Article

The Effects of Machinima on Communication Skills in Students with Developmental Dyslexia

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Abstract: Many research efforts in the international literature have been conducted to investigate various fundamental issues associated with communication skills cultivation of students with developmental dyslexia. However, little is known when it comes to the impact that 'immersive technologies', such as three-dimensional virtual worlds, without considering any exploration of their impact to assist boys and girls with developmental dyslexia cultivate communication skills. Motivated by this inadequacy in the literature, the purpose of this study is to explore the effectiveness of the machinima approach, created via OpenSimulator and Scratch4SL, for students with developmental dyslexia in vocabulary learning and practicing. This embedded mixed-methods research was conducted over a four-week timetable in-class course, with forty students (n = 40) aged 10–12 years old. All students were equally separated into two groups in line with their gender. Boys and girls were encouraged to unfold the communication skills developed (i.e., spelling, writing, reading) by creating their own stories, after viewing educational videos and machinima scenes, before and after the treatment. The results indicate that machinima positively affected students' learning outcomes and achievements. Machinima can improve immediate knowledge gains in boys compared to girls to purposefully translate their cognitive thinking into storytelling, when problem-solving situations through simulated realism are considered. This study also offers insights for educational implications and design guidelines for machinima creation, providing empirical evidence on its effect on the participants' linguistics understanding and communication skills for language learning in girls and boys with developmental dyslexia.

Keywords: communication skills; developmental dyslexia; embedded mixed-methods research; machinima; virtual worlds

1. Introduction

Special education has been of particular interest to scientists for several years. It is a discipline designated to meet the unique needs of those individuals who present some form of disability (mental, physical, social, and emotional) that requires particular attention. Instructional technologists and professionals in this field focus on ensuring that people with special needs have equal opportunities in all aspects of their lives, including social participation and education [1,2]. Developmental dyslexia (DD) is considered as one of the most common brain-based learning disorders that is not linked to any genetic- or sensory-related deficiencies. Individuals with DD face difficulties in both language learning and practicing [3]. Although its impact varies across individuals, it has been widely associated with a wide variety of learning complications (e.g., fluent handwriting or poor spelling), the roots of which are grounded on discrepancies related to reading, recognizing, and decoding words [4]. Recent studies [5,6] have admitted that the provision of adequate and continuing support can help individuals with DD to cope with those difficulties and achieve their potential, which can support communication skills (i.e., spelling, writing, and reading) development in language learning.

The integration of technological aids in the school context enables instructional practitioners to experiment with diverse teaching approaches and identify the most engaging methods to help individuals realize different achievements. A wide variety of didactic techniques and methods have been found to be highly beneficial when countering the needs and practical challenges that individuals with DD have and face, respectively. The adoption of 'immersive technologies' provides the context and the means to attract and maintain students' attention, while constructing their knowledge and developing their skills. To this end, the increased accessibility offered by three-dimensional virtual worlds (3DVWs) seems to satisfy students' expectations which, in turn, leads to better learning outcomes and achievements [7]. Moreover, researchers specializing in developmental learning disabilities also underline the added value that 3DVWs offer on individuals' cognitive development [8] and well-being improvement, with particular emphasis on the development of social skills and interaction patterns [9], both attributed to the embodied presence that learners develop via their avatars when interacting with embedded multimedia elements [10]. Another noteworthy approach that has demonstrated strong potential in special education is the design and development of storytelling via 3DVWs. The so-called 'machinima' approach blends the spectrum of fantasy with multimedia elements of realism and immediacy for digital story-like narrative creation in several learning subjects, such as linguistics and language learning [11]. Specifically, prior research [8,11] indicates that computer-supported audio-visual narratives can be delivered to students with less effort and fewer resources, allowing students with DD to think and act in a similar manner to the real-world context, and thus enabling them to increase their interactivity levels to promote a higher degree of engagement and learning.

However, the effectiveness and usefulness of machinima-supported instruction is debatable as far as students with DD are concerned and the role that gender plays in such alternative instructional approaches. Persistent concerns about the underrepresentation of boys in learning activities are observed, as DD is significantly more frequent among males [12], considering the increasing elimination of the gender "gap" in learning activities that can potentially influence their learning outcomes in terms of vocabulary learning and practicing [2,13]. The topic of gender differences is of great interest to instructional technologists and educators who seek to improve their widespread understanding regarding the barriers that students with DD face in reading, writing, and spelling with the use of interactive environments. However, there is still an under-researched topic for language learning development. There is also a growing interest to investigate gender differences in verbal and language abilities using 3DVWs, as several studies [e.g., 4,6] have suggested the conduct of studies that measure the impact and the learning effectiveness of such new-fangled technologies on students with DD. Furthermore, little research has been conducted on the effects of machinima on communication skills in students with DD, let alone any investigation about gender differences [7,9–11]. Therefore, this argument sets the principal focus of this study based on investigating linguistics and language learning via machinima, which sought to answer the following research questions (RQs):

RQ1: *Is there any significant difference between the academic performance of girls and boys with DD who followed machinima instruction considering the development of communication skills (i.e., spelling, writing, and reading), as demonstrated by their capacity to communicate their own stories?*

RQ2: *What are the differences on learning gains that students demonstrate after following the machinima instruction to develop and expand their communication skills for vocabulary acquisition and practicing?*

This study investigates the impact of machinima instruction on learning effectiveness in students with DD, while also considering the gender impact, with the key focal points being on: (a) vocabulary learning and practicing (including learning outcomes and achievements) and (b) the creation of their own stories after viewing machinima via hardcopies, contributing to linguistics and language learning.

2. Background

2.1. Machinima Instruction

The concept of storytelling emerged in the early 1990s as an alternative leisure paradigm, wherein the traditional approach was enhanced under the aid of images, audio, and video. It has traditionally been one of the most compelling and inspirational techniques for communication, entertainment, and education [14]. When considering the application of narrative art in the modern societal context, alongside the growing demand for interactive entertainment, it can be argued that multimedia instructional contexts represent a new type of 'transmedia' storytelling. It also enables viewers to actively shape the narration of the story and ultimately participate in the story world [15]. The integration of storytelling in the educational process enables students with DD to explore new situations and experience new emotions, in a safe way, via multimedia scenarios, which are embedded in one or more video streams [16,17].

Machinima refers to a short-animated screencast video created into video games or 3DVWs. It is a creative work for animation considering various multimedia visual contexts that storytelling can be created. Representing the conjunction of filmmaking, animation, and videogame development within an interactive virtual space, machinima is an exciting emerging digital media, and a new frontier in technologies for designing and communicating audio-visual narratives [17]. As an experiential learning approach, it promotes the development of strong connections between the learners' past experiences, with the present digital storytelling multimedia material, for the formation of new cognitive schemas [18]. Faddoul and Chatterjee [19] attribute the educational value of this approach to the 'relationship' that students develop with the theme and the content of the story. Relevant literature reviews [14,20] report that students who have developed their communication skills (spelling, writing, and reading) within conducive contexts find it easier to master them and ultimately demonstrate better performance. Furthermore, a growing body of literature [16,21] also argues that the communication skills of primary school students can be improved via: (a) activities that allow multimodal expression, (b) the integration of interactive media to support the conduct of the educational activities, and (c) digital storytelling sceneries that promote creative reading and writing.

As an instructional approach, machinima creation via 3DVWs has also been recognized for its effectiveness in language learning. Rainbow and Schneider [22] have proposed visualization and elements as resources for an ad hoc grammar point or other illustration as video production can be quickly, easily, and cost-effectively created for in-class language learning courses. For the integration of machinima in-school contexts, the same authors admitted that instructors should pay attention to a specific story, grammar point, or other topics of interest, whereas students need to use such videos to demonstrate better knowledge and understanding, or as evidence of their outcomes and achievements within simulated real-world contexts. Machinima production was examined as an alternative instructional approach that can be utilized for self-reflection, feedback, and assessment. For this reason, a number of studies point out the following abilities: (a) to reshoot a specific activity or repeat a role play which reflects upon their actions as visual feedback [22]; (b) to combine well-established traditional cultural practices of film 'language of new media' with a wide number of numerical scales of image adjustment, and the new paradigmatic choices [23]; (c) to support students' experience via role-playing which reviews their interaction and extra-linguistic performances, considering captions with explanations and links to problem-solving activities [18]; and (d) to orchestrate modes of filming and editing to encourage thinking before applying processes for simulated realistic scenarios [17].

Based on the above, as an extension of storytelling, machinima 'compiles' and 'exports' the interactive features and elements with simulated high-representational fidelity into a computer-supported, partially immersive observational narrative, which can be delivered to students with less effort and fewer resources. To the best of our knowledge, there are no studies which assess the potential of machinima-based training, not only in consideration

of the needs that individuals with DD have, but also in view of the impact that gender difference plays.

2.2. 3DVWs in Special Education

Interestingly, 3DVWs are computer-generated (networked) platforms that enable individuals from all over the world to connect in a shared, user-created, virtual environment [24] (Christopoulos et al., 2018a). A 3DVW constitutes a typical example of an interactive multimedia platform as it is one of the most popular computing technologies in the entertainment industry. Over the past ten years, the so-called 'social' 3DVWs (e.g., Quest Atlantis and Second Life©) and 'open source' alternatives (e.g., OpenSimulator and Open Wonderland) have received great attention, both from scientific and educational communities, as they provide the means to design and conduct interactive educational activities [25]. In these environments, all users are represented via their virtual persona (avatars), which facilitate interaction both with the content of the environment and among the users. In addition, the wide variety of tools allow both synchronous and asynchronous communication (e.g., text messages, notecards, voice over IP) with additional opportunities for interplay and facilitate the conduct of (collaborative) interactive tasks. The most unique feature of these environments is the opportunity given to users to shape the environment in accordance with their own preferences and/or needs by offering them the tools to design and animate 3D content creation [26].

The wide adoption of these environments led to the emergence of various community-driven forums and the release of third-party software tools, such as the Scratch4SL visual palette, aimed at supporting both novice and expert users in creating interactive experiences without strict code analysis. For this reason, multiple efforts have been made to integrate such solutions into the educational context with reportedly positive and encouraging results on knowledge acquisition and skill training [7]. Even though the primary emergence of such environments has aimed to fulfil entertainment and socialization needs, they were rapidly deployed in the educational context too. For instance, the systematic review of Pellas and colleagues [26] highlights the benefits that 3DVWs offer in education. Some of the key findings that have been reported, in consideration of the activities that can be conducted within these environments, are as follows: (a) situated learning activities (such as role-playing, experimentation, and virtual tours), (b) project-based learning activities (such as content design and programming), (c) inquiry-based learning activities (such as field work and case studies), and (d) problem-based learning activities (such as, problem-solving, research, and collaboration). Although the vast majority of the identified efforts derived from science and technology disciplines, successful implementations were also reported from social sciences with special emphasis on linguistics and language learning.

The international literature has effectively documented the potential of 3DVWs in special education, with positive results on both students' cognitive, behavioral, and social engagement, as well as on their learning outcomes and achievements. Individuals who have memory disabilities, attention problems, or an inability to control their emotions often express enthusiasm when interacting in 3DVWs. Relevant studies [10,25] attribute these outcomes to the greater safety offered by the digital context, in terms of comparing real-world environments, as well as to the increased opportunities for communication and interaction with people who face similar difficulties. For instance, individuals within the autism spectrum can meet their peers on equal terms (i.e., without being dependent on social cues or barriers otherwise implied by the real-world context). Wang et al. [27] created a 3D game and explored the relationships that individuals with autism developed during the conduct of collaborative learning activities. The key findings revealed strong associations between participants' confidence and their willingness to interact with others using the available verbal and non-verbal communication channels.

Other studies focusing on special education have taken a closer look at students' achievements and outcomes. The semi-longitudinal study by Gilbert and colleagues [8] examined the psycho-emotional impact that 3DVWs have on individuals with mental

disabilities. Although more than half of the participants dropped out, those who were still active after 3 months reported great improvements in their emotional state and self-esteem. The authors linked the reported improvements on the overall involvement that participants had with the Second Life© platform and the opportunities offered to create relationships with other people who face similar difficulties. Conclusively, the authors report that such multidimensional environments can provide multiple benefits to people with (learning) disabilities, regarding both their mental health and wellbeing. In another study, Ke and Moon [9] utilized the 3DVW of OpenSimulator to create a virtual playground. In the context of this effort, individuals diagnosed with high-functioning autism took over the role of an architect and requested to perform profession-related tasks. The primary aim of the work was to explore the potential of the gamified content to engage those children with assigned tasks. Moreover, light was shed on the achieved degree of social interaction that participants maintained with each other, while being in the virtual environment. For the collection of primary data, an inclusive approach was adopted wherein screen recordings and physical observations were analyzed in conjunction. The concluding remarks confirmed the potential of gamification to engage students in the learning activities and further revealed that children with high-functioning autism had a much higher degree of social interaction in the 3DVWs than in the physical context. As Moon and colleagues [28] reported, the high representational fidelity that 3DVWs inherently have can enable students to interpret information in a more diverse and logical way. As a result, students can develop a less abstract picture of the phenomena under investigation, further facilitating the development of critical thinking and planning skills. Lastly, Hussin and Fouzi [29], after analyzing the statistical information available on road accidents and incidents, observed that the category including youths was the most frequently reported one. Participating students were asked to undertake a knowledge quiz related to the traffic codes, prior to the conduct of the intervention, followed by active engagement with machinima scenes that were designed by the road safety unit for the needs of this study. The post-intervention evaluation results as well as the systematic observation that researchers performed during the interaction time revealed that students' awareness of traffic hazards significantly increased.

In light of the above, a concluding line implies that the integration of 3DVWs in special education can provide various benefits which are otherwise hard or even impossible to obtain following traditional approaches. Research works [28,29] have reported that a high degree of engagement and excitement during the 3DVW-supported learning activities attribute these outcomes to the transformation of educational content into a sequence of different phases. Similarly, the adoption of storytelling has the potential to engage learners in an interactive narrative which leads to better achievements and outcomes [9,28]. Nevertheless, these studies provide minimal information regarding the instructional settings or the impact that students' gender has on the observed outcomes.

According to the above-mentioned findings from previous studies, this works intends to provide an in-depth description of the machinima instruction that can potentially benefit students' learning outcomes on vocabulary learning and outcomes, especially when compared to educational video-based instruction.

3. Materials and Methods

3.1. Machinima Design

For the needs of this study, we utilized OpenSimulator technology (combined with the Scratch4SL visual palette) to create interactive 3D content and Adobe® Premiere® Pro to create and edit the machinima instructional video. The design procedures were based on the guidelines that emerged from relevant review studies [7,25], whereas for the creation and editing of the machinima video, we followed the steps provided by Xu et al. [30]. Table 1 summarizes the steps followed during the design process.

Table 1. The machinima design process.

Main Steps for Machinima Design (Adapted by Xu et al. [30])	Explanation of Scenes Related to Design Features and Elements
Step 1. Introduction to OpenSimulator	The class teachers were informed and proposed several educational videos which could potentially be utilized in class settings and uploaded via well-known video share platforms as related course material to real-life situations. After that, the conducted training on how to use the main elements and features of the OpenSimulator and Scratch4SL visual palette during a 3-h workshop was followed by a demonstration of the machinima instructional video. Additionally, a demonstration of educational videos was conducted before the machinima intervention to aggregate data on the pre-test measurements.
Step 2. Introduction to digital storytelling/machinima	For the storytelling scenario, a multidisciplinary space was designed and subsequently divided into four separate rooms. Each room was associated with different themes and purposes, whereas the interaction channels between the main avatar and the objects were programmed via the Scratch4SL visual palette. Both the virtual space and the decorative objects were all included elements and attributes that could facilitate students' learning.
Step 3. Story topic	The topic of the story was communicated as "*The Virtual Traveller*", which enables users as avatars to navigate through the virtual environment and perform exploration-related actions.
Step 4. Imagination of the story	The 3D educational environment as a rich seam of different interactive models and objects. The narration of events ranged from practicing the Greek alphabet to reading, spelling, and writing words, while observing the machinima instructional video at a later point. The key topics that were demonstrated include natural colours and geometrical shapes. A combination of both was also communicated in view of the traffic law signs. Finally, a small number of domestic and wild animals was also included as the means to teach students about their names and also facilitate some additional practicing of colours.
Step 5. Writing the story	Prior to the intervention time, the students were offered a set of hardcopies that displayed different tasks and exercises. Based on the story that was active during the machinima playtime, they were asked to fill in the respective form. The machinima was separated in four scenes. Each disclosed movement, insisting that an avatar (virtual storyteller) needed to walk ahead the main road and watch out for traffic sings to enter the school without injuries. Inside it, there are some classrooms visited by the avatar, such as the fine arts class. Outside it, there is a garden to play with various animals that the virtual storyteller interacts with, and several messages project some messages and information. All of them were visible via machinima.
Step 6. Creating the story scenes in OpenSimulator	**Scene #1: The Traffic Signs** In the first scene, a variety of traffic law signs were illustrated. The purpose of this room was two-fold: on the one hand, to help students practice the names of the shapes and colours and, on the other, to teach them about basic road safety signs. In a similar manner to the previous room, upon clicking on the signs, an audio message was triggered, mentioning the shape and the colour of the sign, as well as its importance in view of the traffic law code. **Scene #2: The School Classroom** The first scene is a replica of a school classroom with desks, chairs, books, and an interactive whiteboard which displayed the alphabet. When the whiteboard was clicked, the alphabet letters were presented and pronounced. This enabled students to refresh their memory, regarding both the visual structure of the letters and the respective vocals. **Scene #3: The Fine Arts Classroom** The third scene concerns the presentation of colours. The avatar enters a fine arts room framed by different cube-shaped objects, which display a wide range of colours, but only one colour is rendered on each object at a time to help learners distinguish them easier. Every time the storyteller's avatar approached a coloured object, a sound was played which read the name of the colour and subsequently spelt each letter. In addition, a text message appeared on the avatar's screen while individual labels were also placed in the background to promote passive reading. **Scene #4: The Garden** In the last scene, several animals were spread on the ground. As with the previous cases, upon the storyteller's avatar interaction, a text and a voice message were displayed and played, respectively. Both communication media mentioned the name of each animal and some basic information related to their characteristics.

Table 1. *Cont.*

Main Steps for Machinima Design (Adapted by Xu et al. [30])	Explanation of Scenes Related to Design Features and Elements
Step 7. Sharing stories	The narration was delivered through the avatar of the virtual storyteller. Precisely, the storyteller explored the various spaces, interacted with the virtual objects, and offered advice to students along the way. Upon interaction with the 3D models and objects, a combination of audio-visual feedback was provided to students via a digital voice, messages rendered on the screen, and gestures. During the machinima playtime, students were encouraged to keep notes (words and sentences) that could be later used to create their own stories and after that describe orally what they have written in hardcopies. Every time that class teachers recognized a minor or major error in writing, spelling, and reading, they marked each participants' story accordingly.

For the narration creation process, we opted to: (a) contextualize the storytelling in a classroom-like environment to enable students to think and act in a similar manner to the real-world context and (b) combine different multimedia elements to increase the interactivity level and therefore a promote higher degree of engagement. Figure 1 illustrates the content created within the OpenSimulator environment.
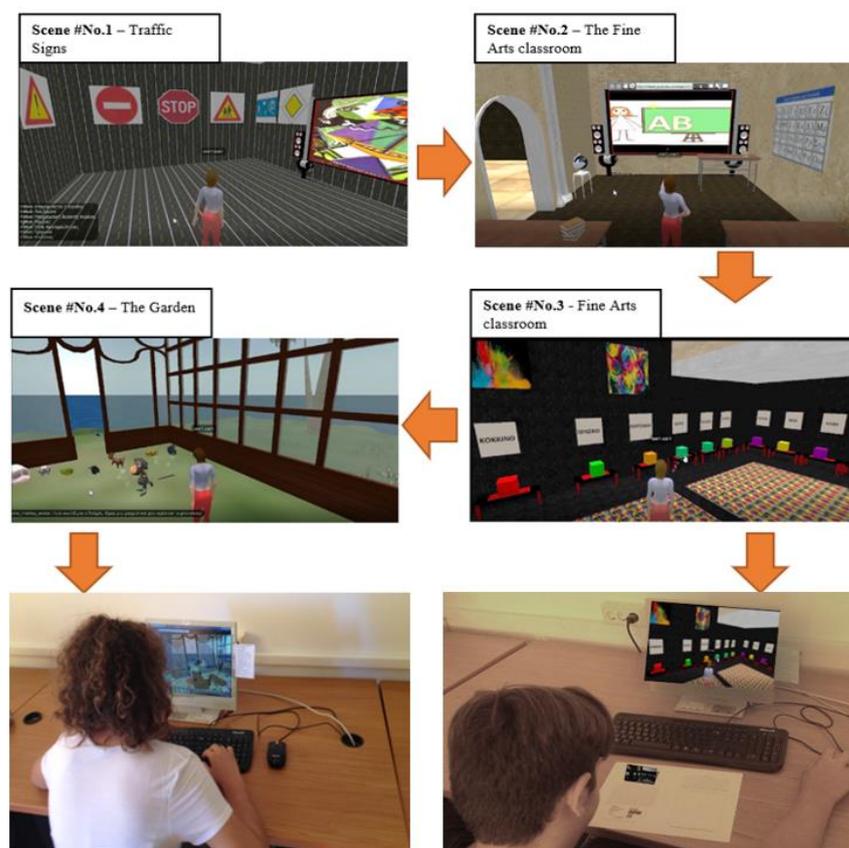

Figure 1. The machinima instruction.

3.2. Research Design

The embedded mixed-methods design allows the collection of quantitative and qualitative data within experimental naturalistic settings. It also facilitates the development of a clear understanding over participants' capacity to develop contextual arguments during the formulation of hypotheses, negotiation, and the presentation of facts in real-life school contexts, which (a) enabled researchers to elicit a clear picture of the outcomes that learners with DD have to achieve after being exposed to a particular treatment [31] and

(b) facilitated the development of a better understanding around the 'ideas' that boys and girls expressed, when constructing and aligning their thoughts in oral and/or written form based on qualitative and quantitative data collection [32]. Therefore, in the context of this study, we utilized this approach as a means to (a) examine whether our target students were able to observe and understand the machinima instruction and (b) determine the extent to which participants' understanding and communication skills can be improved using this approach.

To explore the effectiveness of the proposed machinima approach on participants' linguistics understanding and communication skills related to reading, writing, and speaking for language learning, we focused on measuring their ability to identify grammar rules correctly and their capacity to unambiguously spell/write words (as a sequence). For this reason, we used custom knowledge evaluation tests, distributed to participants as hardcopies, both prior to and after tests. The study took place in conventional classroom settings, without the presence of the researchers, to avoid adding unnecessary stress to the participants. To compensate for the absence of the research team and prevent any possible misunderstandings from occurring, educators in charge were provided with detailed information and training on the following aspects: (a) the integrated research plan and data collection methods; (b) the process related to the conduct of workshops; and (c) OpenSimulator combined with the Scratch4SL palette, as compensation for their willingness to participate in the present study.

3.3. Treatment

Prior to conducting the intervention to investigate any possible contributions to linguistics and language learning, the class teachers received an intense 4-h training course related to the use of educational videos (for the pre-test) and OpenSimulator with the Scratch4SL visual palette (for the post-test), followed by a demonstration of how the machinima instruction can be utilized for didactic purposes. The training aimed to increase teachers' confidence with regard to the integration process and further prepare them for any prospect questions that students may have had. Subsequently, each teacher prepared this teaching intervention, including the data collection process, which targeted the collection of both quantitative and qualitative data. All students completed a preliminary survey which enabled us to explore their background. The machinima-supported lessons (approximate duration of 50 min) were scheduled over the course of a 4-week treatment. To ensure that everything could fit into the proposed timelines, we separated the sceneries into individual parts (one educational element at a time) and adjusted the knowledge tests accordingly. Figure 2 illustrates the procedures followed.
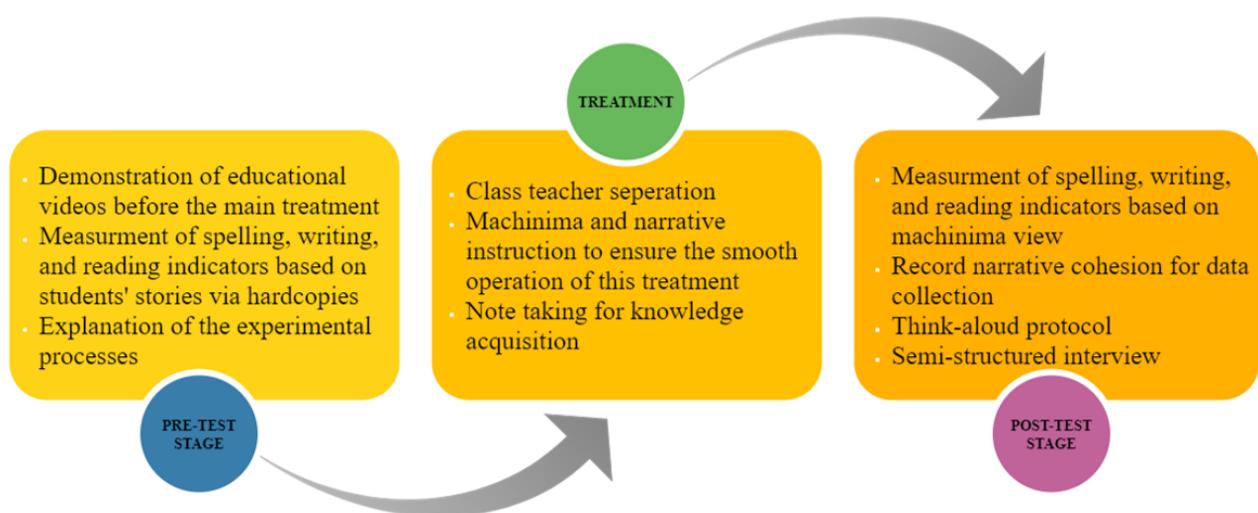

Figure 2. Experiment design.

Following the grouping of students in the first session, we initiated the treatment which started with the Greek alphabet letters and the communication of words from diverse real-life situations. However, given the advanced complexity and escalation that the remaining scenes (i.e., colors, shapes, and animals) involved, participants were invited to maintain notes in their hardcopies based on the behavior displayed from the avatar during the machinima playtime. Upon completion of the intervention, an additional set of hardcopies was delivered to students, with the class teachers requesting them to describe any situation that can take place in the real world. The completed documents were later used to assess the acquired knowledge and skills (i.e., the effectiveness of this approach on vocabulary learning and sentence structuring) that students demonstrated at the end of the intervention. For the evaluation process, specific model answers were prepared to judge the correctness of the Greek grammar rules and the spelling of each word used by participants to describe their own stories before and after the treatment. Both the pre- and post-assessments were examined as open-ended stories in line with the participants' cognitive level and capacity. The experimental process is described in detail in Table 2.

Table 2. Experimental process.

Week	Treatment	Operations
1	Grouping	Participants based on their gender were assigned to one of the two groups and prior to their treatment participation.
2	Pre-test	Students were requested to independently complete a pen-and-paper story based on a video. The focus was on describing a personal story via hardcopies for a topic about situations, involving "fantastic personas" in 3D contexts, such as a shop with original paintings colours, animals care in a zoo, alphabet learning activities in classroom settings, and traffic safety law education. This activity lasted approximately 10 min. Before distributing the pre-tests, a video demonstrating real-world setting Greek letters and relevant words was presented to all participants. At this stage, we measured the correctness of participants' sentences and any major or minor mistakes to mark them properly. This activity lasted approximately 15 min.
	Presentation	A brief session related to the use of OpenSimulator and Scratch4SL for machinima creation, as well as the potential use of interactive platforms, was given to all students as a compensation for their willingness to participate in this study. The students learned basic word and grammar structures (times, conjunctions, etc.) and wrote a story in Greek about any country within the range of 200–250 words. This activity lasted approximately 25 min.
3	Activity	Machinima came into play after the first week. Therefore, before participants completed their post-tests by writing and orally describing their own stories in hardcopies. Each scene contained four separate scripted encounters, with advanced complexity and escalation, whereby a scenario in each one, described by using different letters and words via OpenSimulator. After that, class teachers allowed the participants to disseminate all ideas and write them in hardcopies. For each scene, participants were asked to write their own stories in hardcopies based on what they saw, which could account for the avatar behaviours being paused, and showed the current question at the appropriate point and time that each scene played. This activity lasted approximately 25 min.
	The teacher's role	During the main activity, the class teacher examined the stories written by the students and gave them feedback on any incorrect structures. In the next class, the class teachers separated the stories to the students and asked them to write the second version of the stories in line with the feedback they received when they viewed the machinima. All teachers who participated had the chance to supervise the treatment and recorded students' voices for the think-aloud protocol and written texts, ensuring that their concerns would be addressed after viewing machinima. This activity lasted approximately 25 min.
4	Post-test	Students were requested to complete the same test used for the post-test. The order of the questions/items was altered to prevent memorization of answers. This activity lasted approximately 60 min. Post-tests in this treatment were proposed as open-ended story descriptions to investigate how students with DD express themselves, both in writing and orally. This activity lasted approximately 50 min.

3.4. Sample

Forty young students, aged 10–12 (Mage = 11.3, SDage = 2.88; ngirls = 20, nboys = 20) participated in this study. Participants were chosen from a dyslexia center in Greece which follows the national curriculum/instructional processes dedicated to students with DD and possesses all the equipment (e.g., computers, tablets, etc.) required for this treatment. During the treatment process, the research team was in a nearby classroom, as a precaution measure, and was readily available to intervene in case it was deemed necessary. Extracurricular activities for students with DD are provided by after-school programs in Greece to increase their lifelong interest and communication abilities. All students were diagnosed with DD, as confirmed by their parents/legal guardians, teachers, and the school doctor.

To counter validity threats, we separated girls and boys equally, following the principles of the non-randomized sampling approach which required the same sample size in both groups and an almost equal variation in terms of the participants' gender to prevent undetected constant bias and flawed inference in this study's results. Additionally, as indicated by our demographics, which have been gathered prior to the conduct of the intervention, all participants had previous experience with digital resources and (online) games, which enabled us to rule out the novelty effect [33].

3.5. Measures

For the pre- and the post-test analysis, we opted to explore whether participants acquired new or improved existing communication skills. The machinima sections were separated into different categories in accordance with the grammar or the vocabulary rules that were being taught and examined at a time when students tried to express their own stories before and after the treatment. The error scheme included three categories: (a) no errors were identified (Correct, C), (b) minor errors were identified (Error 1, E1), and (c) major errors were identified (Error 2, E2). In accordance with these categories, the following (negative) marking scheme was generated: (a) no deduction of points, (b) deduction of 0.25 points, and (c) deduction of 0.5 points. We also aggregated the marking range (points) that participants could potentially gain based on specific indicators related to their spelling, writing, and reading skills. Participants gained 10 points for each indicator, and therefore, the maximum number that could be achieved was 30. The main error code analysis is presented in the Appendix (see Tables 2 and A1).

As we wanted to develop a more in-depth understanding of participants' consistency with the answers provided during the treatment process, a think-aloud protocol was also utilized. All participants were asked to describe their own stories, both orally and then in writing, without the support of the classroom teacher (e.g., suggestions or modifications). Lastly, a semi-structured interview, at the end of the experimental process, was conducted, during which boys and girls freely expressed their opinion regarding their own stories.

3.6. Data Analysis Tools

For the data analysis, we utilized the Statistical Package for the Social Sciences (SPSS) software. The initial analysis included descriptive statistics followed by additional tests to explore the internal consistency (Cronbach's alpha) and reliability of the pre- and post-test data. Accordingly, we conducted Kolmogorov–Smirnov and Shapiro–Wilk normality tests to measure the homogeneity of the variance. Due to the violation of the normal distribution assumption and the non-homogenous variance of the data, we performed non-parametric tests to reveal differences between the two cohorts (Mann–Whitney U) and investigate any differences between the pre- and the post-test results (Wilcoxon signed-rank test), with particular emphasis on the variations observed between genders. The audio recordings related to participants' answers during the "think-aloud" session and the comments made during the semi-structured interviews were analyzed using NVivo (ver. 10) software. By the time that this treatment was made when the machinima view was finished and after that each student prepared his/her own story via hardcopies.

3.7. Reliability and Validity

In favor of validating the consistency of this study' findings generated by different data collection methods, multiple sources of data, such as pre-and post-tests analysis and think-aloud protocols, were compared and contrasted. On the one side, all of the data coding and analyses were shared from the class teachers to the professionals (researchers) to confirm the categories to reduce potential bias. On the other, the role of teachers was to check through face-to-face conversations to verify and validate the data analysis by checking the consistency of the data.

To strengthen the reliability and validity of the findings, the gathered data were not only examined from diverse perspectives but also cross-checked across this study's authors as recommended by Naughton and Hughes [34]. Precisely, the first author coded all the data, whereas a randomly selected sample of 25% of the responses was coded by the second, with the purpose of examining: (a) Pearson's r for inter-rater reliability to measure the correlation between the scores from the two rates and (b) Cohen's Kappa (k) to identify any optional agreement between the error coding. The pre-test has $r = 0.82$ ($p < 0.001$) on scores and $k = 0.86$ ($p < 0.001$). The post-test has $r = 0.88$ ($p < 0.001$) on scores and $k = 0.85$ ($p < 0.001$). Thence, high inter-rater reliability and high inter-rater agreement for the coding were both provided.

4. Results

4.1. Demographic Information

From the demographics, we found that no participant had previous experience with machinima, but all were exposed to some sort of storytelling via comics (physical form) and/or digital resources (videos, online). The majority of boys (83%) reported that they play video and computer games for nearly 4h per day, such as *Fortnite* and *The Sims*, whereas most girls (79%) reported usually spending almost 2h per day on the same games. Moreover, all of them had access to personal computers, with 67% of boys and 73% of girls reported to use their computers really often, whereas 33% of the former and 27% of latter claimed to occasionally engage in self-directed learning activities. The most reported activities included the frequent use of digital textbooks, the observation of course podcasts and webcasts, as well as notetaking and the completion of interactive exercises.

4.2. Sum of Grades

Participants, during the machinima integration sessions, were encouraged to keep notes and spell them as completely and unambiguously as possible. However, the final grades were given only to the answers provided in the final versions of the hardcopies, as delivered at the end of the experiment. The internal consistency for the boys is as follows: (i) spelling (a = 0.81), (ii) writing (a = 0.71), and (iii) reading (a = 0.73), and (i) spelling (a = 0.86), (ii) writing (a = 0.91), and (iii) reading (a = 0.93) for the post-test. The internal consistency for the group of girls is as follows: (i) spelling (a = 0.73), (ii) writing (a = 0.76), and (iii) reading (a = 0.78) for the pre-test, and (i) spelling (a = 0.86), (ii) writing (a = 0.81), and (c) reading (a = 0.83) for the post-test. In view of these findings, we can conclude that all components have a satisfying internal consistency (a $\geq$ 0.7), both before and after the treatment, as recommended by Singh [35].

In response to *RQ1*, we identified a potential improvement in students' vocabulary expansion across all the relevant aspects (spelling, writing, and reading). Descriptive statistics (Figure 3) of the grades for each group are as follows: (a) boys received 11.5 (SD = 1.71) and 18.7 (SD = 3.12) in the pre- and post-test, respectively, and (b) girls received 14.2 (SD = 2.15) and 18.1 (SD = 2.98) in the pre- and post-test, respectively. The initial observation suggests that boys received slightly better grades than girls after using machinima. To confirm the substance of this observation, we performed a Mann–Whitney U test which indicated a high significance between the difference in the two groups (n = 40, U = 3.03, z = −2.47, $p = 0.01$, r = −0.61).
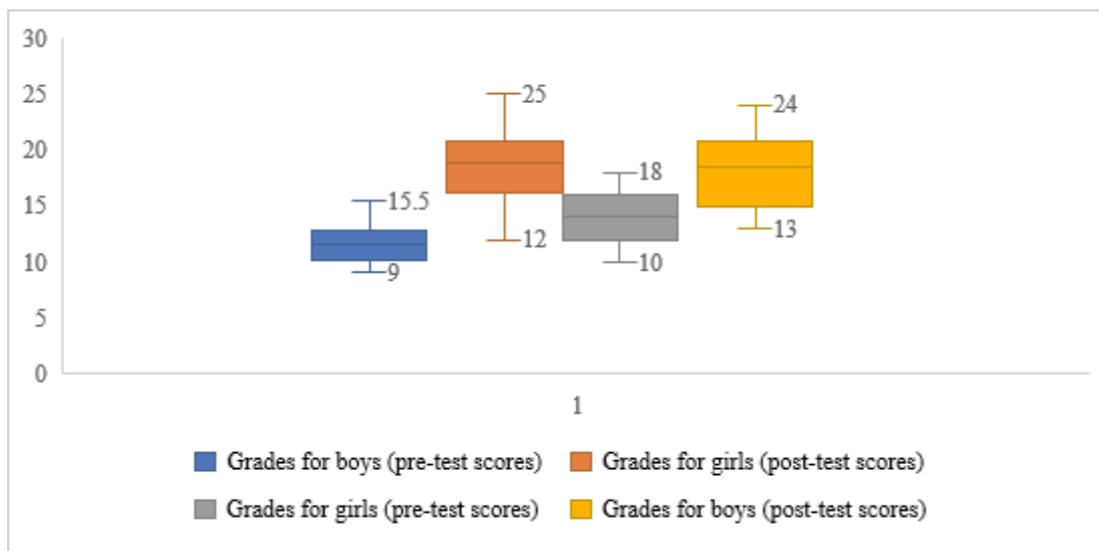
Figure 3. Overview of the final grades (mean scores).

Some noticeable points for consideration are as follows. None of the participants, either in the pre-test or the post-test, achieved the maximum grade. Even though boys scored a lower minimum score in the pre-test (nine points), the impact of the integrated learning method had a greater influence on them. However, such a finding is slightly different when considering the final grades between the boys and the girls. In particular, the maximum number of points in the post-tests was achieved only by two boys—who scored 25 points—whereas, in the other group, four girls received 24 points.

After examining the sum of grades to identify any gender differences, it became apparent that the boys acquired lower grades in the pre-test, when compared to the outcomes that girls demonstrated across all exercises (spelling, writing, and reading). The analysis of participants' achievements in the post-test revealed that boys demonstrated a considerable improvement in writing and reading but not in spelling. On the other hand, girls demonstrated better learning outcomes across all the three categories. Figure 4 comparatively illustrates students' outcomes across the undertaken knowledge assessments.
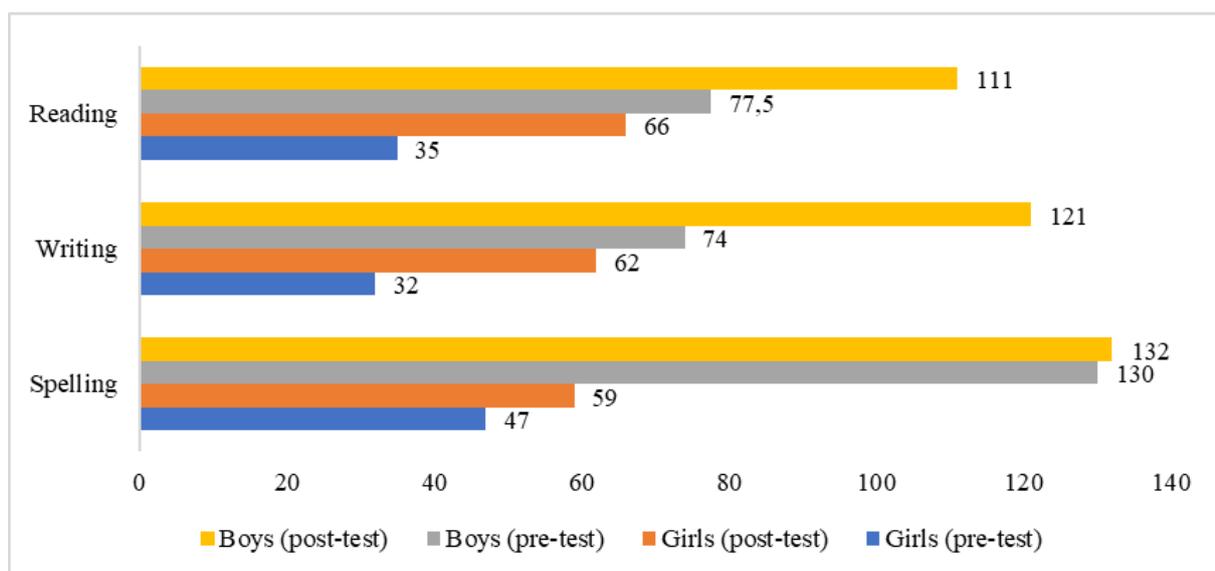

Figure 4. Sum of grades across the evaluation focus points.

In addition, we explored the effectiveness of the intervention on the conceptual understanding of language and vocabulary learning. To measure the normalized learning change (maximum possible gain or loss), we analyzed the absolute differences in the mean scores of the pre- and post-tests [36]. A variant on normalized learning gain is considered to be essential for situations where, for instance, negative learning gain is observed for a small number of participants [37]. The formula to calculate the variant of normalized learning is as follows: 100x (post-pre)/(100-pre), whereas for negative learning gains, the formula is: *100x (post-pre/pre).* We identified an overall positive normalized gain of 36.3%. We can, therefore, conclude that the machinima intervention positively affected students from both genders, but had a greater effect on the boys.

4.3. Pre- and Post-Test Analysis

To determine any gender-related differences on participants' communication skills (understanding and expression), as demonstrated by their ability to communicate words and key concepts before and after the intervention, we utilized a set of diverse indicators. The findings emerged from this analysis are accordingly used to provide an answer to RQ2.

Figure 5 illustrates the mean scores of participants' answers from the spelling indicator. Boys achieved the lower mean scores and standard deviation in the pre-test (Mboys = 1.3, SDboys = 1.11; Mgirls = 1.7, SDgirls = 0.75) to recognize the sound of vowels and/or consonants, but also in post-tests using the machinima (Mboys = 1.42, SDboys = 0.97; Mgirls = 1.50, SDgirls = 0.86). Specifically, the machinima instruction assisted boys and girls to more easily recognize the number of words they heard (Mboys = 1.35, SDboys = 1.29; Mgirls = 1.11, SDgirls = 0.94), and was accurately transferred in text, as compared to in the pre-test (Mboys = 0.9, SDboys = 0.71; Mgirls = 1.07, SDgirls = 0.88). While boys produced better scores in taking notes or copying words in the post-test (Mboys = 1.68, SDboys = 1.28; Mgirls = 1.27, SDgirls = 0.96), they had significantly better outcomes after the machinima view than the educational video instructional approach, as indicated by their scores in the pre-test (Mboys = 0.72, SDboys = 0.65; Mgirls = 1.17, SDgirls = 0.91).
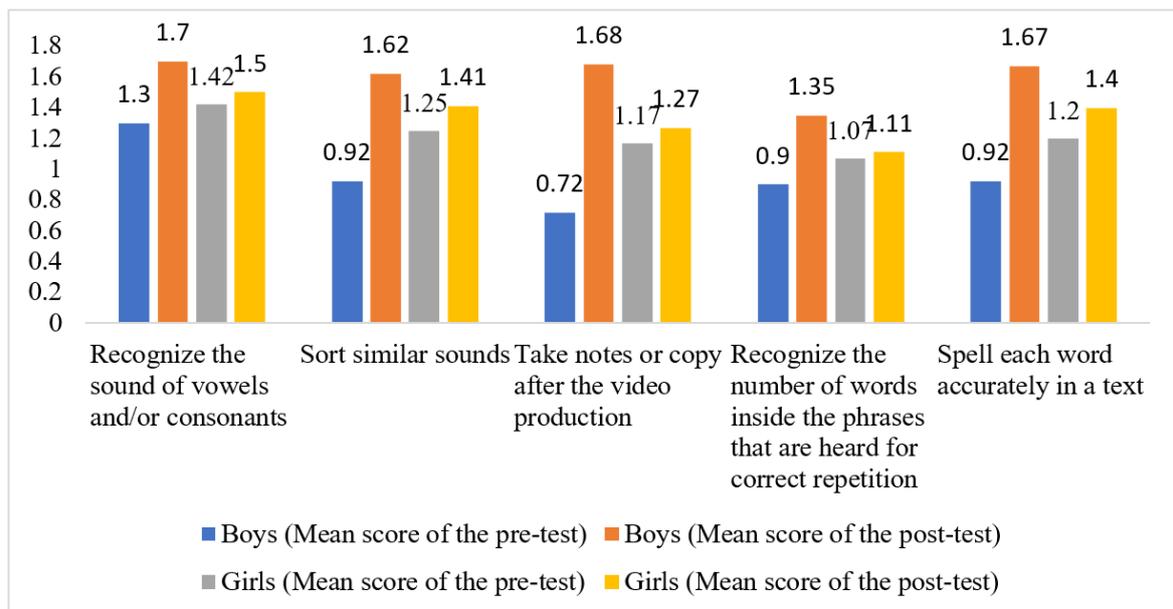

Figure 5. Mean scores of the spelling indicators.

Figure 6 presents the mean scores of participants' answers from the writing indicator. There is a remarkable finding where boys inverted or reversed the letters or incorrect letters that were placed into words after observing scenes via machinima at a higher level (Mboys = 2.2, SDboys = 2.02; Mgirls = 1.7, SDgirls = 1.41). Moreover, boys with DD were able to write words exactly as they heard them after viewing machinima (Mboys = 2.1,

SDboys = 1.93; Mgirls = 1.65, SDgirls = 1.46), as demonstrated by the post-test scores, i.e., significantly better than girls.
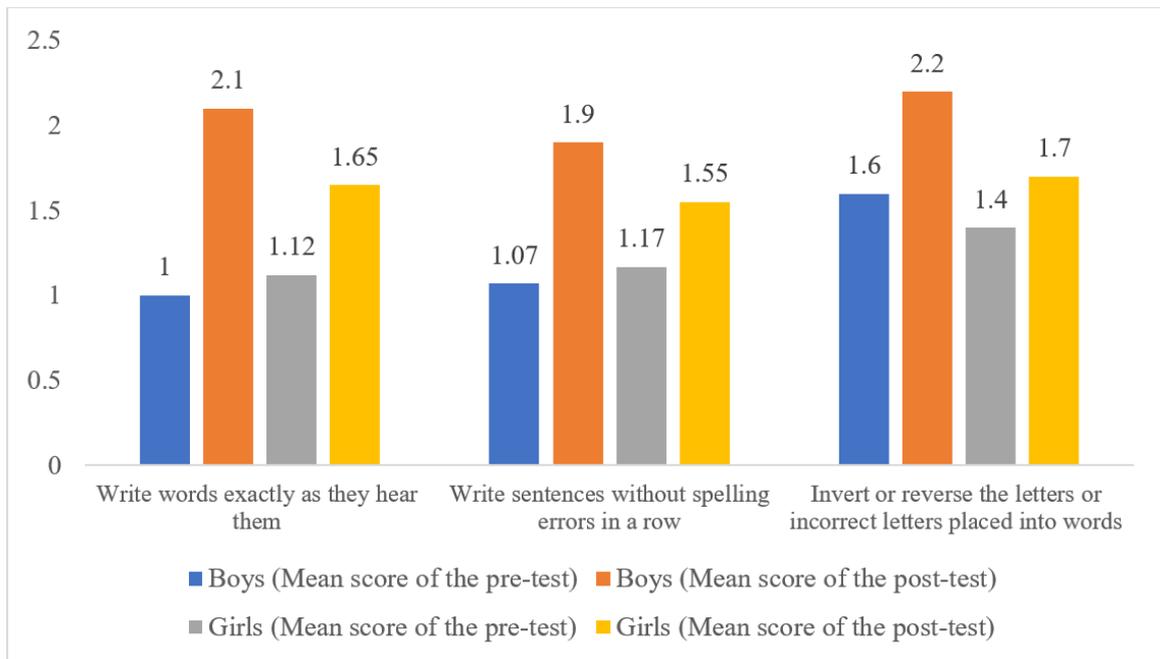

Figure 6. Mean scores of the writing indicator.

As Figure 7 depicts, while boys achieved lower mean scores in the pre-tests for realizing and understanding all words in a row (Mboys = 1.6, SDboys = 1.42; Mgirls = 1.97, SDgirls = 1.24) and correctly writing, letters, words, and sentences based on sounds they heard, a noteworthy improvement was evident in their post-test scores in contrast to girls (Mboys = 3.1, SDboys = 2.83; Mgirls = 2.9, SDgirls = 2.31).
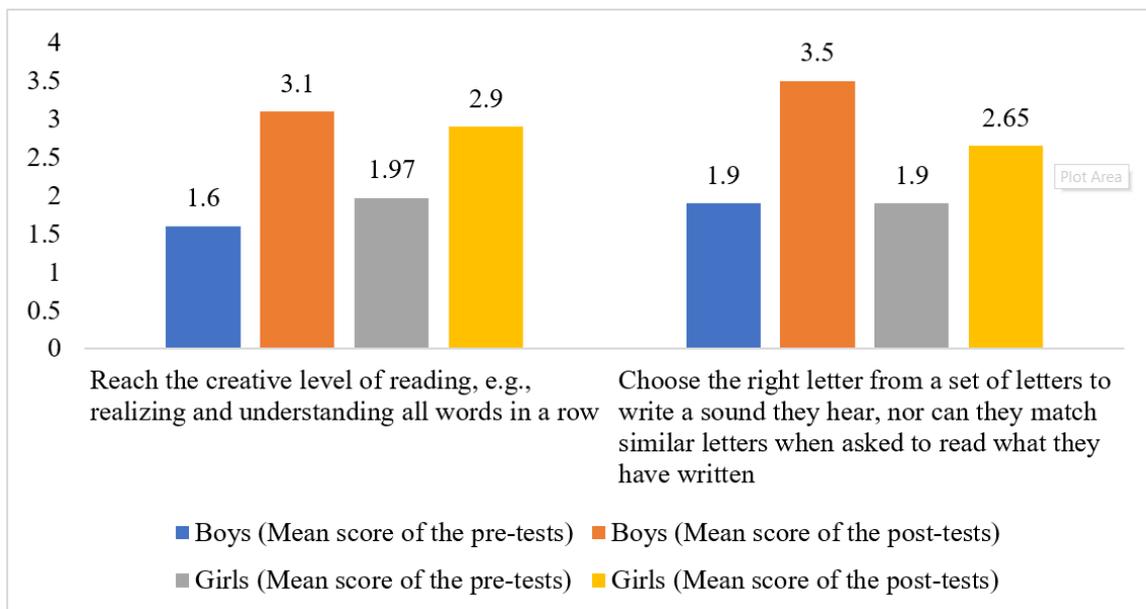

Figure 7. Mean scores of the reading indicator.

Table 3 below presents participants' scores on communication skills split by gender. Boys in the post-test received higher mean scores than their counterparts in view of all the assessment points (spelling, writing, and reading).

Table 3. Wilcoxon signed-rank tests.

Indicators	Gender	Pre- and Post-Test Scores				Wilcoxon Signed-Rank Tests
		M (pre)	SD (pre)	M (post)	SD (post)	
Spelling	Boys	0.95	0.34	1.21	0.54	Z = −1.52, *p* = 0.01, r = −42
	Girls	1.32	0.67	1.30	0.61	Z = −1.82, *p* = 0.01, r = −51
Writing	Boys	1.22	0.52	2.06	1.65	Z = −4.36, *p* = 0.11, r = −46
	Girls	1.23	0.66	2.01	1.63	Z = −4.49, *p* = 0.12, r = −46
Reading	Boys	1.75	0.81	3.31	1.95	Z = −1.33, *p* = 0.01, r = −46
	Girls	1.93	0. 78	2.77	1.72	Z = −4.04, *p* = 0.01, r = −38

The Wilcoxon signed-rank tests showed a significant (z = −1.52, *p* = 0.01) and large (r = −0.42) increase in the spelling outcomes of boys when comparing the pre-test (median = 1.08) with the post-test (median = 2.16) results. Specifically, the spelling-related scores in the pre-test (median = 1.05) and post-test (median = 2.03) were also significant (z = −1.82, *p* = 0.02) with a similarly large effect (r = −0.51).

The Wilcoxon signed-rank test for reading shows that there was a significant increase of boys from the pre- (median = 1.21) and post-test (median = 1.92), when they determined skills related to reading (z = −1.33, *p* = 0.01), and the increase was large (r = −0.46). This improvement was observed in reading undertaken by girls in the pre-test (median = 1.55) and the post-test (median = 2.22, z = −2.04, *p* = 0.01), and the increase was large (r = −0.38). Nevertheless, in terms of writing indicator, there was not any significant difference observed among boys or girls.

The Mann–Whitney U test was used to compare differences between boys and girls, as the data were skewed. The results showed that boys scored higher on writing, spelling, and reading skills indicators. Considering the spelling tasks, boys (median = 2.67; mean rank = 2.88) significantly outperformed (U(1) = 1.93, z = −2.43, *p* = 0.01) their counterparts (median = 2.12; mean rank = 2.57) with a large effect on the difference (r = −0.66). Likewise, regarding the writing indicator, boys also scored (median = 2.65; mean rank = 2.56) significantly (U(1) = 2.11 (z = −2.55), *p* = 0.01) higher than girls (median = 2.38; mean rank = 2.24), also with a large effect (r = −0.44).

We also aggregated some of the most indicative responses based on semi-structured interviews with the participants, as many did not provide any feedback (Table 4).

Table 4. Indicative answers from the semi-structured interviews with students.

	Students' Answers in the Interview
A girl	*"I do believe that all scenes were designed well to understand each time what it was going on. All messages received to me directly on the computer screen. The machinima helped me not only to comprehend my writing and reading skills. In contrast to some other educational platforms, I found interesting the machinima and I want to see it again soon".*
A boy	*"I knew Scratch, but I did not know how good was combined with a virtual world. The machinima helped me really to transfer in hardcopies my answers, as I visually saw the avatar speaking and interacting with other objects".*
A boy	*"The machinima had 4 scenes and enabled me to write and correctly read my answers as far as while I was tried to describe what an avatar made into OpenSim. I would like to become an avatar and produce my own story as well"*
A girl	*"Knowing virtual worlds, like "Sims", I did not want the class teacher's guidance so much to express and write my answers in hardcopies").*

A discussion from transcribing and observing the participants' answers is provided with their think-aloud responses and retrospections. Before initiating the post-tests, students were asked to verbalize what they were thinking when seeing specific scenes via machinima. A regular example was focused on a scene about traffic law education (Table 5).

Table 5. Students' answers via the think aloud protocol.

Students' Answers		
A boy	*"Can you please explain the traffic law signs and write your story as a sum of sentences to describe your actions? An indicative example was answered by a boy, who claimed that "it was nice to see all traffic signs that have been chosen by the avatar, as I read as well as their meaning and I understood what is each one when walking in a road".*	*"The avatar would like to walk across the road; however, he saw the red octagon shape and color of the "STOP" sign and he stopped immediately to see if other cars were passing across the road. After that he continued to walk".*
A girl	*"What are the animals you are seeing? Can you tell us what they are doing here?"*	*"I liked the garden outside the mansion. The little dog named "Bob" asked the little monkey named Marina: What are you eating Marina? She answered: "I grabbed a banana from a tree to eat. Do you want to share the banana with me Bob?".*

The qualitative data from the students' interviews revealed the importance of students' positive emotions for the successful implementation of such alternative interventions. Individuals with DD who participated in this study had the chance to express their feelings and supplement their explicitly positive effect on their linguistics understanding and communication skills for language learning in girls and boys with DD. Another significant finding is the fact that the majority of students viewed costless machinima instructional video to express and then write their own stories. A significant point of view considers the virtual scenes, including scenarios with an appealing visual design of multimedia features and objects that students already know, like similar platforms and tools from their previous exercises within in-school settings. As also indicated by the semi-structured interview as well as the "think-aloud" protocol during the intervention, the simulated real-world scenario and the avatars' embodied experiences can increase vocabulary acquisition, understanding, and expression on their own stories' creation. These findings support the importance of conducting such training events and respective pilot studies.

To sum up and answer *RQ2*, boys seemed to achieve better outcomes using machinima based on the description of their own stories, as they seemed to determine their skills related to spelling, writing, and reading in a higher level, whereas they achieved lower mean scores in pre-test scores than girls.

5. Discussion

This study's findings provide evidence that the integration of machinima for linguistics and language learning can become a valuable "tool" to students with DD and the development of their communication skills. The critical finding reported is that machinima creation via 3DVWs led to significant learning achievements, especially of boys with DD, and can be considered as an indicative future outlook suggested by prior research, when naturalistic school contexts are considered. Such findings are consistent with previous studies [18,25], which indicated that, unlike the restricted intuitiveness that the two-dimensional graphic images in textbooks and paintings present, the 3D environment that OpenSimulator offers enabled primary education students to develop stronger spatial awareness related to the structure and functionalities of the abstract features/elements from machinima to produce their own stories after viewing it via hardcopies. Likewise, even though simulated real-world contexts are still emerging, if any potential drawbacks and deficiencies imposed were accounted for when considering the conduct of laboratory practices (e.g., the cost of specialized equipment, the need for monitoring, and supervision from the teachers), the machinima intervention via 3DVWs, complimentary to the typical didactic scenarios, can be considered as valuable for linguistics and language learning.

The main argument put forward in this study suggested that machinima instruction can support students with DD to improve their vocabulary and communication skills. Regarding *RQ1*, the main outcomes are consistent with previous works [9,23,29], indicating that 3DVW-supported instruction in-class settings can aid the learning activities and provide unique benefits to learners. Nevertheless, the key findings revealed that the ma-

chinima approach had greater effectiveness on boys, as they received slightly better grades than girls across all communication skills. This outcome becomes even more notable when comparing the significantly lower scores that boys achieved in the pre-test. Nevertheless, in both cases, the improvement was more visible on the development of students' writing and reading skills', as opposed to the changes identified in their spelling capabilities.

The present work validates the outcomes of the most recent relevant studies [21,22] and further contrasted the impact that immersive technologies have over more traditional educational videos. The machinima intervention seems to be capable of advancing the communication skills of students with DD, due to the simulated representation fidelity (efficacy of the visuals) that the 3D features and elements provide, as well as the embodied experience that users achieve via the avatars, as also suggested by relevant studies on machinima instruction [17,18].

Regarding *RQ2*, the results indicate a greater improvement identified on boys' communication skills with a normalized gain of 36.3%. While DD is a neurodevelopmental disorder that is significantly more frequent among males [2,12,13], this study's findings revealed that boys performed significantly better than girls, albeit with lower grades in pre-tests. This study's results are in line with previous studies [5,19], as there is strong evidence of the deeper understanding and critical thinking development demonstrated by boys when communicating observed stories using their own descriptive skills and narratives. Regarding the learning outcomes, as boys stated, observing an avatar's actions crucially impacted their motivation and their engagement. In a sense, it was the 'avatar' who was later describing their personal stories [26,28]. Therefore, while utilizing this approach, positive outcomes can be expected on the boys' language learning development. Another possible reason where boys in the post-test outperformed girls may be the fact that they spend more time to play with video games, which have similar virtual characters (avatars), such as those in OpenSimulator, as indicated both by this study's demographics and previous studies [4,6]. This study's results are also in line with previous studies [13,17], which concluded that visuo-spatial attention can support the reading, writing, and spelling processes of students with DD.

6. Implications for Design and Practice

The findings advance the corpus of knowledge in the following ways: (a) by providing empirical evidence of the impact that machinima instruction has on students with DD, especially when simulated real-world scenarios are displayed with the intention to facilitate the development of students' communication skills; (b) by highlighting the impact that the gender difference has on students' vocabulary acquisition, understanding, and expression; (c) by comparing the effectiveness of the machinima instruction on vocabulary learning and practicing, against educational/instructional videos; and (d) by delivering a better conceptual understanding in the design and practice of implications over the approach that students use to express themselves while describing the observed simulated scenarios in their own stories and with their own words. Additionally, it informs how a 3DVW-supported instructional approach via machinima can be adjusted to the context of exploratory research and paves the way for the integration of similar in-class activities. Finally, the instructional decisions made to create the machinima instructional video contribute to scholarly discussions on how to efficiently and effectively design similar educational interventions [c.f., 8,27].

While building on the successful integration of this work, we provide the following theoretical and practical implications for instructional design and development based on this study's qualitative and quantitative data. These are as follows:

- The scenes in machinima that entail appealing visual design of multimedia features and objects can support students to formulate and understand better real-life situations.
- The features and the elements of 3DVWs (e.g., avatars, realistic representations of the real-world context, etc.) provide a fertile ground for the conduct of problem-solving activities, whereas the machinima approach enables designers to map out scenes that

can be utilized to demonstrate the consequences that the main actors face using visual and acoustic feedback.

- The increase in learning outcomes and achievements is associated with the inclusion of interactive features and elements. Simulated real-world scenarios and the avatars' embodied experiences can increase vocabulary acquisition, understanding, and expression, as determined by the student-crafted stories after viewing machinima via hardcopies.
- The machinima-supported instruction should be optimally designed in a challenging way so as to increase students' incentives to interact and engage due to the embodied experience via avatars to support procedural knowledge acquisition during the in-class tasks.
- The provision of opportunities for active engagement from the participants' end with a particular focus on the communication aspect. For instance, introducing pop-up messages to explain specific elements of the current scenery or subtitles to highlight key information can assist students to develop a better understanding of the concept under investigation and therefore improve language learning.

7. Conclusions

The present study demonstrates the positive benefits of machinima instruction created via OpenSim&Scratch4SL to primary education students with DD in terms of knowledge gain and performance. This study's findings showed that machinima instruction affects boys' learning effectiveness more than girls with DD, with the main key focal points being on (a) vocabulary learning and practicing (including learning outcomes and achievements) and (b) the creation of their own stories via hardcopies. The machinima intervention, consisting of short-time scenes, with enclosed pop-up messages, small talks generated by avatars, and focused sceneries in real-life contexts, can facilitate visual-attentional training and mitigate the impact of the novelty effect that 3DVWs may provide. In addition, if the integration of this approach is supported by memory-oriented and decision-making exercises, it can enable students to actively engage in the learning process and thus further improve their learning gains.

The current study adds to the body of literature by providing (a) empirical evidence on the development of students' communication skills and learning outcomes, as emerged from the creation of their own stories after the proposed machinima intervention; (b) an in-depth discussion, as revealed by the key differences on students' outcomes in view of gender differences; and (c) design guidelines and practical implications on how the machinima intervention can support students with developmental dyslexia.

8. Limitations and Future Work

This study's results show how machinima instruction can be integrated in class settings for students with DD. This work informs practitioners and educators on how to advance their instructional approaches and settings using alternative multimedia methods, other than the traditional ones (e.g., educational videos), by combining rich audio-visual norms in simulated realistic experiences. We felt that students with DD did not have any adversity to transfer their ideas into hardcopies, as revealed by the higher scores that they attained in spelling, reading, and writing skills, in consideration of the pre- and post-tests.

Despite this study's contribution, several limitations need to be highlighted. First, we conducted this study with forty participants, all from Greece, which makes it difficult to generalize the results. Nonetheless, this study was conducted with younger and lower-educated dyslexics, as Knoop-van Campen et al. [1] recommended. As others also noticed [11,21], the advantage of studies with small samples can enable an evaluation of students' learning outcomes based on their responses to an intervention, therefore allowing other researchers to adapt or perform better instructional conditions in the future. Second, the limited number of measures, which mainly focused on students' learning outcomes and achievements, was inevitably due to the COVID-19 pandemic. Nevertheless, this

intervention was time-efficient, as there was often not enough time to make any further measurements within such difficult conditions.

Future works need to investigate the factors affecting students' behavior and engagement when integrating machinima instructional videos. In addition, what is currently missing from the literature is a classification of the factors that impact learners' outcomes. Another matter requiring attention is the examination of the educational effectiveness of machinima in a long-term context (i.e., longitudinal studies), alongside tools which track participants' actions and interactions. Such efforts need to be conducted with larger sample size and wider diversity. Finally, researchers can also comparatively explore the potential of this approach with an experimental group (formed by students with DD, in which machinima instruction will be provided) and a control group (formed by students who are not facing any particular learning disorders, again provided with video-based instruction).

Appendix A

Table A1. Error Analysis Code.

Category [Marking]	Explanation	Indicators
C. Correct [No negative marking]	Correct answers are described and applied in hardcopies correctly without errors not only in short sentences expressed but also in natural language expression [C]	**Spelling** 1. Difficulty to recognize the sound of vowels and/or consonants. 2. Lack of sorting similar sounds. 3. Difficulty taking notes after video production. 4. Difficulty to recognize the number of words inside the phrases that are heard and their repetition. 5. Strive hard to spell accurately a text.
E1. The errors of omission for the description and understanding of a proposed sentence written and expressed in Greek (minor spelling, writing, and reading errors) [0.25 grade can be lost for any error that is identified in a row]	Some of the key words for answering questions are missing, such as: Some grammar rules in few words Few grammar rules and minor errors in a row Lack of grammar rules in some words.	**Writing** 1. Difficulty writing three and more words in a row 2. Writing sentences with spelling errors 3. Inverting or reversing the letters or incorrect letters placed into words that have already written. 4. Writing words exactly as they hear them and not as they should be spelled correctly.
E2. The errors of commission for the description and understanding of a proposed sentence written and expressed in Greek (major spelling, writing, and reading errors) [0.5 grade can be lost for any error that is identified in a row]	A large portion of the key words for answering questions are missing, such as: Many grammatical errors in rules (up to three) Flawed information using irrelevant words Ambiguous information in a row	**Reading** 1. Difficulty to reach a creative level of reading, e.g., realizing and reading alongside all words in the line. 2. Tendency not choosing the right letter from a set of letters to write a sound they hear, nor can they match similar letters when asked to read what they have written.

Table A2. Error Analysis Code.

Indicators	Marking Range (*n* = Number of Times That Each Indicator Was Used)
Spelling	
Recognize the sound of vowels and/or consonants	0–3
Hear words and sounds for object description	0–2
Describe orally after the video production any potential notes	0–1
Recognize the number of words inside the phrases that are heard with correct repetition	0–2
Spell each word to syntax them properly in a row	0–2
Writing	
Write words exactly as they hear them	0–3
Write sentences without spelling errors in a row	0–3
Invert or reverse the letters or incorrect letters placed into words	0–4
Reading	
Reach the creative level of reading, e.g., realizing and understanding all words in a row	0–5
Choose the right letter from a set of letters to write a sound that is heard and matched similar letters when asked to read what they have written	0–5

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