study explored the current and desired use of web search, particularly for health information, by adults with intellectual disabilities. The study surveyed 39 participants from supported employment or day centers in Australia using structured interviews, and the responses were analyzed through thematic analysis. The findings highlight participants' interests in daily health information, their approaches to finding information, and their expectations for self-sufficiency (Kuruppu et al., 2023). Other authors described a project involving augmented reality (AR)-based rehabilitation as a teaching tool for simulating daily activities for autistic children. The aim is to observe the children's performance in terms of concentration, attention, and identification using AR technology (Abdullah et al., 2024). Regarding research on user satisfaction assessment in educational technology, particularly focusing on methodologies for gathering and analyzing feedback from students with Down Syndrome, no references have been found.

This paper presents the results obtained in the design phase of a virtual learning tool carried out within the Project. The tool has been adapted to young people with Down´s Syndrome and to different competences (Level I and Level II of the European Qualifications Framework (EQF)). SUSKIDS uses a psychological approach, which involves acquiring new habits through game-based learning and self-involvement in the specific field of media and construction, through contents related to recycling and sustainable construction and through the use of information and communication technologies (ICTs).

Based on the aforementioned studies, the research questions posed in this work were:

RQ1. How can a Virtual Learning Environment Platform (VLE) adapted to learners with Down Syndrome such as the SUSKIDS VLE be created?

RQ2. How does the opinion of expert technologists, practitioners and educators of students with special needs on the usability of the SUSKIDS VLE help the development of this platform?

RQ3. How does a group of students´ perceived satisfaction with the thematic content and the VLE help the development of the platform?

2 Methodology

The method used to develop the e-learning platform, consisted of the following three phases. At the beginning the adaptation of the content to the target group and the definition of the technological approach were carried out. Then, the technological development of the platform was made including the universal design principles (RQ1). The evaluation of the platform during its development was carried out through statistical analysis in terms of its simplicity, intuitiveness, performance, robustness, and accessibility by tutors and professionals (RQ2), and in terms of satisfaction of a group of users (RQ3) to improvement the SUSKIDS platform.

The study employed a multi-phase approach, which included the adaptation of content and technology to the target group, the technological development of the SUSKIDS Virtual Learning Platform, and the evaluation of the platform's usability by students with Down Syndrome and professionals. Convenience non-probabilistic sampling was utilized to select 60 students from different Down Syndrome associations in Spain, along with 34 professionals, creating a cognitively homogenous group of students with ages ranging from 27 to 44 years. Data was collected through anonymous questionnaires hosted on the SUSKIDS platform, including closed and open-ended questions. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of the University of Burgos. Data analysis involved descriptive analysis,

transformation of variables, creation of indicators, and statistical tests such as Shapiro-Wilk, Kolmogorov-Smirnov, Chi-square tests, and Kruskal-Wallis test, performed using IBM SPSS software version 25. The duration of the study was the 2022-23 academic year.

Reliability: After applying Cronbach's alpha, a value of 0.78 was obtained, indicating that the questionnaire enjoys acceptable internal consistency.

Sampling: Convenience non-probabilistic sampling was employed, selecting users from different associations.

Phase 1. Adapting content and technology to the target group

The various actors involved in the project worked jointly to create the tool. The adaptation of the technical content to those with Down Syndrome work was carried out in conjunction with the Burgos Down Syndrome Association and the research team in Building Engineering at the University of Burgos (Spain), the Department of Civil Engineering at Trinity College, Dublin (Ireland) and the technology company "Bjäland".

In order to adapt the technology and create an EVE adapted to the needs of students with DS, the principles of universal design (Centre for Excellence in Universal Design [CEUD], n.d.) were taken into account, as well as the ten heuristics of usability in interfaces by Nielsen (1994). In terms of digital didactics, this project took as a reference the Technological Pedagogical Content Knowledge (TPACK) model shown in Figure 1 (Anderson & Putman, 2020; Liu et al., 2019; Mishra & Koehler, 2006; Mishra et al., 2011) and considered Stanford University professor and researcher BJ Fogg's proposal of his method for developing new technological tools aimed at eliciting behavioural design to adopt new habits and behaviours through the use of technology (Fogg, 2009).

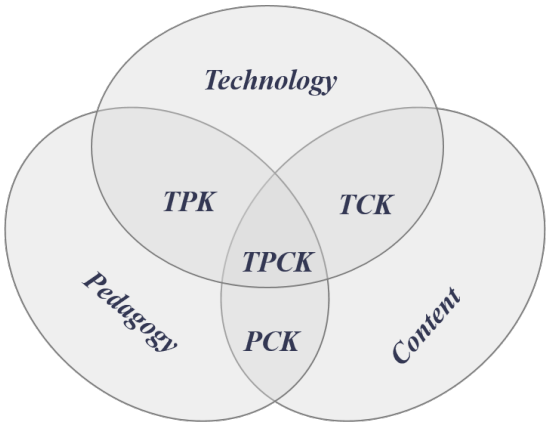

Fig. 1 Technological Pedagogical Content Knowledge.'Source: Author's own creation'

In creating the VLE, special attention was paid to the following aspects in an effort to maximise learning outcomes. The recommendations are based on van Hooste & Maes (2008):

• **Minimise the quality of information**: individuals with DS can easily get distracted. Moreover, broadly speaking, individuals with DS are unable to focus their attention for as much time. This platform was therefore designed to keep students interested as well as focused on the task allocated to them, thereby speeding up their learning (Rodrigues et al., 2019) .

• **Importance of visual information**: verbal knowledge may often be restricted owing to unhurried verbal development (brought about by limited audio memory capacity and/or hearing difficulties) (Toffalini et al., 2018). It is thus important for words and verbal instructions to be backed up by visual information. Auditory support of written information does not prove as effective visual support. Visual support should be given preference over verbal support.

• **Repeat & repeat**: individuals with DS need more time to learn and to internalize skills (Meneghetti et al., 2020), such that much repetition is needed. Exercises should be repeated over time so as to ensure that lessons have truly been learnt, and repetition must be spread throughout the whole programme. The learning effect (of memorizing and generalising) can be boosted.

• **Many varieties on the same exercises**: individuals with DS tend to generalise less the skills and information they learn. Generalisations can be enhanced by repeating the same type of exercise in different contexts (i.e.,

sorting out waste in the kitchen, in class, in public spaces). Exercises not only need to be repeated over time; the contexts of the exercises should also be varied in these repetitions.

• **Exercises need to be built on pupils' existing knowledge** so as to take full advantage of the learning outcomes.

• **Attention to the student's learning process.** A student's learning capacity is influenced by their mood. Experiencing success before new skills and lessons are provided might boost the learning process. This might be accomplished by allowing the pupil to do an exercise they are already familiar with or by playing a game prior to the start of the lesson. Teachers should always be in a position to choose the levels of any exercises so that they can be adapted to the pupil's own level.

• **Sufficient time to respond**: the reaction times of those with DS may be longer. The stress triggered by time pressure should be averted.

• **Support analysing and structuring**: the analytical and structuring skills of those with DS are often less developed. When sorting out exercises, special attention needs to be provided in supporting these skills (i.e., things I can eat are organic, I can eat a banana; therefore, a banana is organic).

• **Strong link between the VLE and reality**: abstraction often proves difficult for those with DS. It is therefore important to provide examples, exercises etc. that resemble their world and context as closely as possible.

• **Teacher/caregiver control:** those with DS often employ a trial-and-error technique when they don't know how to tackle the exercise. In such instances, the VLE needs to inform the teacher so that help can be provided and the lesson/exercise explained again. Should there be any changes in the results of the exercises, teachers/caregivers should be informed: should the results be worse, the teacher may reduce the level of the exercises or explain the lesson again so as to avoid failure (which may diminish motivation and learning outcomes). Should the results improve, the level may then be raised, for example.

Firstly, the minimum requirements needed for the students to access and use the tool were established, as were the general content lines to be included therein, considering the characteristics of the target group. Subsequently, the content format and types of activities, their sequencing, as well as the points and rewards programme were agreed on, together with various inputs related to the enhancers, error markers, time control, and so on, to be included in the platform structure. Once the platform structure had been put together, the texts and activities were written and the videos were recorded to illustrate the content. Throughout the whole process, constant communication was maintained, generating continuous feedback, which helped to ensure that common standards and criteria were applied (Figure 2).

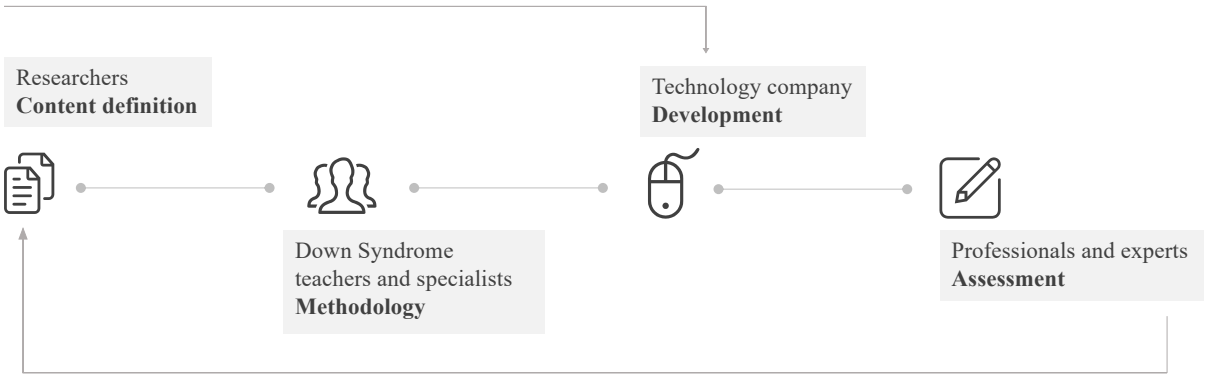

Fig. 2 Actors involved in the SUSKIDS VLE development 'Source: Author's own creation'

Phase 2. Technological development of the SUSKIDS Virtual Learning Platform

VLE Technical Details

Content Management System

The content management system (CMS) employed in this VLE is WordPress. WordPress is open-source publishing software which may be locally installed on a webserver and then viewed on a proprietary website or hosted in the cloud as well as viewed on the WordPress website.

Database

The WordPress database is a MySQL database which stores website data in tables, rows and columns. The WordPress database is dynamic, such that the information contained therein can be added, modified and deleted.

Code Language

Furthermore, the following are used to create the VLE contents and visualizations:

- PHP: a widely-used open-source general-purpose scripting language that proves particularly appropriate for web development and which may be embedded into HTML.
- JAVASCRIPT using jQuery framework. JavaScript is a scripting or programming language which enables users to execute complex features on webpages. jQuery is a fast, small, and feature-rich JavaScript library that simplifies things such as HTML document traversal and manipulation, event handling, animation, and Ajax as a result of an easy-to-use API which functions across a wide array of browsers.
- HTML: a standard markup language for creating webpages. It enables sections, paragraphs, and links to be created and structured using HTML elements (the building blocks of a webpage) such as tags and attributes.
- CSS CODE: the code which styles web content.

The VLE is developed under the WordPress framework using the above-mentioned mentioned language programme systems.

Plugins

After that, several plugins are used to incorporate the requirements and functionalities needed to create the course. There are two types:

- General plugins: plugins previously created for any user of WordPress that are installed (cookies, legal aspects…)
- Specialized plugins: plugins made to custom development for every course.

These specialized plugins are the main differential character of a VLE. Some of the plugins developed are:

- Learning activities: quiz test, matching images and sentences, crosswords, ranking levels, true or false.
- Statistical tools: time used in every lesson, number of log ins, time dedicated to doing the activities.
- Collaborative tools: advanced users can help other users who are lost.
- Certificate tools: at the end, users receive a certificate with their picture.

Database structure

Figure 3 shows the database structure from WordPress that is used.

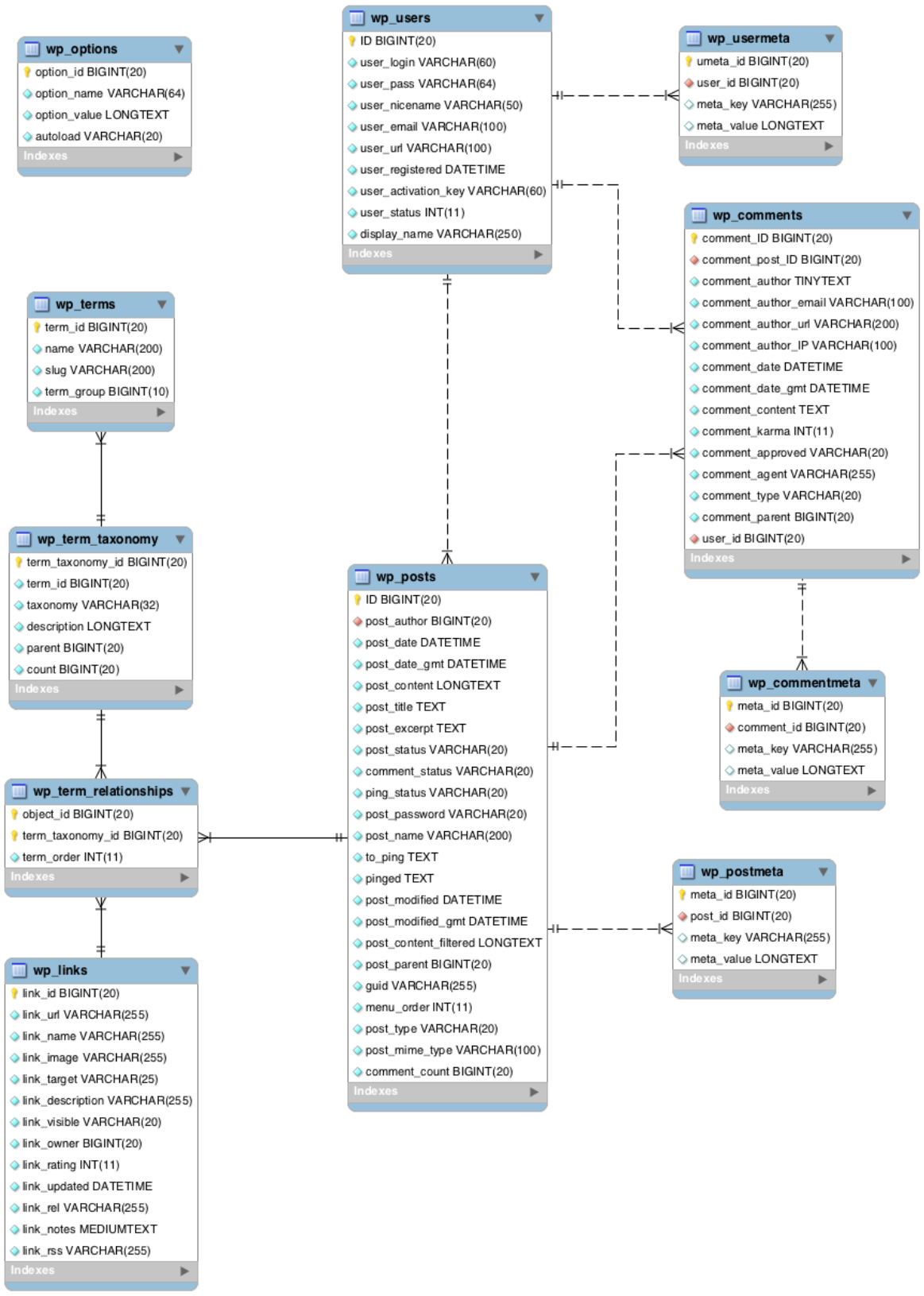

Fig. 3 Database structure from WordPress. 'Source: Author's own creation'

VLE Structure

The VLE has been designed in line with the pyramidal structure shown in Figure 4.

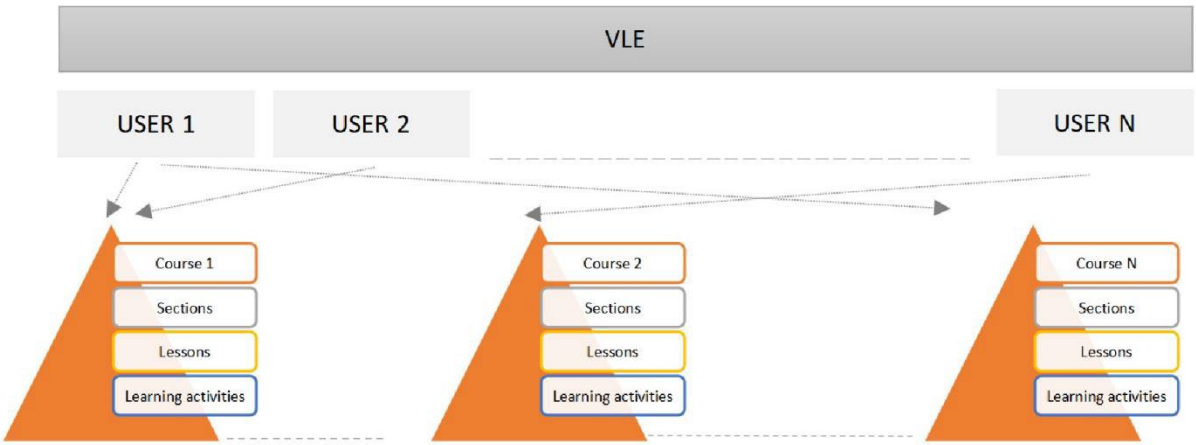

Fig. 1 Structure of the VLE design. 'Source: Created by author'

- COURSE includes significant information about the main aspects of the course: dates (start and end), limited duration, data from students, tutors, facilitators, keywords, Search Engine Optimization (SEO) aspects.

- SECTIONS and LESSONS contain the information, activities and ways of learning the knowledge we are developing. Platform content management capabilities allow any course configuration with the corresponding number of lessons and sections.

VLE Roles or profiles

There are different roles for every user:

- Administrator or Tutor: the functions of an administrator are to manage, administer and organise the workshops or courses to be taught. There is also the option of configuring a virtual environment that arouses the participant's curiosity to learn.

- Facilitator: the facilitator is a participant who has already completed the course. Their main function is to encourage other future course participants to successfully complete the course, motivating them with their own experience. This role has the option of sending different pre-set texts through the platform, such as "well done", "keep it up", etc. Facilitator can choose a message and send it directly on the platform in order to encourage the participant to continue with the course (Figure 2).

- Participant: their main function is to be eager to learn in an adapted and motivational environment.

Phase 3. Usability of the VLE by students with Down Syndrome and professionals. Statistical analysis

The sample consists of a total of 60 students from different Down Syndrome associations in Spain (Cantabria, Burgos, and Salamanca). The sample was selected to create a cognitively homogenous group (moderate) with ages ranging from 27 to 44 years.

Likewise, 34 professionals –such as educators and technologists– reviewed the usability of the VLE. This review was aimed at pinpointing the platform's possible strengths and weaknesses, with the ultimate goal of providing feedback to the developers in order to improve the tool.

The SUSKIDS VLE was evaluated using an anonymous questionnaire created ad hoc for each of the groups. The evaluation of the platform was carried out through statistical analysis in terms of its simplicity, intuitiveness, performance, robustness, and accessibility by tutors and professionals and in terms of student satisfaction.

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of the University of Burgos (protocol code No. IO 10/2022) for studies involving humans.Two surveys were developed and are hosted on the SUSKIDS platform itself. *SUSKIDS VLE:* open access https://suskids.bjaland.co/en/courses/. One was a questionnaire for professionals (educators, teachers, researchers, and technologists). This survey was made up of 30 items, of which 13 were closed responses on a five-point

Likert-type scale, six were closed responses on a dichotomous scale, and eight were open questions. The survey for the students was made up of 16 items. Of these, 14 were closed responses on a three-point Likert-type scale, and two were open response.

Firstly, a descriptive analysis was carried out, followed by a transformation of the variables for the professionals' questionnaire, creating three indicators: the first, derived from the average of the scores of the content items; the second, using the average of the scores of the items referring to design; and the third, by taking the average of the two previous scores. For the user survey, five indicators were created: the first, using the average of the items referring to clarity; the second, with the averages of the items asking about content; the third, with the average of the accessibility items; the fourth calculated with the average of the items concerning the appearance of the platform; and finally, to calculate the fifth indicator, the average of the previous four indicators was used to obtain a total score (indicators were also created taking into account the total scores). Shapiro-Wilk (N<50) and Kolmogorov-Smirnov (N>50) tests were used to check the normality of the indicators. As for the analysis techniques applied, Chi-square tests were carried out to determine whether there was a relationship between categorical variables. In addition, the Kruskal-Wallis test was used for comparisons with regard to the indicators of the user satisfaction surveys. Analyses were performed with the statistical package SPSS v.28 (IBM, 2022).

~~For the statiscal analysis, IBM SPSS software version 25 was used~~

3 Results and Discussion

Phase 1. Adapting content and technology to the target group (RQ1)

The following characteristics have been taken into account when developing the contents and activities included in VLE:

Content design

- Contents need to be useful, functional, and close to students. They should also have a "usage value".
- Experimental, so they may be manipulated or experienced.
- Applicable to a range of situations and contexts; they should be generalizable.
- They should allow for the contents learnt to be applied in future.
- Contents must introduce cross-cutting contents such as time control and the euro.

Figure 5 shows the courses included in the VLE.

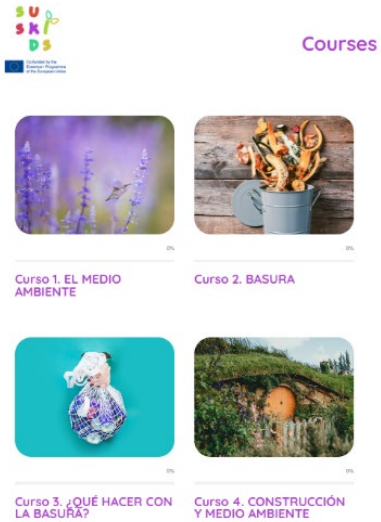

Fig. 5 Screenshot of VLE courses 'Source: Created by author'

Activities design

- Activities need to be simple, easily understandable, clear and should involve short messages.
- Large input of visual stimuli: photos, pictures, etc.
- Activities need to be presented sequentially and split into easy steps.
- Short tips or hints need to be provided in order to foster participant success.

- “Learning to think” and “learning to learn” must be encouraged.
- Autonomy should be promoted.

Figure 6 shows one of the several activities that the VLE offers.

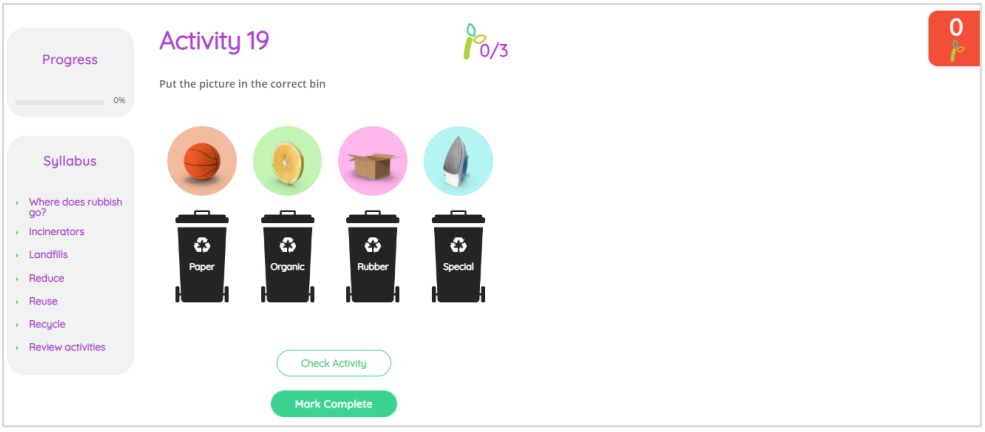

Fig. 6 Screenshot of the VLE design. 'Source: Created by author'

Phase 2. Development of the Virtual Learning Platform VLE-SUSKIDS (RQ2)

The process of implementing the recommendations on content and activity design and the choice of digital technology design and structure has resulted in an open access Virtual Learning Environment (SUSKIDS VLE) for students with Down's syndrome. https://suskids.bjaland.co/en/courses/

The course includes information on general aspects such as starting date, contact details of students, responsible tutor or reference centre. See figure 7.

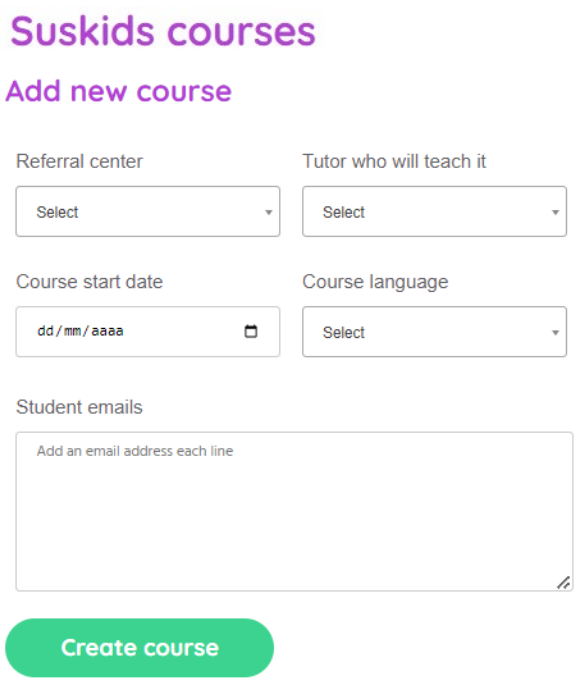

Fig. 7 Screenshot of the VLE new course. 'Source: Created by author'

Each course consists of a certain number of lessons (see figure 8). A lesson is a full page of content. Lessons can be grouped in order to have an intermediate structure of content that would be the sections. Each content page is created with independent text, image and activity modules.

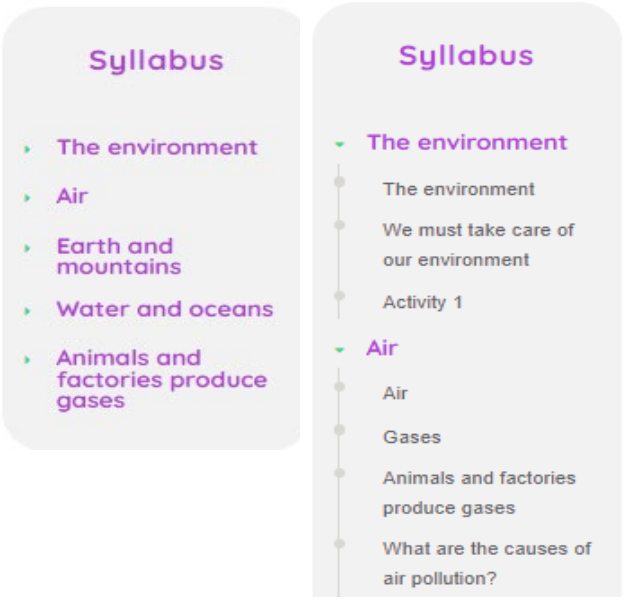

Fig. 8 Screenshot of the syllabus of the course "The environment" . 'Source: Created by author'

Phase 3. Usability of the VLE by students with Down Syndrome and professionals. Statistical analysis (RQ2-RQ3)

The surveys carried out amongst the professionals provided us with insight into their opinion concerning various aspects related to functionality, adaptation and suitability to the target group. Broadly speaking, the professionals rated the platform very highly. As can be seen in Table 1, the score awarded to the platform was above 4 (M=4.17, SD=0.61). The content was rated more highly than the design (Xcontent=4.14 vs Xdesign=3.95).

Table 1 Descriptive statistics in the professionals' questionnaire. *'Source: Author's own creation'*

Items	M (SD)	%
Opinion concerning the content of the VLE: it is organised clearly	4.31 (0.63)	91.4
Opinion concerning the content of the VLE: it is comprehensive	4.23 (0.64)	88.6
Opinion concerning the content of the VLE: it is understandable	4.11 (0.75)	88.6
Opinion concerning the content of the VLE: it is adapted to the level of the target group	3.46 (1.12)	54.3
Opinion concerning the content of the VLE: the information is useful and valuable	4.46 (0.50)	100
Opinion concerning the content of the VLE: the learning objectives are related	4.29 (0.75)	88.6
To what degree is the platform useful for your professional practice?	4.04 (0.93)	80.0
Do you think the platform has an immediate use for your professional practice?	1.21 (0.41)	79.2
Do you think the platform can be used by other different groups?	1.03 (0.16)	97.1
Do you think that persons with problems of accessibility (hearing, motor disability, etc.) will not have problems or difficulties with the platform?	1.55 (0.50)	54.8
Opinion concerning the design of the VLE: it seems fun	4.06 (0.87)	65.7
Opinion concerning the design of the VLE: it is uncomplicated	4.03 (0.84)	78.8
Opinion concerning the design of the VLE: similar words, actions, and exercises are used and tie in so as to function as a whole	4.00 (0.79)	75.8
Opinion concerning the design of the VLE: the structure is sufficiently clear	3.94 (0.99)	78.8
Opinion concerning the design of the VLE: I find the platform self-explanatory or intuitive	3.76 (1.06)	66.7

Did you have technical problems using the platform?	1.71 (0.42)	28.6
If you answered YES, was it easy to deal with the problem?	1.11 (0.33)	88.9
If you answered YES, did you report the problem?	1.38 (0.51)	62.5
Score for the platform	4.17 (0.61)	-
Score for the overall content	4.14 (0.53)	-
Score for the overall design	3.95 (0.67)	-
Overall score	4.05 (0.56)	-

* *M* = Mean; *SD* = Standard deviation; *%* = percentage.

In light of the results shown in Figure 9, it can be seen that 88.6% of the professionals consider the platform content to be comprehensive (M=4.23, SD=0.64), understandable (M=4.11, SD=0.75) and closely linked to the objectives (M=4.29, SD=0.75), while 91.4% (M=4.31, SD=0.63) also feel that it is clearly organised. The information was deemed to be useful and valuable by 100% (M=4.46, SD=0.50) of those surveyed, although only 54.3% (M=3.46, SD=1.12) considered the content to be suited to the target group. Some of the reasons why 45.7% of the professionals did not feel that the content was suited were, for example, that some of the activities seemed complex, the vocabulary was abstract and not fully understandable, the activities were geared towards persons with a high level of Down Syndrome (level two students on the European reference framework), but not apt for all those with Down Syndrome, such that some users might need constant support.

Another aspect worth highlighting concerns accessibility, given that 54.8% (M=1.55, SD=0.50) of participants considered that persons with hearing, motor or visual disabilities and so on, might not have difficulties with the platform. (See Table 1).

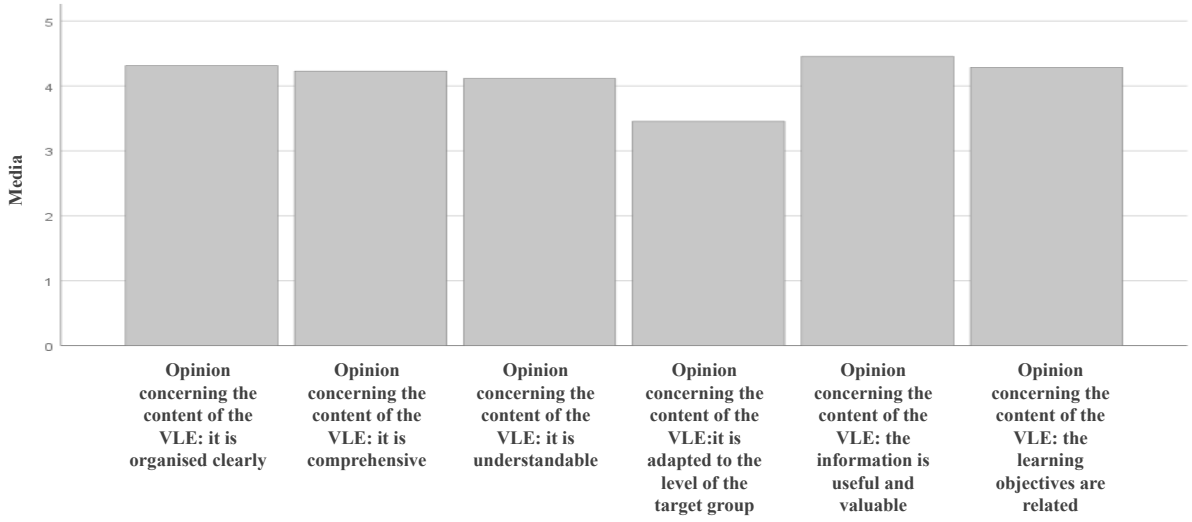

Fig. 9 Results of the mean score awarded in the overall opinion of professionals concerning the VLE content. 'Source: Author's own creation'

When asked about the platform's utility, 80% (M=4.04, SD=0.93) felt that it would prove useful to their professional practice and 79.2% (M=1.21, SD=0.41) considered that this utility would be immediate. Moreover, 97.1% (M=1.03, SD=0.16) of those surveyed thought that the platform could be used by groups other than Down Syndrome students. (See table 1).

The mean scores reflecting the overall opinion of professionals regarding the VLE content reveal the platform's notable strengths in terms of content comprehensiveness, organization, and perceived utility. However, they also shed light on areas for potential enhancement, notably in ensuring better alignment of content with the target group and addressing accessibility concerns.

The figure 10 shows that the design was thought to be fun by 65.7% (M=4.06, SD=0.87), uncomplicated by 78.8% (M=4.03, SD=0.84), while 78.8% (M=3.94, SD=0.99) deemed the structure to be clear, and 66.7% (M=3.76, SD=1.06) intuitive. Of those surveyed, 75.8% (M=4.00, SD=0.79) believed the words, actions and exercises combined well to function as a whole.

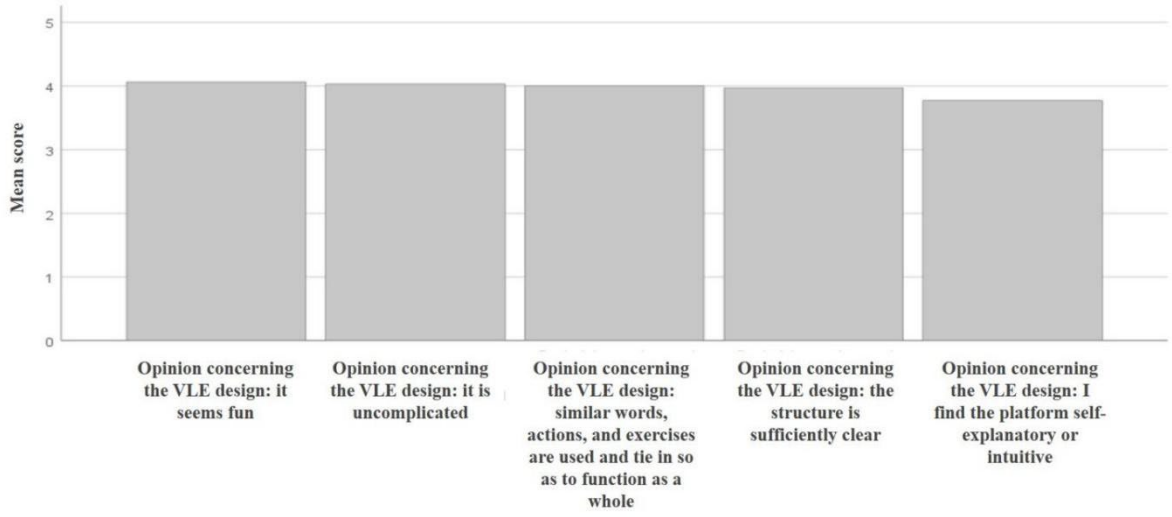

Fig. 10 Results of the mean score awarded in the overall opinion of professionals concerning the VLE design. 'Source: Author's own creation'

When interacting with the platform, 68.6% of the professionals experienced some difficulty related to accessibility, the size of the texts, legibility and the characteristics and mechanics of the activities. Likewise, 28.6% (M=1.71, SD=0.42) experienced some technical problem, although 88.9% (M=1.11, SD=0.33) of these were able to find a clear solution to the problem. Only 62.5% (M=1.38, SD=0.51) of the problems were reported. (See table 1). These findings highlight both the positive aspects of the platform's design and functionality, as well as areas requiring improvement, particularly in addressing accessibility challenges and technical issues to enhance user experience and satisfaction.

Perceived user satisfaction (RQ3) shows how users awarded a higher overall score to content and appearance than to accessibility and clarity, as can be seen in Table 2 and Figure11. (Xcontent=1.77, Xappearance=1.65 vs Xaccessibility=1.49, Xclarity=1.62). Of those surveyed, 66.7% felt that they had understood everything, 70% thought the activities had been clear, 61.7% found the exercises easy, 85% of users liked the exercises, 81.7% stated that they would have liked to have learnt more about the topic, 78.3% found it easy to work in the platform, 73.3% considered it was easy to stop an exercise, 75% stated it was easy to change to another exercise, 91.7% thought the virtual platform was attractive, 83.3% considered it to be clear, 35% would like to change the appearance of the platform, and 30% found errors in the platform. Overall, these findings provide valuable insights into user perceptions and satisfaction, highlighting both positive aspects of engagement and areas for potential enhancement to optimize user experience and overall platform effectiveness.

Table 2 Descriptive statistics in the users' survey. *'Source: Author's own creation'*

Items	M (SD)
Did you understand everything?	1.53 (0.81)
Dou you think the activities were clear?	1.67 (0.54)
Did you find the exercises easy?	1.47 (0.74)
Did you like the exercises?	1.83 (0.46)
Would you have liked to have learnt other things about the topic?	1.72 (0.64)

Was it easy for you to work in the platform?	1.72 (0.58)
Was it easy to stop an exercise?	1.65 (0.63)
Was it easy to change to another exercise?	1.65 (0.65)
Was it easy to do another exercise again?	1.75 (0.57)
Is the learning platform clear?	1.83 (0.42)
Did you find the virtual platform attractive?	1.88 (0.41)
Would you like to change the appearance of the platform?	0.78 (0.94)
Did you find any errors in the platform?	0.64 (0.94)
Clarity score	1.62 (0.47)
Content score	1.77 (0.45)
Accessibility score	1.49 (0.41)
Appearance score	1.65 (0.36)
Overall score	1.63 (0.29)

* *M* = Mean; *SD* = Standard deviation.

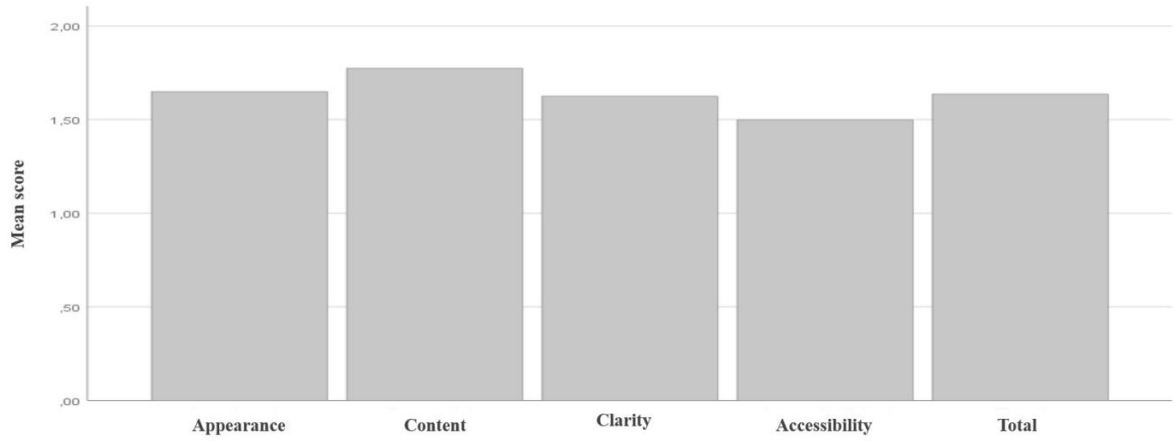

Fig. 11 Results of the mean score awarded in the overall opinion of users concerning the VLE. 'Source: Author's own creation'

In order to test whether or not a negative response to the questions depended on having understood everything, Chi-square tests were carried out using the likelihood ratio for their interpretation, as can be seen in Table 3. Their appraisal of the clarity of the activities, how easy the exercises were, their opinion of the exercises, how easy it was to work on the platform, how easy it was to both stop an exercise and go back to it, as well as the clarity of the platform were found to depend on whether or not they had understood everything ($p<0.05$).

Table 3 Chi-square tests . *'Source: Author's own creation'*

Items	Likelihood ratio	**Sig.**
Do you think the activities were clear?	22.959	0.001
Did you find the exercises easy?	35.779	0.001
Did you like the exercises?	18.148	0.001
Would you have liked to learn more about the topic?	3.343	0.502

Did you find it easy to work in the platform?	32.020	0.001
Was it easy to stop an exercise?	13.009	0.011
Was it easy to change to another exercise?	4.690	0.321
Was it easy to go back to an exercise again?	13.664	0.008
Is the learning platform clear?	16.728	0.002
Do you think the virtual platform was attractive?	3.570	0.624
Would you like to change the appearance of the platform?	2.387	0.303
Did you find any errors in the platform?	6.953	0.033

~~*Sig –~~

Kruskal-Wallis tests were also carried out in order to test whether having understood everything or not influenced the score obtained in each index. In all areas apart from appearance, users awarded a higher score if they had understood everything and a worse score if they had not, as reflected in Table 4.

Table 4 Kruskal-Wallis tests. *'Source: Author's own creation'*

Index	**Kruskal-Wallis** H	**Sig.**
Clarity score	36.724	0.001
Content score	6.818	0.001
Accessibility score	16.460	0.013
Appearance score	0.631	0.081
Overall score	24.753	0.001

~~*Sig –~~

Professionals awarded the VLE an overall score of 4.17 out of 5, and in particular highlighted various aspects such as its straightforward and intuitive design as well as the actual content. For their part, results from the survey conducted amongst users reflected how the latter valued the content and appearance more than the accessibility and clarity. The survey also reflected their satisfaction concerning the use of the platform as a work tool, awarding an average score of 1.72 out of 3, and for the activities an average score of 1.83 out of 3.

4 Conclusions

The SUSKIDS VLE platform represents a significant virtual learning resource offering comprehensive information on various environmental topics, designed to serve as an engaging and educational tool for individuals with Down Syndrome. Its primary aim is to broaden opportunities for this demographic, particularly in the realms of environmental education, employability, and social inclusion, focusing on areas such as construction and recycling. The collaborative efforts of experts in environmental sustainability, construction, recycling, alongside professional educators and technologists, were instrumental in tailoring the platform to meet the specific needs of individuals with Down Syndrome. As a result, we have developed an accessible, intuitive, and navigable VLE that not only enhances students' digital skills but also fosters their understanding and engagement with environmental sustainability and construction through visually rich content and real-life scenarios.

Regarding the platform's usability, feedback from both professionals and users has been overwhelmingly positive, as evidenced by the results obtained from surveys and satisfaction questionnaires. However, the study and data analyses have also highlighted areas for improvement, ranging from technical enhancements to content and activity adaptations to better accommodate a wider range of students with special educational needs. Additionally, the availability of information regarding users' degree of disability would be beneficial in determining the platform's efficacy across various cases.

Recommendations and Future Directions:

We propose several potential areas for improvement and future implementation in educational platforms catering to individuals with Down Syndrome, including the provision of expanded vocabulary levels and support glossaries to enhance content accessibility and comprehension, simplification of content to aid in the understanding of abstract concepts, and review of technical features such as the speed and adaptability of the automatic reader across different devices. Moreover, exploring the broader application of the automatic reader to various activities could further enhance the platform's accessibility and usability.

Looking ahead, a prospective research avenue could involve assessing students' learning outcomes post-VLE usage through a case study approach, incorporating pre-test and post-test measures to gauge knowledge acquisition and retention effectively. Such research endeavors would contribute to ongoing efforts in advancing inclusive educational practices and optimizing learning outcomes for individuals with Down Syndrome within the digital learning landscape.

~~The SUSKIDS-VLE platform is a virtual learning tool that offers information on different topics related to the environment, and which aims to be a didactic and motivating tool for people with Down Syndrome.~~

~~The main objective of the platform is to serve as a tool to increase opportunities for people with Down Syndrome, especially concerning environmental education (construction and recycling), employability and social inclusion.~~

~~In order to adapt this to people with Down Syndrome, the collaborative work of all the actors involved in its development has proved vital; expert researchers in the field of environmental sustainability, construction, recycling, etc., professional educators of those with Down Syndrome and technologists. Thanks to this work, we created an adapted VLE that is easy to access, intuitive and easy to navigate and which not only enables students to develop and enhance their digital skills but also brings them closer to environmental sustainability and construction. The organisation and presentation of the content can allow and encourage student access and independence, offering them visual support, images and videos that are highly representative, which helps with their understanding, thanks to the presentation of everyday situations.~~

~~As regards the platform's usability, it has been found that in general it gained a positive opinion from both professionals and users alike – reflected in the results obtained in the surveys carried out amongst professionals and in the users' satisfaction questionnaires.~~

~~The study and analyses of the data provide information on certain aspects that can be improved. These range from technical improvements to adapting the content and activities so that learning software can reach a wider target group of students with special educational needs. It would also be useful to have information available concerning the degree of user disability in order to determine whether the platform may prove useful in all cases.~~

~~We point to some aspects that could be improved and/or implemented when developing educational platforms for people with Down Syndrome:~~

~~Considering the possibility of offering wider levels of vocabulary and support glossaries so as to facilitate access and understanding of the content presented.~~

~~Considering the possibility of offering more straightforward content so as to help understand and acquire abstract concepts.~~

~~Reviewing possible technical improvements such as the cadence, rhythm and speed for the automatic reader, and its possible adaptation to different devices, etc.~~

~~Broadening the possible use of the automatic reader used to different activities.~~

~~A future line of research could be aimed at measuring students' learning after using the VLE by means of a case study with pre-test and post-test measures of knowledge.~~

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request

References

Abdullah, A.S., Karthikeyan, J., Gomathi, V., Parkavi, R., Rajarajeswari) P. (2024). Enabling Technology Integrated Learning for Autistic Children Using Augmented Reality Based Cognitive Rehabilitation. *SN Computer Science* 5(1),151 (2024)]. http://doi.org/10.1007/s42979-023-02495-5

Alesii, R., Graziosi, F., Marchesani, S., Rinaldi, C., Santic, M., & Tarquini, F. (2013). Short range wireless solutions enabling ambient assisted living to support people affected by the Down syndrome. *Eurocon 2013*, 340–346. https://doi.org/10.1109/EUROCON.2013.6625006

Anderson, S. E., & Putman, R. S. (2020). Special Education Teachers' Experience, Confidence, Beliefs, and Knowledge About Integrating Technology. *Journal of Special Education Technology*, *35*(1), 37–50. https://doi.org/10.1177/0162643419836409

Augusto, J. C., Grimstad, T., Wichert, R., Schulze, E., Braun, A., Rødevand, G. M., & Ridley, V. (2013). *Personalized Smart Environments to Increase Inclusion of People with Down's Syndrome* (pp. 223–228). https://doi.org/10.1007/978-3-319-03647-2_16

Banta Lavenex, P., & Lavenex, P. (2021). A Critical Review of Spatial Abilities in Down and Williams Syndromes: Not All Space Is Created Equal. *Frontiers in Psychiatry*, *12*. https://doi.org/10.3389/fpsyt.2021.669320

Bottino, R. M., Freina, L., Ott, M., & Costa, F. (2015). Cloud-mobile Assistive Technologies for People with Intellectual Impairments. *Proceedings of the 5th International Conference on Digital Health 2015*, 103–104. https://doi.org/10.1145/2750511.2750530

Centre for Excellence in Universal Design (CEUD). (n.d.). *The 7 Principles*. Centre for Excellence in Universal Design. Retrieved February 8, 2023, from https://universaldesign.ie/what-is-universal-design/the-7-principles/

Costa, F., Freina, L., & Ott, M. (2015, March 1). *A cloud computing based instructional scaffold to help people with the down syndrome learn their way in town. INTED. MADRID*.

Dang, Wang, & Van-Thac Dang. (2019). An Integrated Fuzzy AHP and Fuzzy TOPSIS Approach to Assess Sustainable Urban Development in an Emerging Economy. *International Journal of Environmental Research and Public Health*, *16*(16), 2902. https://doi.org/10.3390/ijerph16162902

de Menezes, L. D. C., da Silva, T. D., Capelini, C. M., Tonks, J., Watson, S., de Moraes, Í. A. P., Malheiros, S. R. P., Mustacchi, Z., & Monteiro, C. B. de M. (2020). Can individuals with down syndrome improve their performance after practicing a game on a mobile phone? A new insight study. *Learning and Motivation*, *72*, 101685. https://doi.org/10.1016/j.lmot.2020.101685

dos Santos Dourado, G., Silva, J. A. O. S., di Menezes, A. R. C., Silva, K. C. R., de Souza Hannum, J. S., & de Andrade Barbosa, T. M. G. (2019). An ARSandplay System for People with Down Syndrome. *2019 IEEE MIT Undergraduate Research Technology Conference (URTC)*, 1–4. https://doi.org/10.1109/URTC49097.2019.9660441

Engler, A. & Schulze, E. (2017). POSEIDON - Bringing Assistive Technology to People with Down Syndrome: Results of a Three Year European Project. *Studies in Health Technology and Informatics*, *236*, 169–175. https://doi.org/10.3233/978-1-61499-759-7-169

Fogg, B.J. (2009). A Behavior Model for Persuasive Design. *Persuasive'09: Proceedings of the 4th International Conference on Persuasive Technology*, 40, 1–7. https://doi.org/10.1145/1541948.1541999

Franchi, F., Graziosi, F., Rinaldi, C., & Tarquini, F. (2016). AAL solutions toward cultural heritage enjoyment. *2016 IEEE 27th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, 1–6. https://doi.org/10.1109/PIMRC.2016.7794584

Freina, L., Bottino, R., Ott, M., & Costa, F. (2015). Social Empowerment of Intellectually Impaired through a Cloud Mobile System. *Future Internet*, *7*(4), 429–444. https://doi.org/10.3390/fi7040429

Hermann, R. R., & Bossle, M. B. (2020). Bringing an entrepreneurial focus to sustainability education: A teaching framework based on content analysis. *Journal of Cleaner Production*, *246*, 119038. https://doi.org/10.1016/j.jclepro.2019.119038

Holmgren, M. (2022). Enacting Special Education in a Digitalized School: Opening for New Understandings of a Digitalized Special Educational Practice. *Journal of Special Education Technology*, 016264342211317. https://doi.org/10.1177/01626434221131776

Kramer, D., Covaci, A., & Augusto, J. C. (2015). Developing Navigational Services for People with Down's Syndrome. *2015 International Conference on Intelligent Environments*, 128–131. https://doi.org/10.1109/IE.2015.26

Kuruppu Arachchi, T., Sitbon, L., Zhang, J., Koplick, S., Hoogstrate, M. and Brereton, M. (2023). Web search to access health information by adults with intellectual disability. *Online Information Review,* Vol. 47 No. 6, pp. 1098-1115. https://doi.org/10.1108/OIR-06-2021-0337

Liu, H., Wang, L., & Koehler, M. J. (2019). Exploring the intention-behavior gap in the technology acceptance model: A mixed-methods study in the context of foreign-language teaching in China. *British Journal of Educational Technology*, *50*(5), 2536–2556. https://doi.org/10.1111/bjet.12824

Meneghetti, C., Toffalini, E., Lanfranchi, S., & Carretti, B. (2020). Path Learning in Individuals With Down Syndrome: The Floor Matrix Task and the Role of Individual Visuo-Spatial Measures. *Frontiers in Human Neuroscience*, *14*. https://doi.org/10.3389/fnhum.2020.00107

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record: The Voice of Scholarship in Education*, *108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Mishra, P., Koehler, M. J., & Henriksen, D. (2011). The Seven Trans-Disciplinary Habits of Mind: Extending the TPACK Framework Towards 21st Century Learning. *Educational Technology*, *51*(2), 22–28. http://www.jstor.org/stable/44429913

Moreira, S. A. S., Brandão, N. S., Belcavello, M. P. P. dos S., & Andrade, G. de O. (2017). The presence of TIC in the teaching-learning process of youth and adults with Down syndrome: The game as didactic-pedagogical resource. *2017 Twelfth Latin American Conference on Learning Technologies (LACLO)*, 1–7. https://doi.org/10.1109/LACLO.2017.8120893

Navarrete Mendieta, G., Guamán Coronel, M. de los Á., Arteaga Marín, M. I., & Guamán Coronel, D. C. (2020). Aulas virtuales como mediación pedagógica para la inclusión y discapacidades. *PUBLICACIONES*, *50*(2). https://doi.org/10.30827/publicaciones.v50i2.13941

Nielsen, J. (1994). Enhancing the explanatory power of usability heuristics. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems Celebrating Interdependence - CHI '94*, 152–158. https://doi.org/10.1145/191666.191729

Ok, M. W., & Rao, K. (2019). Digital Tools for the Inclusive Classroom: Google Chrome as Assistive and Instructional Technology. *Journal of Special Education Technology*, *34*(3), 204–211. https://doi.org/10.1177/0162643419841546

Olakanmi, O. A., Akcayir, G., Ishola, O. M., & Demmans Epp, C. (2020). Using technology in special education: current practices and trends. *Educational Technology Research and Development*, *68*(4), 1711–1738. https://doi.org/10.1007/s11423-020-09795-0

Rodrigues, T., Valencia, N., Santos, D., Frizera, A., & Bastos, T. (2019). *Development of Game-Based System for Improvement of the Left-Right Recognition Ability in Children with Down Syndrome* (pp. 627–634). https://doi.org/10.1007/978-981-13-2119-1_96

Rus, S., & Braun, A. (2016). Money Handling Training - Applications for Persons with Down Syndrome. *2016 12th International Conference on Intelligent Environments (IE)*, 214–217. https://doi.org/10.1109/IE.2016.48

Sánchez Montoya, R. (2008). TIC para estimular las Inteligencias. In *II Congreso Nacional sobre Discapacidad Intelectual Jaén, 13-14 de Noviembre*.

Shahid, N. M. I., Law, E. L.-C., & Verdezoto, N. (2022). Technology-enhanced support for children with Down Syndrome: A systematic literature review. *International Journal of Child-Computer Interaction*, *31*, 100340. https://doi.org/10.1016/j.ijcci.2021.100340

Statistical Package for the Social Sciences. 2022. "SPSS v.28. IBM Corporation. https://www.ibm.com/es-es/products/spss-statistics

SUSKIDS - Enabling professionals and families to transfer SUstainable knowledge and SKills to Down Syndrome individuals. (n.d.). Retrieved February 8, 2023, from http://suskids.eu/

Toffalini, E., Meneghetti, C., Carretti, B., & Lanfranchi, S. (2018). Environment learning from virtual exploration in individuals with down syndrome: the role of perspective and sketch maps. *Journal of Intellectual Disability Research*, *62*(1), 30–40. https://doi.org/10.1111/jir.12445

UNESCO. (2022). *Global Monitoring Report 2020: Inclusion and education: All means all.* https://en.unesco.org/gem-report/report/2020/inclusion

UNITED NATIONS. (2022). *Transforming our world: the 2030 Agenda for Sustainable Development.* https://sdgs.un.org/2030agenda

van Hooste, A., & Maes, B. (2008). *Kinderen Met Down. Een Kind Met Een Verstandelijke Handicap In Je Gezin*. Lanoo.

Zăvăleanu, M., Stepan, R. A., Roşulescu, E., Stănoiu, C., Ilinca, I., & Cosma, G. (2019). Intervention strategies to improve active and well ageing for down syndrome persons. *Journal of Sport and Kinetic Movement*, *1(33)*. https://jskm.ro/images/pdfs/33volI/INTERVENTION-STRATEGIES-TO-IMPROVE-ACTIVE-AND-WELL-AGEING-FOR-DOWN-SYNDROME-PERSONS.pdf

Zhang, M., Ding, H., Naumceska, M., Zhang, Y. (2022). Virtual Reality Technology as an Educational and Intervention Tool for Children with Autism Spectrum Disorder: Current Perspectives and Future Directions. *Behavioral Sciences*, 12(5), 138. https://doi.org/10.3390/bs12050138